Jr. of Industrial Pollution Control 34(2)(2018) pp 2152-2158
www.icontrolpollution.com
Research Article

INDUSTRIAL SYMBIOSIS AND INDUSTRIAL WASTE MANAGEMENT IN WOOD-BASED INDUSTRIES

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(Received 24 September, 2018; accepted 26 October, 2018)

Key words: Industrial estate, Re-use, Re-cycling, Pollution, Wood-waste.

ABSTRACT

This work is an attempt to study Hayatabad Industrial estate with the objective to identify and evaluate groups of industries for Industrial symbiosis. For this purpose, a questionnaire was conducted among 15 industries. Furthermore, 11 industries were observed personally for their manufacturing process to know about raw material, by products, waste material and its utilization in another industry as input. Wood-based industries, selected for industrial symbiosis include match, chip-board, paper and mold. Their respective solid waste generation rates were 45-50 tons, 30-35 tons, 2-3 tons and 1.5-2 tons/day. This waste is inter-changeable, but wood-waste is generally sold to outside and used as a fuel. If the wood-waste of match industry is used as an input in chip-board and paper industries, demand for fresh wood will decrease by 10% and 90% in chip-board and paper industries respectively. Moreover, utilization of this wood-waste will decrease the energy in these industries by 10% and 20% respectively. Due to lacking of industrial symbiosis, there is not only wastage of resource but contributes the pollution level also. It is therefore required to seek ways and means for efficient industrial symbiosis.

INTRODUCTION

Industrial estates are also called industrial parks. This concept was introduced in 1800 with the idea to facilitate the industrial management for the availability of basic inputs such as water, electricity and gas supply (Parka, *et al*., 2008). It also helps to provide and manage the required infrastructure like phone and roads (Dong, *et al*., 2014). In Indo-Pak Subcontinent, the concept of industrial estate was introduced by the Mughal king Bahadur Shah Zafar during 1850. He placed 22 industries inside Lal-Qila (Red- Fort). The aim of industrial setup inside Lal-Qila was to manage labor force, security and maintenance of industries at one place (Qamar, 2016). This concept of industrial estate can also be used for waste management and minimization by incorporating the idea of industrial symbiosis (Geng, *et al*., 2010). The concept of industrial symbiosis was introduced in 1989 by Frosch and Gallopoulos. They published an article, "Strategies for Manufacturing", in which it was suggested that the waste of one industry can be used as an input in another industry (Baina et al., 2010). For example the waste of sugar mill is used as raw materials in production of alcohol, paper pulp, cement and fertilizer. Literature revealed that for industrial development, the practice of industrial symbiosis has been proved to be an effective measure for recycling, conservation and to reduce resource use (Simboli, *et al*., 2014).

Industrial process cause pollution problem. Industries generate wastes in the form of effluents, solid waste and fumes etc. (Bangash, *et al*., 2006). Studies revealed that there is no proper arrangement for treatment of industrial effluents and solid waste management in Pakistan in general, and Khyber Pakhtunkhwa province in particular (Arshad, 2016; Shah, 2014; Shaheen, *et al*., 2013). Usually the industrial estates are kept away from residential areas but due to labor availability, industrialist construct labor colony inside or near the industrial zone. Therefore proper zonation

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is required to prevent the negative environmental impacts (Tariq and Shah, 2003).

Industrial symbiosis has been adopted in European countries as a tool for waste management and pollution abatement (Baina, *et al*., 2010). By following the idea of industrial symbiosis, a waste is considered as a resource for another industry (Puente, *et al*., 2015). Such exchange of waste is possible within the vicinity of industrial estate. In this way industries are benefited financially by exchanging such type of materials (Zhang, *et al*., 2015). Many countries of the world are adopting this idea to mitigate pollution such as the wastewater of paper mill consists of cellulose and can be used in paper molding industry, packing material for eggs, fruits and vegetables (Zhu, *et al*., 2007). In this way industrial symbiosis plays a vital role in collaboration amongst industries for pollution abetment (Leigh and Li, 2008).

In industrial progress, the availability of raw material is very important. Wood is one of the raw-material and is often in competition with other materials like plastic, steel etc. (Petersen and Solberg, 2005). With rapid increase of industrialization, demand for fresh wood is increasing day by day. It is very difficult for wood based industries to meet their needs (Siddiqui and Khan, 1991). Pakistan has limited wood resources with forest covering area of about 4.4 million hectares (Nafees, *et al*., 2010; Nazir and Olabisi, 2012). The total wood consumption recorded for the country is 47.73 m^3 by the year 2010. Wood shortage and low state of forests is a challenge for Pakistan. Therefore Pakistan has to import wood to meet the rising demand (Zaman and Ahmad, 2012). The study is mainly focused on saving and protection of natural resources and reduces waste output under the Industrial Symbiosis strategy. Still the Hayatabad industrial estate is not fully established and small scale zonation is possible. It was therefore, considered important to survey the Hayatabad Industrial Estate (HIE) for waste management in the light of Industrial symbiosis.

METHODOLOGY

To study the concept of Industrial symbiosis, data was collected through site visits and by conducting interview and questionnaire surveys.

Preliminary Survey

Was conducted to know about the present industrial set-up. For this, 10 field visits were paid to the estate. This survey was helpful to divide the industries in groups suitable for industrial symbiosis. To collect preliminary information related to Hayatabad Industrial Estate (HIE), office of (Sarhad Development Authority (SDA), 2016) was visited. It is an administrative organization; the Hayatabad Industrial Estate is run by SDA. The officials were interviewed to know about operating and closed industries in the industrial estate.

Selected Group of Industries for Industrial Symbiosis

To identify and evaluate groups of industries for Industrial symbiosis, one group of four different industries was selected for detail survey, i.e., paper, match, chipboard and mold industry. Each industry was kept under observation and a questionnaire was designed to collected data. Total number of these four categories was 25 i.e., 15 match, 2 paper, 6 chipboard and 2 mold industries. 13 questionnaires were filled from the selected group (Table 1). For further confirmation 11 industries were observed personally. The selected group was studied for waste management and sharing of raw materials in the light of symbiosis strategy. The waste material was characterized for its utilization in another industry as input. The main emphasis was on raw material consumption and waste production.

Input/Raw Material

To know about the type and quantity of inputs/raw material used, each industry was observed for one complete shift/cycle (8 hours). Some open questions were asked from manager about the areas from where the raw material is being supplied, type of loading vehicles etc.

Output/Production

Per-day production was calculated for each industrial unit. As wood is the basic raw material used in

Table 1. Wood based industries for industrial symbiosis.

Type industry	Total Industries	Questionnaire distributed	Questionnaire received	Percentage (%)	Number of Industries observed for processing
Match	15	08	06	40	4
Chipboard	06	03	3	100	3
Paper	02	02	2	100	2
Packing/Mold	02	02	2	100	2
Total	25	15	13	85	11

match, paper and chipboard industries therefore, this wood undergoes various processing to make the final product. During manufacturing, waste is generated in different forms and was quantified. Besides wood-waste, the paper-waste, plastic-waste and wastewater is also generated and were also quantified as per day.

Energy Consumption

For energy estimation, monthly electricity and gas bills were noted for consumable units. Total 16 monthly electricity bills, 4 for each industry were examined. Similarly gas bills (4 for each industry) were checked to get the data. While the quantity of fuel usage was asked from managers.

RESULTS AND DISCUSSION

Present status of Hayatabad Industrial Estate

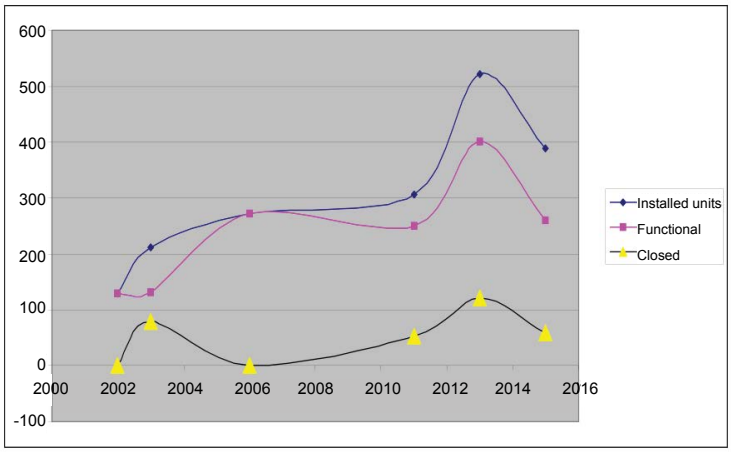
(Fig. 1) summarizes the overall picture of industrial estate for total, operational and closed industrial units during 2002-16. Various studies have been conducted on industrial estate showing different number of industrial units. As per SDA record, 372 industrial units have been installed. Out of the total, 58 and 242 were functional (Fig. 1). According to SDA, the closed units caused Rs. 429.402 million loss. (Tariq and Shah, 2003; Khan, 2011; Khan, *et al*., 2002) reported that financial crises and miss-management issues increased the closing rate of industries.

Industrial Symbiosis in Wood-based Industries

The production capacity of each industry was calculated per day as 20-25 tons for chipboard, 13-15 tons for paper mill, 10-12 tons for match industry and 8-9 tons for packing industry (Table 2). These industries generate waste or residues, but the re-use, sharing and disposal status is unknown. The reason is that these industries are placed away from each other. It was required to know about the sharing of raw-material.

Match Industry

Match industries use poplar wood as basic raw material which is supplied from the surrounding districts include Charsadda and Mardan. The quantity of total raw-material required for industry was calculated as 18,029 Kg/day including wood, cardboard, wrapping paper, plastics, water and chemicals (phosphorous, Potash etc). The industry consumes considerable quantity of cardboard/paper for packing and wrapping purposes depends upon the production capacity of industry. About 4000 Kg cardboard/paper and 50 Kg plastic is used per day. Water is used as a solvent for preparation of chemicals (Fig. 2a).



Sources: Khan, *et al*., 2002, Tariq and Shah, 2003, Nafees, *et al.*, 2010, Khan, 2011, Shaheen, *et al*., 2013, Sarhad Development Authority (SDA) 2016.

Fig. 1 Functional and closed industries in Hayatabad industrial estate.

Table 2. Selected group of industries for industrial symbiosis.

S. No	Industry	Number	Wood Demand (tons/day)	Production capacity (tons/day)	Production capacity of Total Industries (tons/day)	Wood-waste Produced from Total Industries (tons/day)
1.	Match	15	13-15	10-12	150-180	45-50
2.	Chipboard	06	30-35	25-30	120-150	30-35
3.	Paper	02	15-17	13-15	26-30	02-03
4.	Mold	02	10-00	08-09	16-18	1.5-2 (paper-waste)

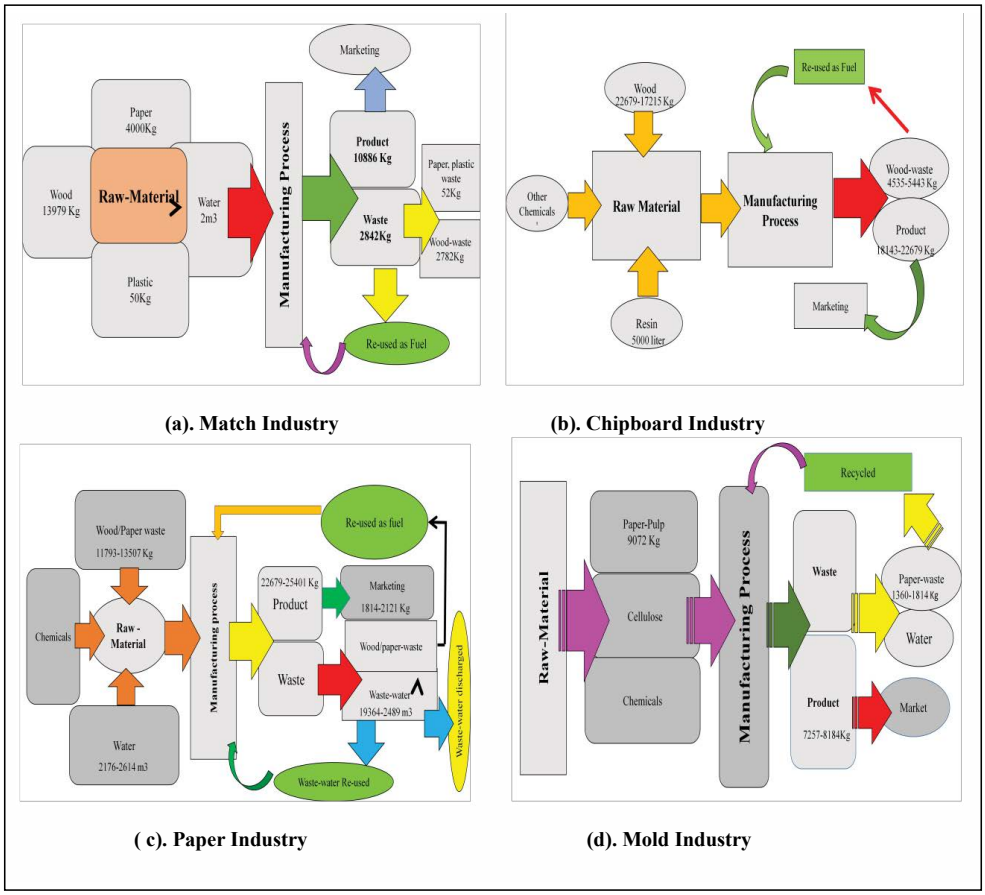


Fig. 2 Manufacturing process of selected industries.

The outputs include match sticks and waste emissions. Waste is generated in the form of dust, wood-waste, missed sticks, paper, plastic-waste and wastewater. Approximately 2842 Kg/day waste is produced by each industry. Wood-waste is a good input for paper mill and chipboard industries but due to distance and transportation problems the waste is not shared to the wanted industries and is sold to community. Water is discharged as wastewater, containing chemicals.

Chipboard Industry

Chipboard is an important wood-based industry as it is cheaper, denser and attained highest value in economical development (Particle board, 2016). The raw material required for chipboard manufacturing include wood, glue, laminating sheets, resins and chemicals. Demand for wood of each industry ranged between 22679-27215 Kg/day (25-30 tons). Amino-formaldehyde and urea melamine are the resins used in chipboard manufacturing at 5000 liter/day. Other raw material include chemicals such as dyes, wax, wetting agents etc.

The production rate was counted in the range from 18143 to 22679 Kg/day for each industry and 108862-136078 Kg/day (120-150 tons) for all 6 industries. The industries prepare different sizes of chipboard such as 8ft x 4ft, 6ft x 4ft, 4ft x 4ft and 2ft x 4ft. Beside it, waste comes as dust and waste-wood at 4535-5443 Kg/day (Fig. 2b). Dust is collected through gravity chambers. This dust and wood-waste is re-used inside industry or given to community for burning purposes.

Paper Mill

There are two paper mills working in Hayatabad industrial estate. These industries are equipped with machinery to prepare paper from both sources such as wood and paper-waste respectively. Both industries consume 23586-27215 Kg (26-30 tons) wood per day. Paper mill needs excessive quantity of water (72 m^3/ton) for processing and generates wastewater consists of cellulose materials. The cellulose matter is recoverable and can be used as a basic input in mold/packing material industry. The production capacity ranged from 22679 to 25401 Kg/day (Fig. 2c). About 1814-2721 Kg/day (2-3 tons) waste is produced from both industries. A part of these wastes, paper-waste is recycled by industry while some waste (0.5-1 tons paper & wood) is discarded or given to the community/workers, they

collect it for free and use it as a fuel.

Mold Industry

Mold industry is important from environmental point of view as it recycles the paper mill waste. These industries prepare packing material for vegetables, fruits, eggs etc. These recycling plants have underground tanks with capacity to store 120-150 m^3 water. The wastewater of paper mill is used as a basic input in mold industry. The suspended load, which is basically cellulose, is settled, concentrated and shaped into packing material.

The production capacity was calculated as 7257-8164 Kg/day (8-9 tons) (Fig. 2d). Waste is generated in the form of paper-waste at the rate of 1360-1814 Kg/day (1.5-2 tons). The waste is discarded or given to workers on payment. They use this as fuel (Table 3).

Energy Consumption

In chipboard industry, chip and flake manufacturing require more energy for cutting and chips formation. By using match sticks as raw material, the energy consumption by this machine can be reduced to low level. The average consumption in chipboard is 466,000 kW units of electricity, 1000 liter of oil and 1100 Kg fuel wood per day. Fuel gas is usually used in canteen. The water consumption is 26.3 m^3 per day (Table 4).

Paper mill consumes energy as at 110,000 units of electricity, 1700 liter oil, 2614 m^3 water and fuel wood as 800 Kg/day. If the shredded wood-waste of 15 match industries is used as raw material in 6 chipboard plants and 2 paper mills then receiving industries will consume less energy by 10% saving in paper mill and 20% in chipboard industry.

The energy consumption by match industry was determined at 573,330 kW electricity, 1200 liter oil, 50 m^3 water and 400 Kg fuel-wood/day. The mold industry was observed with usage of electricity and oil at the rate of 55,000 kW and 700 liter respectively (Table 4).

Industrial Symbiosis as a Waste Management Approach for HIE

Waste can be minimized through waste sharing among different industries. Based on the observation of this study a model is proposed for the proper location of industries at Hayatabad Industrial estate (Fig. 3). The whole estate needs to be re-arranged by dividing it into different zones/sectors. The inter-dependent industries should be placed in separate zone based on the demand of raw-materials such as industries like chipboard, paper, mold, match and furniture industries should be placed in a single zone. By bringing the similar nature industries in one zone, it will be cost effective for industries to shift their location but on other side it will reduce the transportation charges of raw material. Chipboard industries are located at a distance of 3-5 km away from match industries. One industry of chipboard needs 4.244 million for installation. If the 7 chipboard industries are brought at one site near to match industries then it will require at least Rs. 29 million. The transportation charges will be reduced at 35000 Rs perday. In this way the supply of waste wood from match industries will become easy that will reduce the demand of fresh wood and will benefit the industry at 10% saving of wood perday.

If Paper mills are placed near match and mold industries it will cost Rs. 2 million. By reducing the transportation charges and supply of waste-wood from match industries, it will fulfill 90-100% demand of paper mills for wood. The paper mills are located on same drain as mold industries and it is easy to collect the cellulose components for mold industries. But the problem is that mold industries are far apart (5-6 km) from paper mills and the wastewater containing cellulose components is diluted after mixing with industrial drain water.

Table 3. Water consumption and wastewater discharge in paper and mold industries

S. No	Industry Type	Production Capacity/ day (tons)	Water Consumption/day (m^3)	Wastewater discharged/day (m^3)
1	Paper Mill	13-15	2176-2614	1936.4-2489.5
2	Mold Industry	8-9	16-20	120-150

Table 4. Energy consumption by industries

S. No	Type of Industry	Electricity units/ day/ industry (kW)	Oil use/day / industry (liter)	Water consumption /day/ industry 4hp.h (m^3)	Fuel use/day/ industry (kg)
1	Chipboard	466,000	1000	26.3	1100
2	Paper mill	110,000	1700	2614	800
3	Match	573,330	1200	50	400
4	Mold	55,000	700	ND	ND

Therefore, much of cellulose content is lost which is not effective in packing manufacturing. By bringing mold industries near to paper mills, it will be helpful to share the waste-paper of packing material from mold industries to paper mills. The cost estimated for shifting of 2 mold industries is 3-4 million.

This model will be also beneficial for other industries such as marbles industries are scattered out through whole industrial estate and therefore need a separate sector to relocate. If the industries are brought in one zone then they will throw the discharges in same drain that will be helpful to collect the sludge from one specific site. Furthermore, there will be possibility for the installation of a combine treatment plant near marble industries to recycle their wastewater. Marble waste is rich in calcium carbonate contents and is used a important raw-material in cement, washing powder and tiles preparation. Therefore, these industries should be kept in a single zone. Cement and ceramic industries depend on marble waste and therefore must be placed near marble industry. Similarly the pharmaceutical, plastic and food industries produced indoor pollution and need to be place in a separate zone (Fig. 3).

Steel mill and metal industries are interdependent industries to each other and need a separate zone. While sugar mill should be installed at a proper site which is accessible to fertilizer and beverages industries. The establishment of sugar mill will encourage the practice of industrial symbiosis and the proposed model for Hayatabad industrial estate will help in waste minimization and management. In this way the rate of waste generation can be possibly reduced to zero and the resource will be utilized in better way.

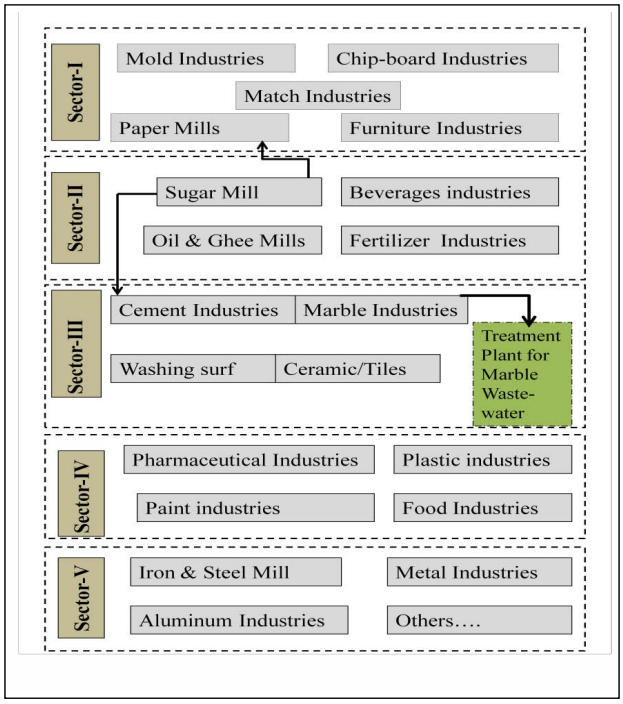


Fig. 3 Industrial symbiosis model prepared for HIE for waste management.

CONCLUSION AND RECOMMENDATIONS

The functional industrial units of selected group (match, paper, chipboard and mold industries) generate considerable amount of wood and paper-waste. This waste is not used as raw material in wanted industries and is used as fuel. There is need to find ways for their proper treatment (recycling or reuse) and avoid the wastage of waste wood/ paper. There was potential for recycling that was overlooked. The industrial estate is still lacking proper arrangement and placement of industries in the right location. The industrial estate needs to be monitored for its suitable zonation in such a way that interdependent industries should be placed close to each other. If the idea of industrial symbiosis is adopted in the proposed industrial estate it will be helpful in the installation of other industrial units which are expected in other parts of the province in terms of waste minimization and waste management. To develop the concept of industrial symbiosis, there is need of suitable forms to institutionalize industrial symbiosis initiatives and to facilitate the coordination of projects.

ACKNOWLEDGMENT

Authors are thankful to the nice staff of Sarhad Development Authority, Peshawar and honorable managers and Plants incharge of visited industries for their assistance in providing relevant data.

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