A Strategic Model for Cleaner Production Implementation In a Paper Making Mill

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ABSTRACT

The aim of this paper is to identify and prioritize the cleaner production implementation of a paper making mill. Because of high initial cost of cleaner production implementation, it was important to develop a model for prioritization. The research mythology employed was analytic hierarchy process (AHP). Using field study and literature reviewed, the proposed model could be a framework for paper making mill in cleaner production implementation. The results showed that process change gave the higher priority between 5 criteria and repair of all leaks in paper making resulted higher priority between 35 sub-criteria.

Key worlds: Analytic Hierarchy Process (AHP), Cleaner Production, Paper Mill

1. Introduction

To ensure the world's productive capacity, the protection of the eco-system requires environmentally sustainable forms of development. It is an important issue in view of the limited global resources and increasing of population and industrialization. Industrial production without adequate regard to environmental impacts has led to increase in water and air pollution, soil degradation, and large scale global impacts such as acid rain, global warming, and ozone depletion. To create more sustainable means of production, there must be a shift in attitudes toward proactive waste management practices moving away from control toward prevention. A preventive approach must be applied in all industrial sectors. The cleaner production is a practical method for protecting the human and the environmental health and supporting the goal of sustainability (Avsar and Demirer, 2006). The cleaner production approaches that can be applied in production processes include recycling, modifying of process, improving of plant operation, and input substitution. On the other hand, the Cleaner production can be obtained by methods such as redesigning the products, modifying the production processes, and changing the chemicals used to less hazardous ones (Ghazinoory, 2005). The necessity of adopting such a program in Iran was reviewed in detail and it was demonstrated that implementation of cleaner production is very essential because of high energy consumption, technical backwardness, lack of competitiveness, increased role of SMEs, and many critical environmental conditions in some regions and industries of Iran. Ghazinoory and Huisingh (2006) summarized the SMEs barriers to implement of the cleaner production schemes in clue the lack of professional management, poor record keeping, and resistance by decision makers, limited technical capabilities and access to technical information, unstable finances, and high cost combined with limited low availability of capital for CP in Iran.

In general, the paper industry applies the great amounts of natural resources especially water and energy. Thus, it has a significant impact on the environment. In pulp and paper industries, environmental problems vary from both size and category of mill. The Kaveh paper industry produces 120 ton/day paper board from recycling waste paper and paperboard in Iran. The Kaveh paper industry consumes a great amount of freshwater at about of 11.5 m^3 /ton paper. Also, average consumption of steam in dryer section is high. It is at about of 2.5 kg steam /kg of evaporated water. Whereas standard of water consumption in paperboard industry is 4-7 m^3freshwater/ton paper and average consumption of steam in dryer is 1.1-1.3 kg of steam/ kg of evaporated water (William, 1996; Gullichen et al., 1999).

In this paper, in order to promote cleaner production awareness on the paper sector and reduction of high initial costs for implementation of cleaner production, analytic hierarchy process (AHP) model was used to prioritize and select the best choice in cleaner production elements in Iran's Kaveh paper mill.

2. Methodology

AHP was first introduced by Thomas Saaty in the 1970's and it has been used in many areas including finance, marketing, energy resource planning, sociology, and architecture. It can be defined as a multi-criteria decision making approach that compares all defined measures in pairs and calculates their relative importance. Most of times, the AHP was used in aspect of making decision. Afterwards, other techniques such as linear programming, queuing, multiple objective decision making were used to solve the problems. In fact, the aim of AHP is to combine quantitative factors to evaluate all the objectives (Saaty, 2001). The AHP for decision making is a theory of relative measurement based on paired comparisons used to derive normalized absolute scales of numbers whose elements are then used as priorities (Saaty, 1980, 2000). Metrics of pair wise comparisons are formed either by providing judgments to estimate dominance using absolute numbers form the 1 to 9 fundamental scales of the AHP or by directly constructing the pair-wise dominance ratio using actual measurements. The AHP can be applied to both tangible and intangible criteria based on the judgments of knowledgeable and expert individuals. Although how to get measure for intangibles is its main concern. The weighting and adding model of synthetic process applied in the hierarchy structure of the AHP combines multidimensional scales of measurement to a single "uni-dimensional" scale of priority. Finally, we must fit our entire word experience into our system of priorities if we are going to understand it (Saaty, 2007). To investigate the view of different stakeholders on evaluation of cleaner production implementation in paper making mill, the authors conduced a three-phased study, including:(1) identifying the elements (criteria and sub-criteria) and planning a hierarchy model for prioritization.(2) constructing the questionnaire and collecting of information. (3) Determining the normalized weights. Opinions coming from different stakeholders including academia, enterprises, and experts were collected via carefully designed questionnaires and then synthesized and analyzed using an AHP software device.

2.1. Identifying the structure of hierarchy model for prioritization

On the basis of the literature reviewed, 35 sub-criteria were identified and grouped in to five categories. A tree-hierarchy was structured to facilitate the prioritization process (Fig1). The tree is segmented into five levels: the top level contained the cleaner production elements; the second level contained the five categories. In total, there were 35 sub-criteria in the five levels.

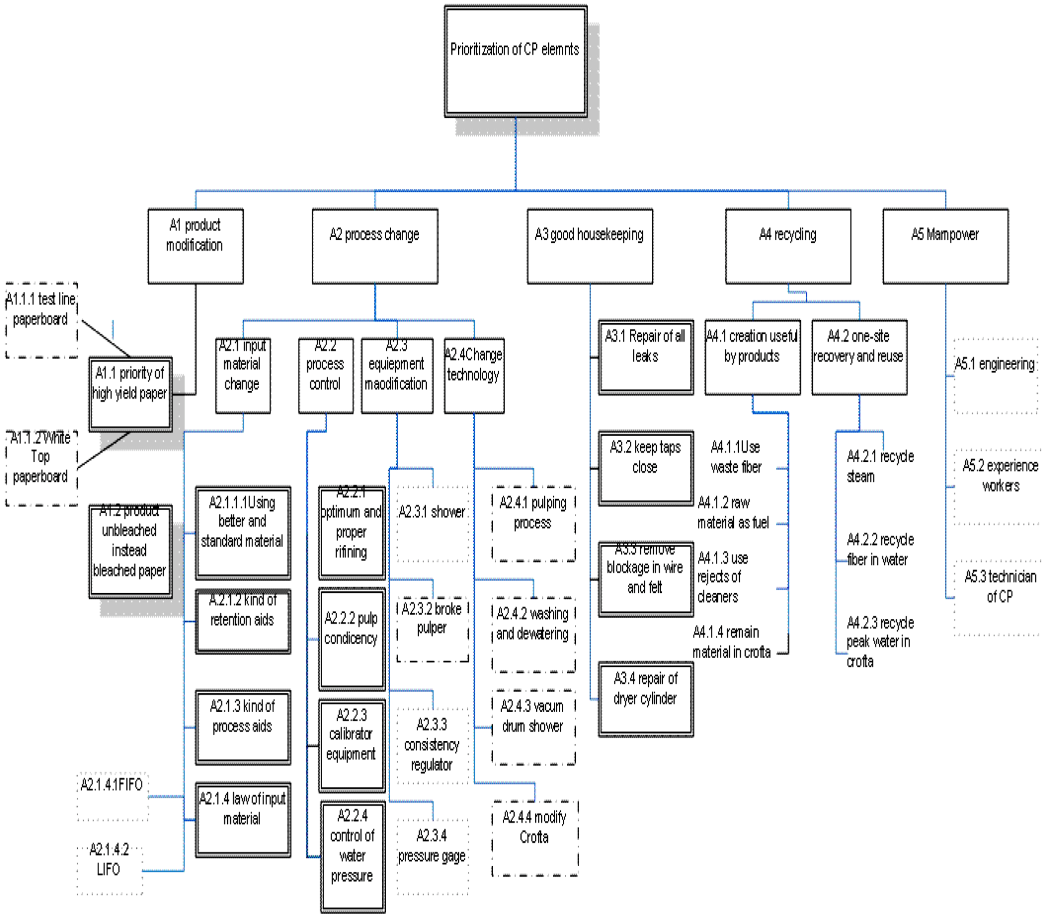

Fig1- A hierarchy model of CP implementation

2.2. Developing the questionnaire and collecting of the information

Collection of the information was the next step in AHP that done through a systematic series of pair-wised comparisons among the specific criteria and sub-criteria. Pair-wised comparisons allow to respondents to focus on only two criteria, simultaneously. Thereby, translating of the complex; multi-criteria prioritize the problem into a series of pair-wised assessments. The pair-wised comparison matrixes were completed by 10 experts from industry and academia. Afterwards, these comparisons converted by AHP to criteria weight using a matrix algebra-based algorithm along with checking for results of consistency.

2.3. Determining the normalized weights

Mathematical computations were concluded after completion of the pair-wised comparisons. The first step in evaluation of mathematical computations is to normalize each matrix by adding the values of each b_{xy}. So, a matrix (B) can be normalized:

$$B = \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & & \vdots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{pmatrix} = \begin{pmatrix} 1 & b_{12} & \cdots & b_{1n} \\ 1/b_{12} & 1 & \cdots & b_{2n} \\ \vdots & \vdots & & \vdots \\ 1/b_{1n} & 1/b_{2n} & \cdots & 1 \end{pmatrix}$$

The local weight (W_{Bi}) was calculated according to following formula:

$$W_{Bi} = \frac{\left(\prod_{j=1}^{n} b_{ij} \right)^{1/n}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} b_{ij} \right)^{1/n}}$$

After determining the local weights, the global weights of each criterion and sub-criteria were calculated. To avoid misdirection analysis affected by interviewers' incompatible judgments, AHP establishes a consistency indicator as the standard judgment if the values are incompatible. The questionnaires involved in incompatible judgments were discussed normally with their answerers. Only the matrices that passed the consistency test were included in the final analysis.

3. Results and Discussion

As shown in Table 1, the A2– process change category is the most prominent cleaner production criteria with a normalized global weight of 0.302 on the second hierarchy level. The A3– good housekeeping category follows behind with a global weight of 0.249. The global weights of the A5– manpower, A3– recycling, and A1– product modification are less than half of the total weights. At the third hierarchy level, A2.1– material change is regarded as the most prominent CP sub-criteria under the A2– process change with local weight of 0.324. A1.1- high yield produce of paper is regarded as the most prominent CP sub-criteria under the A1– product modification with local weight of 0.654. Repair of all leaks, creation of useful by-products, and engineering and educational technicians are regarded as the most prominent CP sub-criteria in the third level under the good housekeeping, recycling, and manpower criteria, respectively. By examining the global weight ranking for the 35 sub-criteria (Table2), A3.1– repair of all leaks, A5.1– engineering and educational technicians, A3.4– modification and repair of dryer cylinder, A5.3 – professional and technician in the CP field, A1.1.1 – test line paperboard, A5.2– experience workers, A1.2– production of unbleached instead of bleach paperboard, A3.3– remove blockage in wire and felt showers, A2.1.1– using suitable and standard raw material, A4.2.1– recovery of steam condensed are regarded as the top ten sub-criteria which have high effects on evaluation of the cleaner production implementation in the paperboard mill of Iran. Furthermore, we can implement the cleaner production concepts in paper making mills with lower initial costs which persuade paper industries and managers to implement the cleaner production. Implementing the cleaner production concepts of this paper led to a variety of options for the reduction of environmental effects in Iran. These options have both economic and environmental advantages.

Table1. Local and global Criteria and Sub-Criteria of all cleaner production elements

Elements	*Local weight*	*Global Weight*	*Elements*	*Local weight*	*Global Weight*
A1-**products modification**	0.123	0.123	A2.4 change technology	0.258	0.058
A1.1 product high yield verities of paperboard	0.654	0.080	A2.4.1 modify pulping process	0.288	0.078
			A2.4.2 modifying washing and dewatering .e.g. by using twin wire belt press	0.274	0.021
A1.1.1 test liner paperboard	0.589	0.047	A2.4.3 use vacume drum shower	0.190	0.015
A1.1.2 white top line paperboard	0.411	0.033	A2.4.4 modify crofta (pre-refinery) process	0.248	0.019
A1.2 product unbleached instead bleach paper	0.346	0.043	A3- **good housekeeping**	0.249	0.249
A2- **process change**	0.302	0.302	A3.1 repair all leaks	0.468	0.117
			A3.2 keep taps close when not in use	0.103	0.026
A2.1 input material change	0.324	0.98	A3.3 remove blockage in wire and felt showers	0.170	0.042
A2.1.1 using better and standard raw material	0.410	0.040	A3.4 modification and repair of dryer cylinder	0.258	0.64
A2.1.2 kind of retention Aids	0.268	0.026			
A2.1.3 kind of process aids	0.195	0.019	A4- **recycling**	0.158	0.158
A2.1.4 law of input raw material to product line	0.127	0.012	A4.1 creation useful by products	0.555	0.88
A2.1.4.1 FIFO	0.714	0.009	A4.1.1 use waste fiber	0.305	0.027
A2.1.4.2 LIFO	0.286	0.004	A4.1.2 use raw material as fuel in boiler	0.248	0.021
A2.2- process control	0.228	0.069	A4.1.3 use rejects of cleaners	0.233	0.020
A2.2.1 optimum and proper refining	0.384	0.026	A4.1.4 use remains material in crofta (like sludge...)	0.220	0.019
A2.2.2 refined at highest possible pulp consistency	0.123	0.009	A4.2 one-site recovery and reuse	0.445	0.070
A2.2.3 install calibrator equipment	0.372	0.026	A4.2.1 recycle steam condense	0.504	0.036
A2.2.4 control of water pressure in the edge of cutting paper	0.120	0.008	A4.2.2 recycle fiber in white water	0.250	0.018
			A4.2.3 recycle peak water in crofta (refinery)	0.246	0.017
A2.3 equipment modification	0.190	0.058	A5- **manpower**	0.168	0.168
A2.3.1 install efficient shower	0.236	0.014	A5.1 engineering and educational technicians	0.391	0.066
A2.3.2 provide broke pulper	0.146	0.008	A5.2 experience workers	0.261	0.044
A2.3.3 install consistency regulator	0.280	0.016	A5.3 professional and technician in the cleaner production	0.348	0.058
A2.3.4 use pump of adequate	0.180	0.010			
A2.3.5 install pressure gages for water consumption control	0.157	0.009			

Table2. Ranking of global weight of criteria and sub-criteria

Ranking	Global Weight
Criteria	
1 A2	0.302
2 A3	0.249
3 A5	0.168
4 A4	0.158
5 A1	0.123
Sub-Criteria	
1 A3.1	0.117
2 A5.1	0.066
3 A3.4	0.064
4 A5.3	0.058
5 A1.1.1	0.047
6 A5.2	0.044
7 A1.2	0.043
8 A3.3	0.042
9 A2.1.1	0.042
10 A4.2.1	0.040
11 A1.1.2	0.036
12 A4.1.1	0.033
13 A2.1.2	0.027
14 A2.2.1	0.026
15 A2.2.3	0.026
16 A3.2	0.026
17 A2.4.1	0.026
18 A2.4.2	0.022
19 A4.1.2	0.021
20 A4.1.3	0.020
21 A2.1.3	0.019
22 A2.4.4	0.019
23 A4.1.4	0.019
24 A4.2.2	0.018
25 A4.2.3	0.017
26 A2.3.3	0.016
27 A2.4.3	0.015
28 A2.3.1	0.014
29 A2.3.4	0.010
30 A2.1.4.1	0.009
31 A2.2.2	0.009
32 A2.3.5	0.009
33 A2.2.4	0.008
34 A2.3.2	0.008
35 A2.1.4.2	0.004

4. Conclusions

Cleaner production concepts have been developed as preventive measures for different industrial sectors, in order to increase eco-efficiency and reduce risks to both human and environment. Evaluations of the cleaner production implementation using AHP method are capable of systematically minimizing waste and improving the overall process efficiency and reducing the initial costs. The results indicated that repair of all leaks was the most dominant sub-criteria priority for CP implementation in the Kaveh papermaking mill. Moreover, the resulting local weights of objective to criteria showed that a majority attributes ranked higher. Particularly, process change (0.302) and good housekeeping (0.248) were the most important criteria (Table2). This study provides good insights into identifying and prioritizing the criteria and sub-criteria for implementation of cleaner production in Kaveh papermaking mill in Iran. The necessity for implementation of the cleaner production in Iran is indispensable since the pulp and paper industry is less competitive than Asian countries. Also, this industry in Iran consumes the great amounts of water and energy and it is less competitive than the other similar industries. The main problem in Iran is speed of implementation of CP which can be increased greatly with a national CP program and a systematic approach for each industry like AHP.

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