Octa Journal of Environmental Research
International Peer-Reviewed Journal
Oct. Jour. Env. Res. Vol. 4(4):312-318
Available online http://www.sciencebeingjournal.com

Oct. – Dec., 2016
ISSN 2321 3655

Review Article

Octa Journal of Environmental Research
(Oct. Jour. Env. Res.) ISSN: 2321-3655
Journal Homepage: http://www.sciencebeingjournal.com

MATERIAL CONSERVATION – AN APPROACH TO PREVENTION OF POLLUTION

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Received: 24th Oct. 2016 **Revised**: 15th Nov. 2016 **Accepted**: 29th Dec. 2016

Abstract: Sustainability performance and indicators comprises three pillars, Environment, Economic and Society. Here, we have established a linkage between the two factors of sustainability, a. economical factor and b. environmental factor through material conservation approach. Though, the Material conservation will have direct impact on the economic performance but it is also linked to the environmental performance, is lesser studied and documented. Most of the organizations link material conservation performance to economic gains only without realizing its direct impact on environmental performance as well. Manufacturing organizations practice the approach of optimizing and, reducing the input resource to product, without impacting the quality of output, *i.e.* the product itself, for example, the amount of steel going to automotive product, the amount of consumable oils, paints, rubber and plastic parts, etc. In this paper, a tool using input and output balance is used to demonstrate how the manufacturing organizations can evaluate their material conservation performance which has direct linkage to both economic and environmental performance. ISO 14001:2004, Environment Management System standard defines prevention of pollution as use of processes, practices, techniques, materials, products, services or energy to avoid, reduce or control the creation, emission or discharge of any type of pollutant or waste, in order to reduce adverse environmental impacts. Prevention of pollution can include source reduction or elimination, process, product or service changes, efficient use of resources, material and energy substitution, reuse, recovery, recycling, reclamation and treatment.
Keywords: Material conservation, Prevention of pollution, Resource conservation, Sustainability
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INTRODUCTION

Over the last decade, there has been an increased pressure on the organizations to broaden the focus of sustainability and accountability in business performance beyond that of Financial Performance (Lee and Saen, 2011) Green management in organizations has to go beyond regulatory compliance and needs to include conceptual tools such as pollution prevention, product stewardship and corporate social responsibility (Hart, 2005). Hence, the sustainability of a company is judged according to its economic, environmental and social performance (Figge and Hahn, 2004). Companies have long used standard financial indicators to determine their business success. Only recently have a growing number of firms begun to use environmental, health and safety and social indicators (Veleva and Ellenbecker, 2000). In order to measure the progress toward sustainability, several indicators have increasingly been used. Indicators are typically numerical measures that provide key information about a physical, social or economic system (Veleva *et al.,* 2001). They go beyond simple data to show trends or cause

and effect relationships. Indicators have three key objectives *i.e.* to raise awareness and understanding; to inform decision making and to measure progress toward established goals. Environmental initiatives lead to benefits for organization which in most cases meant reduction in waste, cost savings and improvement in product and process quality. Therefore, the efforts to improve business operations that are aligned with sustainability concepts are part of the larger continuous pursuit of corporate sustainability (Bonn and Fischer, 2011). Here, we are linking Material Resource indicator with Input – Output mass balance which has direct impact on conservation of resource, which directly results in prevention of pollution, and also serves as an indicator for the sustainable production measure. The Law of Conservation of Mass or Principle of Mass Conservation states that for any system closed to all transfers of matter and energy, the mass of the system must remain constant over time, as system mass cannot change quantity if it is not added or removed. Hence the quantity of mass is conserved over time. The law implies that mass can neither be created nor destroyed, although it may be rearranged in space, or the entities associated with it may be changed in form. The law implies or requires that during any chemical reaction, nuclear reaction, or radioactive decay in an isolated system, the total mass of the reactants or starting materials must be equal to the mass of the products. This approach of Law of Conservation of Mass is applied in the Manufacturing, linking to Sustainability, environmental and economic performance. For example, for making an automobile vehicle, the amount of consumption of engine oil, and transmission oil is known which is determined by its sump capacity. For producing the number of required vehicles, thus the amount of oil to be ideally consumed is also known. Therefore, for a particular volume of production, the amount of oil to be consumed is known, this is now compared with the actual amount of oil issued from the Stores by Materials Department. In organizations, this data is accurately maintained in the ERP and SAP data. This will identify the difference in the ideal quantity required for production v/s. actual quantity issued from stores. As per the Law of Conservation of mass, mass can neither be created nor destroyed, but it may be rearranged in space or the entities associated with it. The above manufacturing process can give rise to three situations:

a. The amount of oil required for production and quantity issued from stores is matching and there is no difference. This is an ideal situation.

b. The amount of oil issued from Stores is less than the quantity required for production. This cannot happen as there are poka yoke in design and quality will identify such a situation.

c. The amount of oil issued from Stores is more than the actual quantity required for production. This is possible due to losses in manufacturing process which can happen due to for example, loose hose joints, oil sumps/tanks nut loose, rupture of hose etc.

This causes spillage of oil and release to environment. This leads to a situation where more oil than the actual required is issued from stores. We are going to analyses this situation and link it with material conservation, economic and environmental performance. The spilled oil goes to environment, *i.e.* land, by way of spillage, it reaches to water bodies, and causes land contamination, water pollution and are a waste of resource. This is directly impacting both environment and economic performance. The concept of sustainable development about satisfying Environmental, Economic and Social goals is generally accepted relatively easy to comprehend but the difficulties arise in applying the principles of sustainable development in practice (Azapagic and Perdan, 2000). Hence it is necessary to develop appropriate indicators of sustainable development that will enable this assessment to happen. The paper aims to develop this indicator for material resource and efficiency.

CONCEPTUAL ASPECTS

International Standard, ISO 14031: 2013, Environmental Management–Environmental Performance Evaluation–Guidelines describes two categories of indicators for environmental performance evaluation:

i. Environment Condition Indicators (ECIs): Provide information about the condition of the environment which could be impacted by the organization.

ii. Environmental Performance Indicators (EPIs): Provide information related to organization's management of its significant environmental aspects, and demonstrate the results of its environmental management programs.

These may be KPIs that an organization has adopted for its business purposes:

a) Management Performance Indicators (MPIs) provide information about management efforts to influence the environmental performance of the organization management
b) Operational Performance Indicators (OPIs) provide information about the environmental performance of the organization's operations.

Figure 1 below illustrates the interrelationships amongst organization's Management, Operations and the condition of the environment.

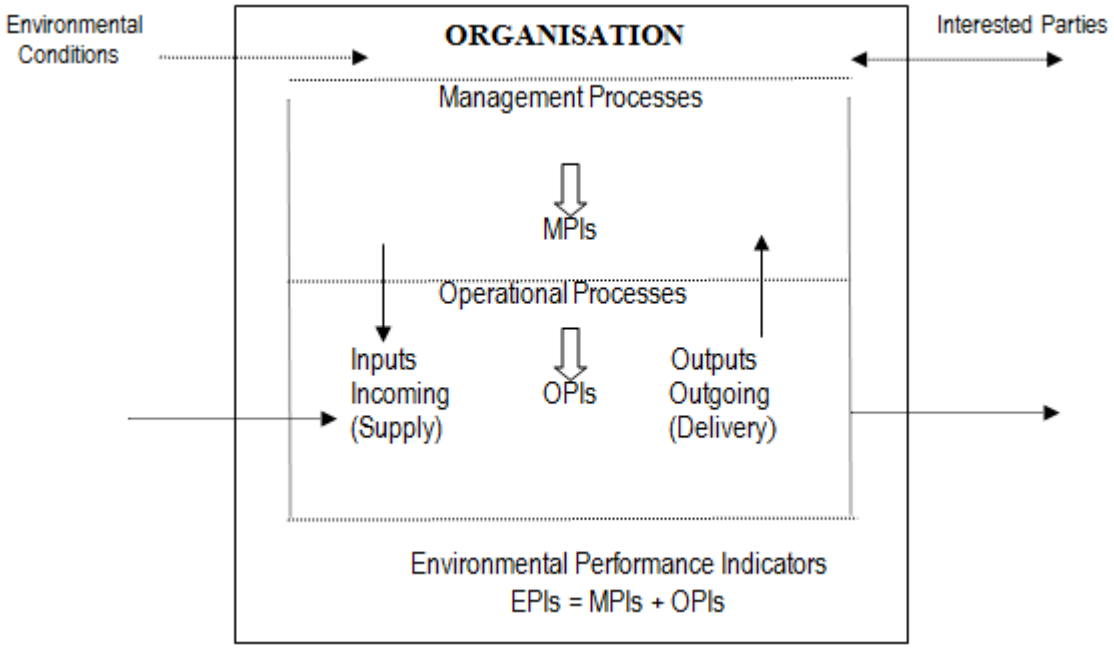

Figure 1. Environment Condition Indicators (ECIs)

The Operational Performance Indicator reflects the efficiency of Operational Process of organization and is directly related to the input and output balance as demonstrated in the figure above. The amount of material going into the process as per the law of conservation of mass should get converted in the form of output in the product otherwise the losses which are happening are going to the environment to air, water, land and directly impacting the environment. According to Krajnc and Glavic (2003), indicators of sustainable production mention six aspects for sustainability assessment *viz*. Resource use aspect, Product aspect, Environment aspect, Economic aspect, Quality aspect, Social aspect. The environmental indicators are divided into input and output based on the flows in manufacturing process as given in Figure 2.

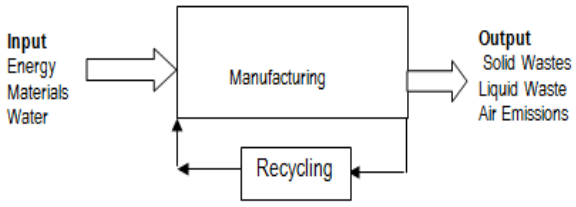

Figure 2. Flows in Manufacturing

The Material consumption indicator reflecting environmental performance is

Specific Material Consumption = Total Material Input/ Production output.

The input of raw material to output in the product is a measure of sustainable production as the gap is causing impact on the environment. Input and Output balance sheet is a material use indicator. Veleva and

Ellenbecker, (2001) suggest six main aspects of Sustainable production with 22 Indicators. The six main aspects of sustainable production proposed by them are:

- Energy and Material Use,
- Natural Environment,
- Economic performance,
- Community development and social justice,
- Workers,
- Products.

The indicators to monitor Energy and Material Use aspects are

- Fresh Water Use,
- Material Use,
- Energy Use,
- Percent of energy from renewables.

The material use indicator reflects the input and output balance and efficiency. The Lowell center for sustainable production (LCSP) defines sustainable production as the creation of goods and services using processes and systems that are non-polluting, conserving energy and natural resources, economically viable, safe and healthful for employees, communities and consumers, and socially and creatively rewarding for all working people.

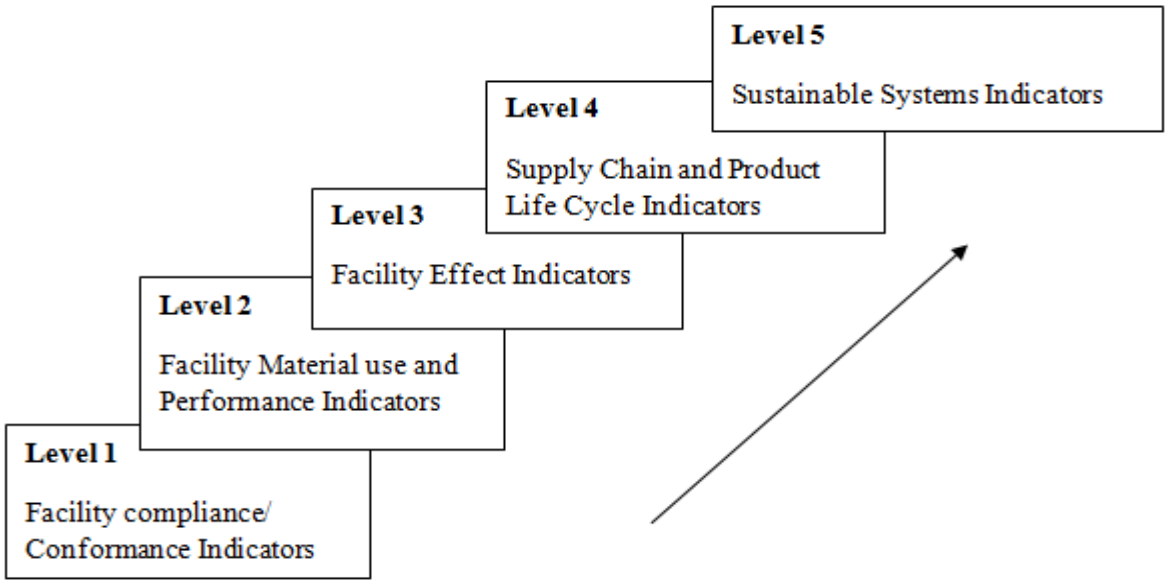

Figure 3. LCSP Indicator Framework

Level 2 Indicators include measures of facility material inputs, outputs and performance (Veleva and Ellenbecker, 2001). This clearly indicates to monitor input and out balance of material in the manufacturing process as it impacts the environment and is directly related to sustainable production. Veleva and Ellenbecker, (2001) in their Core Indicators of Sustainable Production, Figure 3 suggest material use as an aspect of sustainable production covering the LCSP Principle of energy and materials are conserved with a goal to reduce material use. The methodology suggested is to calculate total facility material consumption using the material tracking system and calculate material used per unit of product *i.e.* material intensity. This will help to identify the variation in the material use and consumption and will lead to identify the projects for cleaner production with material reduction. Here, examples are demonstrated to identify the losses in the material consumption through Mass Balance. Organizations identify the Bill of material required for making per unit of product and have it easily and readily available. Green company Rating, CII, Green Business Centre, Hyderabad has developed indigenous guidelines for doing sustainability assessment in India. It has ten indicators for assessing the sustainability performance of an organization as given in figure 4. The Material Conservation, Recycling and Recyclability indicator deals with material input–output balance and efficiency. It is thus important to evaluate input output balance of raw materials in an organization

which is an important measure of environmental and sustainable performance.

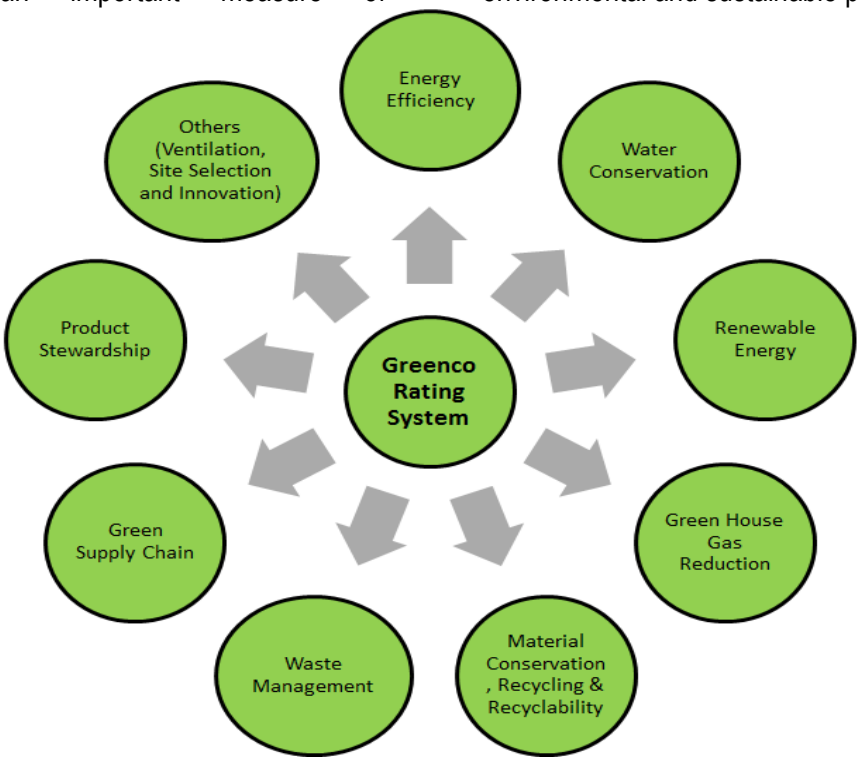

Figure 4. CII, Green Business Centre, Greenco Rating Framework

METHODOLOGY

According to Staniskis and Arbaciauskas (2009), it is commonly agreed that the use of performance indicators is a most effective way to evaluate sustainability performance, but design / selection of sustainability performance indicators and their application wait to be explored at both national and enterprise levels until the consensus concerning the most effective performance indicator systems and methodologies for their application is achieved. Azapagic and Perdan, (2000) suggest to express the indicators for sustainable production per unit of service that the system delivers. This enables a comparison within the company, amongst similar companies' *e.g.* specific fuel consumption, specific water consumption, specific electric consumption and specific material consumption per unit of product. This helps to monitor the performance of indicators within the industry year over year and also helps to track the performance**.** Engineering specifications lay down the design and the bill of material that will be required to make a unit product. This data is made available in SAP and ERP and based on this information the required amount of material for the required volume of Production is procured by the Materials department. Shortfall of the material is monitored but the analysis of the material required versus actual consumed is mostly not done by the organizations for the consumable materials e.g. Paint and different Oils going into the product. Materials, as they pass through the processing operations can be described as material balance. Ideally if there is no loss or accumulation what goes into the process must come out. Material balances are fundamental to the control of processing of the products. After the bill of material is established, material balance should be maintained as a control instrument when the production continues. This is explained through a detailed example as given below:

a) Amount of Paint required for painting one vehicle as specified in the Bill of Material – A Kg
b) Total Paint required for Painting the required amount of Vehicles - No. of Vehicles * A Kg
c) Amount of Paint actually issued from the Stores = Y Kg

d) Wastage of the paint recovered from the exhaust filters – C Kg

Under ideal condition-

Amount of Paint Issued from Stores = Total Paint required for painting + Total Waste = No. of Vehicles * A Kg + C Kg = Y Kg

Consider the situation where losses occur due to process gaps or errors:

Y (Kg) > No. of Vehicles * A Kg + C Kg (Paint issued from stores is greater than the actual required and used in production)

Following assumptions based on the above situations are proposed:

Y – (XA + C) > up to 1% to 2% indicates low impact on environment.

Y – (XA + C) > by and between 2 to 5% indicates medium impact on environment.

Y – (XA + C) > by and above 5% indicates significant impact on environment.

Table 1. Mass Balance Study for Paint in Painting process in Manufacturing Industry to establish input output balance

#	Description	Jan	Feb	Mar	Apr	May	June	Total
a.	Amount of paint actually issued from Stores as per ERP and SAP Records (Kg)	17450	16950	21625	18400	20250	19500	114175
b.	Model A Production in Nos. In Nos. Paint required - 9 Kg / Vehicle	1889	1810	2325	1958	2180	2070	12232
c.	Model A Paint Required (Kg)	17001	16290	20925	17622	19620	18630	110088
d.	Model B Production. In Nos. Paint required 8 Kg / Vehicle	32	53	53	46	39	62	285
e.	Model B Paint Required (Kg)	256	424	424	368	312	496	2280
f.	Total Paint required for Model A and B [c + e] (Kg)	17257	16714	21349	17990	19932	19126	112368
g.	Amount of Paint recovered in the exhaust system / scrap paint (Kg)	60	50	75	60	65	60	370
h.	Unaccounted Difference = Actual Issued – Actual required + Actual Scrap [a – f+g] in Kg	133	186	201	350	253	314	1437
i.	Difference in %	0.76	1.09	0.92	1.90	1.24	1.61	1.25

Source: JCB India Limited, H1-2016.

Table 2. Mass Balance Study for Engine oil in Manufacturing Industry to establish input output balance

#	Description	Jan	Feb	Mar	Apr	May	June	Total
a.	Amount of Engine oil actually issued from Stores as per ERP and SAP Records (L)	31200	26450	25655	25569	22395	18480	149749
b.	Production Volume in Nos.	2073	1759	1703	1700	1483	1222	9823
c.	Engine oil Required - 15 L / Vehicle	31095	26385	25545	25500	22245	18330	149100
d.	Amount of Oil recovered at the time of Oil filling. Scrap Waste oil (L)	50	20	20	15	30	25	160
e.	Unaccounted Difference = Actual issued– Actual required + Actual Scrap [a-c+d]	55	45	90	54	120	125	489
f.	Difference in %	0.17	0.17	0.35	0.21	0.53	0.68	0.33

Source: JCB India Limited, H1-2015.

The overall difference month wise and over duration of period indicates the unaccounted losses that are happening and directly impacting the environment. The loss is economic as well. This analysis gives an opportunity to assess the process which is causing the loss and take appropriate corrective action. The above indicates that in a period of Six months there is 0.33% of unaccounted engine oil and Powder Paint by 1.25% consumption. The amount oil issued from stores is more by 0.33% than the actual required and the waste oil recovered. Similarly the difference in Paint actually required and issued from Stores is 1.25%. As the law conservation of mass states that the material cannot be created nor destroyed but it can be rearranged in space hence this unaccounted oil

0.33% and Paint 1.25% finds space in environment. It can be in the form of waste *i.e.* the spilled oil soaked in cloth pieces and can go to scrap and cause waste management issue, contaminate land, the oil can spill and leak and go to land causing land contamination or reach to water body causing water contamination. The unaccounted mass impacts the environment as well as financially.

CONCLUSION

Sustainable development has been defined as the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The Mass Balance study helps to meet this objective of resource conservation through identifying, capturing, monitoring and reviewing the unidentified losses. This loss, apart from the economic loss has direct impact on the environment as well. Resource loss has both environmental and economic impacts. Unless, this study is conducted, losses cannot be known and monitored. What is not monitored does not get corrected and improved. This study is easy to be conducted but a very important and effective tool in material resource efficiency which is an important indicator in any of the Sustainable Production or Sustainability indicators. Month over month when the study is conducted and reviewed the trends begin to improve and the objective to go towards zero losses can be achieved by the organizations. The organizations can thus benefit economically as well as reduce the impact on environment.

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Source of Financial Support: None.
Conflict of interest: Nothing, Declared.