IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN(P): 2347-4580; ISSN(E): 2321-8851
Vol. 4, Issue 8, Aug 2016, 143-156

"ENVIRONMENTAL IMPACT ASSESSMENT (EIA) AS A TOOL TO ACHIEVE THE SUSTAINABLE DEVELOPMENT"

ANOOP SINGH[1], BRAJESH SHARMA[2], NAVEEN GAURAV[3] & NEETA SINGH4

[1,2]Jaiprakash Associates Ltd, Cement Division, Rewa, Madhya Pradesh, India

[3]S.G.R.R.P.G. College, Dehradun, Uttarakhand, India

[4]Professor, Department of Botany, Govt. PG Girls College, Rewa, Madhya Pradesh, India

ABSTRACT

As the word Environment gained its eloquence, in 1972 from the well focused United Nations Conference on the Human Environment which became the periphery of interrelating day to day human activities & its effect on Environment. Further the momentum has been attained in 1992, from the U.N Conference on Environment & Development named as Earth Summit which resulted in farming action plan to achieve Sustainable Development & so emerged the most relevant tool to assess a potential project for environmental impacts known as "EIA". EIA envisages the future environmental impacts arising from upcoming project or a development activity providing suitable options & feasible measures for reduction of adverse impacts, making project friendly to lives of number of local habitants & hence maintaining sustainable livelihoods. Hence EIA is the best perceived tool for achieving the sustainability, i.e. desired balance between needs of today keeping in mind the demands of future generations.

The approach sustainable development was introduced into the global scenario in the 1980s as a sphere co-relating economic development, the natural environment and people. This paper reviews the various analytical tools available to determine environmental impacts & there applications & respective comparison with EIA. The objectives of study to a large extent has been based on mapping & analysis of relevant flows of material, energy, environmental impacts & CO_2 generation per tonne of clinker & cement in Jaypee Sidhi Cement Plant, Sidhi (M.P.) –India, A unit of Jaiprakash Associates through Life Cycle Assessment tool. LCA methods is used for compiling & examining the inputs & outputs of energy, raw material, environmental impacts & emissions directly attributable to the manufacture & functioning of a production of product from "Cradle to Grave". Production of cement involves the consumption of large quantities of raw materials, energy & pyro- processing. Also cement production is one of the largest contributors to global Co_2 emissions. Environmental impacts are taken in study as per national ambient air quality standards, 2009 of MoFF & CC. LCA methods are more precisely defined in ISO standards 14040 & 14044. Major thrust on following sections have been given in the study is goal & scope definition, inventory analysis, impacts assessment & interpretation. Potential impacts are also evaluated using the software & help of International Reference Life Cycle Data System Method recommended by European Commission in this study. Cost based analyses of above different segments were too taken in account in this research paper.

KEYWORDS: Life Cycle Assessment, Cement, Energy, Pyro- Processing & Co_2 Emissions

INTRODUCTION

The issue of environmental pollution originates with the growth & development. Environmental Impact Assessment (EIA) is a defined procedure adopted worldwide for identifying, predicting, analyzing and monitoring potential impacts of any upcoming activity on the environment. The people of every nation have recognized the need to achieve development coined with it an additional term 'Sustainable'. Although the cost benefit is main area of interest but nations all over the world have become aware & are progressing with the approach not to compromise the ability of future generations to fulfill their basic needs. Different approaches exist in the system to help achieving this Sustainable Development. Approach for EIA began appearing in developing countries legislation during the 1970s, evidenced by the first national Environment law adopted by the United States, in 1969 known as the National Environmental Protection Act (NEPA). Adoption of Standards to achieve Sustainable Development started at the beginning of the 1970s after the Stockholm Conference. By 1980s, few more countries decided to introduce EIA as an element of environmental policy and a legal requirement for the proposed development activities. Since 1990, the legislations on environmental issues have strengthened up and the number of countries with EIA legislation has increased significantly. The link between EIA and sustainability is recognized & well established but still insufficiently explored. Importance of various tools to determine Environment impacts is of high weight age as Environmental issues directly affect humanitarian activities threatening the society & life.

The Cement commerce has already become an indispensable commodity which contributes for global progress which also contributes globally ~5% of man-made CO_2 as an adverse environmental impact on planet earth, during its production phase[1]. Cement manufacturers have already implemented programs aiming to reduce their GHG footprint introducing clinker substituted cement types, utilizing alternative fuels and optimizing the cement manufacturing process. LCA is a tool which can be used to quantify & assess the environmental impacts for a selected scope. Study covers a detail LCA study on different cement manufacturing scenarios selecting GHG emission as the main impact category for a local integrated cement manufacturing facility. As the scope of the LCA 'cradle to gate' approach was selected and functional unit defined as 'one tonne of cementitious material' in order to compare with different clinker percentage cement types. Use of LCA methods have been done as precisely defined in ISO standards 14040 & 14044. [2]

The manufacture, application, and disposal of materials, rapid depletion of resource reserves and other environmental problems such as climate change have been major threats to the species during the recent years. In order to meet these challenges, many tools and indicators for assessing environmental impacts of different systems have been developed. The usual analysis methods mainly include life cycle assessment (LCA) and materials flow analysis (MFA). LCA has been extended too many aspects of production and consumption, including eco-design of products, cleaner production, environment label, green purchase, resource management, wastes management and environment strategy, etc. in this study [3−4].

This tool is compatible with the cement CO_2 protocol published by the WBCSD (World Business Council for Sustainable Development) aligned with GRI (Global Reporting Initiative) & International Panel for Climate Change (IPCC) guidelines.

Jaypee Sidhi Cement Plant a unit of Jaiprakash Associates (Cement Division) is one of the modern & energy efficient plant of the Jaypee Group situated in Sidhi district of Madhya Pradesh, India. Presently, it has two clinkerization units and its total annual capacity of clinker production is 3.0 Million Tonn Per annum & cements production capacity 3.5 Million Tonn per annum. The first unit was supplied & successfully commissioned by L&T (SLC Kiln -1.5 Mn TPA) in February 2009. The second unit supplied & successfully commissioned by FL Smith (ILC –Kiln 1.5 Mn TPA) in January - 2013.

Appropriate measures /modifications are evolved through this monitoring process of use of LCA resulting steady decline in thermal & power consumption. The data of last three years indicates drastic reduction in thermal & electrical consumptions. This has also resulted to bag Certificates of merit National Energy Conservation Award 2014 from Bureau of Energy Efficiency (BEE).

BENEFITS TO ASSESS ENVIRONMENT IMPACTS

The need of tools to assess Environment Impacts arising from any upcoming project or activity is of prime concern to benefit the life on earth in following way-

- Development with Sustainability- Any assessment study carried out during the planning phase imparts the project owner to better design the project so that minimum harm to life & nature occurs. For Example: Setting up a Limestone crusher aids to fine dust in the nearby area. Project owner may discover all the negative impacts of the crusher to nearby locality.
- Reduction of the Impacts- A subsequent development activity can lead to adverse impacts on living(Humans, Flora & Fauna) as well on non living things (Water, Air, Land & other natural resources). Early assessment of the risks can lead to implementation of mitigation measures with the planning phase of an activity. For example, in the above referred Limestone crusher, installation of Dust Pollution Control Devices can be planned to minimize the emissions.
- Reduction in Overall Cost on Long term basis- Saving natural resources, protecting human settlements are always beneficial & economy savers on long term basis. It acts as a holistic approach for reduction of overall cost of the project from beginning to the end. For Example, by the installation of Dust Control measures the crushed fine dust remains in the system rather than emitting out: Raw Material is saved, No prominent effect due to dust & hence saving the quality of life.

TOOLS TO ASSESS ENVIRONMENT IMPACTS

The various tools to assess Environment Impacts arising from any project or activity can vary from depending on the type of project; some basic tools (Table: 1) are elaborated as-

Life Cycle Assessment

LCA is a production-based analytical tool that includes the systematic assessment of the environmental aspects of a product or service system through all stages of its life cycle i.e from cradle to grave starting from raw material extraction stage to final distribution of products, its use & reuse. The design and production of new products and materials should be based on a life-cycle assessment concept. LCA helps to save natural resources, energy & ultimately in minimizing the pollution load of that particular product. With betterment of Environment, LCA also helps in cost savings & other market competition skills.

The goal of LCA is to compare the full range of environmental effects associated with the products and services by quantifying all inputs and outputs of material flows and assessing how these material flows impact the environment taking step wise. There are two main type of LCA-

- Attributional LCAs associated with the burdens emerging from production and use of a product, or with a specific service or process.
- Consequential LCAs identifies the environmental consequences of a decision or a proposed change in a system under study (oriented to the future).

According to the ISO 14040 and 14044 standards, a LCA is a in four distinct phase system as illustrated in the Figure -1:

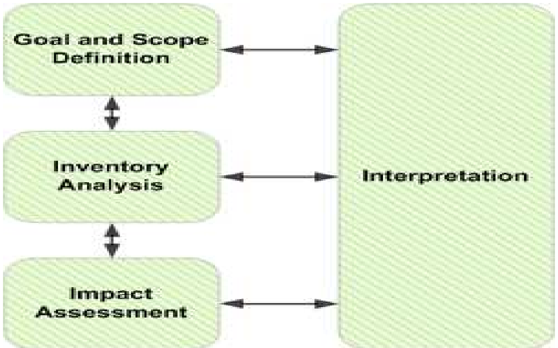

Figure 1: Illustration of LCA Phases

- **Goal & Scope Definition-** The basic preliminary step for LCA is clearly defining goal & scope. All the technical details associated with the project are covered to guide the further process. The most important goal of LCA, according to a survey of organizations actively involved in LCA, is to minimize the magnitude of pollution (S. Ryding, "International Experiences of Environmentally Sound Product Development Based on Life Cycle Assessment," Swedish Waste Research Council, AFR Report 36, Stockholm, May 1994.). The goals & scope vary from user to user depending upon the ultimate requirement. The LCA can be used for product development, product improvement & comparison with the existing products.
- **Life Cycle Inventory –** An inventory is created setting up the relationship of inputs from the nature & outputs into the nature which includes inputs of water, energy, air & outputs in the form of emissions & effluent back to the nature.
- **Life Cycle Impact Assessment-**The various impacts are categorized & classified followed by impact measurement
- **Interpretation-**It is a step to interpret the data by indentifying, quantifying, checking & evaluating the impacts. The outcome of this phase is set of recommendations & summarized conclusion for the study.

On the basis of outcomes, the alternatives are suggested to minimize the negative impacts on the natural resources.

Ecological Footprinting (EF)

The Ecological Footprint concept was introduced by Mathis Wackernagel and William Rees in the early 1990's (Rees 1992, Wackernagel 1994, Rees 1996, Wackernagel and Rees 1996). It is basically used to determine the actual human consumption of biological resources and generation of wastes respectively. Both consumption & generation are defined in terms of appropriated ecosystem area. Ecological footprint analysis is now widely used around the Earth as an indicator of environmental sustainability. It can be used to measure and manage the use of resources throughout the economy. It can be used to explore the sustainability of individual lifestyles, goods and services, organizations, industry sectors, neighborhoods, cities, regions and nations. The principle goal of sustainability is to achieve a state whereby all of humanity is able to live well within the means of One Planet, without compromising the needs of future generations. The 2010 Living Planet Report suggests that by 2030 humanity needs the equivalent of two Earth's to support its consumption habits (The footprint Company)

There are two main methods to calculate the Ecological footprint (Chamber, Simmons & Wacker nagel 2000):

- Compound Method-This method was developed by Mathis Wackernagel & William Rees (1996) to measure ecological footprints of nations. This method uses national trade figures & energy budgets of the nation as a whole.
- Component Method- This method was developed by Best Foot Forward to measure the regions ecological footprint. This method uses local data & life cycle studies.

An ecological footprint:

- tells us about our impacts on Earth on which we live;
- provide us the cumulative demand upon nature;
- allows us to compare where we stand;
- tells us about our available global bio-capacity (productive land and sea area);
- Tells us where we stand, whether we are meeting the minimum requirements for sustainability.

Environment Impact Assessment

Environmental impact assessment (EIA) is an important tool. It is defined as a crucial activity performed during the planning stage of any upcoming project to identify and predict the impact on Environment & so provides optimum mitigation measures to be imparted in the designing stage for maximum eradication of pollution & to achieve sustainable development. The comprehensive EIA study normally consists of the following stages:

- **Screening program**: As per the need of regulatory authority, need & type of EIA required is identified for the upcoming project.
- **Scope**: It involves different stakeholders (public, non-governmental organizations (NGOs), local communities and relevant regulatory authorities) to participate in defining the key Environment issues.
- **Assessment**: Evaluation of selected key issues as per specified assessment methods such as mathematical

modeling, metrics, and professional judgment. Roots of these issues are evaluated & judged properly.

- **Mitigation measures**: Mitigation measures for all environmental issues resulting from the above stage to prevent or minimize their impacts on the environment.
- **Monitoring**: Regular Monitoring to get the baseline data i.e. air, water, soil, noise & socio-economic aspects.
- **Reporting:** The entire pre-study (Rapid EIA) & post-study (Comprehensive EIA) detail is prepared in a report submitted to the regulatory authority for review and approval.

EIA is a regulatory procedure for grant of Environment Clearance as per EIA Notification, 2006

Table: 1: Comparison of Various Tools

Sr. No	Tool	Type	Application Phase	Cost Saving	Time Consuming	Mitigation Measures	Sustainability	Constraint
1.	Life Cycle Assessment	Decision Support Tool	Running Operation	Huge, Optimizatio n of products	Very Much	Provides the cause of pollution	Yes, More Sustainable Products	Aspects like concentration of pollutants & duration of exposure are not accounted
2.	Ecological Footprint	Pollution load accounting tool	-	Accounting of Natural reserves present on earth.	Long Process	-		Determination of Bio-capacity only
3.	Environment Impact Assessment	Prior aspect impacts prediction tool	Done in planning phase	Long Term Cost saving	Fixed	Provides mitigative measures right at the planning phase only	Yes, Make Entire project Environment Friendly & more sustainable	Regular monitoring after EIA, should be done to compare the scenario from base line data

BACKGROUND

Cement Manufacturing Process

The cement manufacturing process is diagramed in the flowchart in Figure 2. Processes requiring energy inputs are outlined in yellow and processes requiring heat are outlined in red. The pollutants emitted during manufacturing are particulates and gases such as CO_2, SO_2 and NO_X. Coal fly ash slag or pozzolans may be blended with the raw material. The addition of these optional materials will result in lower emissions.

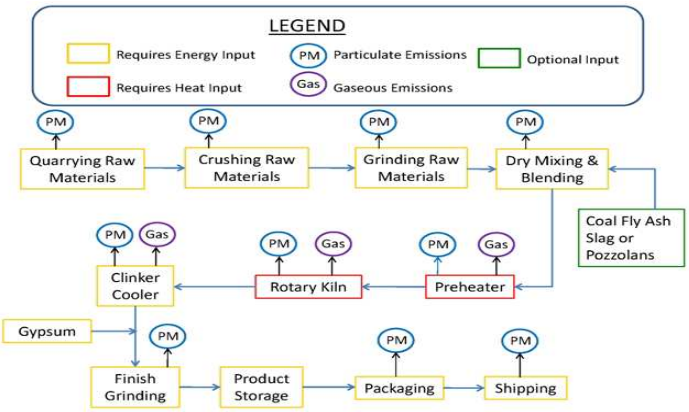

Figure 2: Process Flow Diagram for the Manufacture of Cement

Cement production requires large quantities of raw materials and energy. The main component of cement is called clinker. Clinker consists of cinder lumps formed by heating limestone, bauxite, and iron ore sand to 2,770^{o} Fahrenheit. The production of clinker is very resource intensive. Producing one ton of clinker requires an energy input of between 3000-6000MJ and approximately 1.5tons of raw material.

The amount of clinker needed to produce a given amount of cement can be reduced by the use of supplementary cementitious materials such as coal fly ash, slag, and natural pozzolans (e.g., rice husk ash and volcanic ashes; [5]. The addition of these materials into concrete not only reduces the amount of material landfilled (in case of industrials byproducts), but also reduces the amount of clinker required per ton of cement produced. Therefore cement substitutes may offer reduction in environmental impacts and material costs of construction. The use of natural pozzolans could Save oragnization up to 30-35% per bag of cement (if the cement is blended and concrete mixed onsite), which can provide an economic benefit to the building of new infrastructure [6]. Therefore cement substitutes may offer reduction in environmental impacts and material costs of construction. In developing countries research has mapped natural pozzolans with socioeconomic and industrial indicators [7]; pozzolanic (blended) cement could be an important technology for sustainable development.

The goal of the study is to determine the environmental impacts, specifically global warming potential, from the production of approximately 1 t of cement by examining following products processes:

- Traditional Ordinary Portland cement;
- Blended cement (natural pozzolans /fly ash);
- Use of AFR.

METHODS

The LCA methodology used in this study follows the stages outlined by International Organization for Standards (ISO) 14040[8], as well as those described by Allen and Shonnard [9], Owens [10], Curran [11], and Hunt et al. [12]. The four major stages of the LCA applied in this study include:

- Determination of the assessment scope and boundaries;
- Selection of inventory of outputs and inputs;
- Assessment of environmental impact data compiled in the Inventory; and
- Interpretation of results and suggestions for improvement.

Area of Study for Cement Plant

The scope of the project focuses on the raw material acquisition & Quarrying, Processing, and product manufacturing stages **(Figure 3)**

Each of the products examined has a life cycle, beginning with raw material extraction to the packaging of the finished product. Complete life-cycle assessments also include the use and disposal stages of products have been examined.

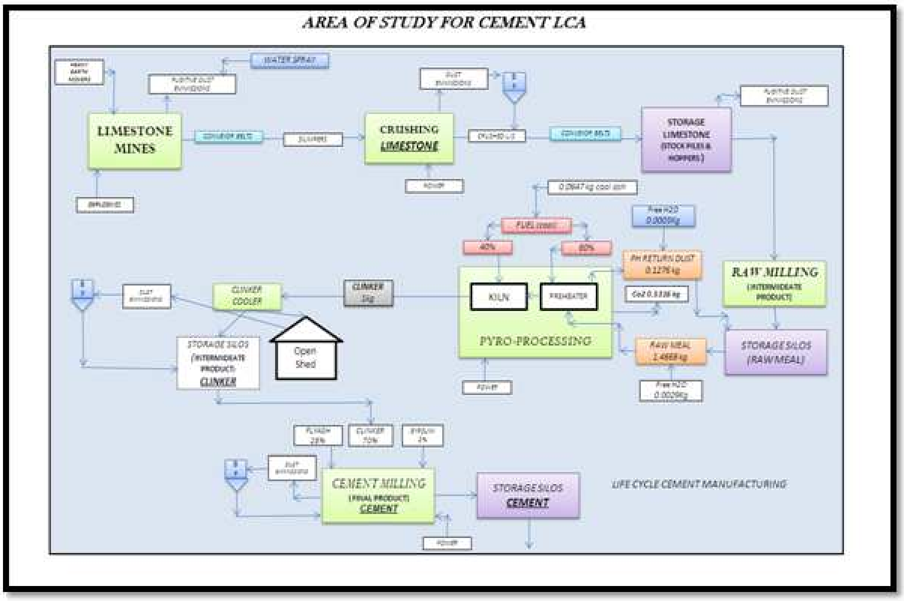

Figure 3: Area of Study for Cement LCA at Jaypee Sidhi Cement Plant

Determinations of the assessment scope and boundaries have been done from Mines section to dispatch section. Both Ordinary Portland Cement (OPC) & Pozzalana Portland Cement (PPC) manufacturing steps were involved in LCA.

Ordinary Portland Cement

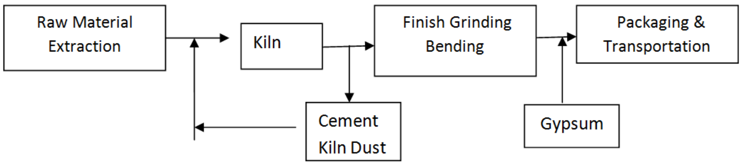

Figure 4: Materials Involved in OPC

Pozzalana Portland Cement

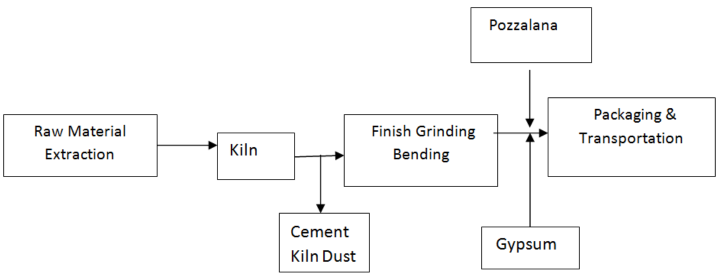

Figure 5: Materials Involved in PPC Manufacturing

INVENTORY ANALYSIS THROUGH MATERIAL BALANCE, ENERGY & HEAT BALANCE OF PLANT

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system.

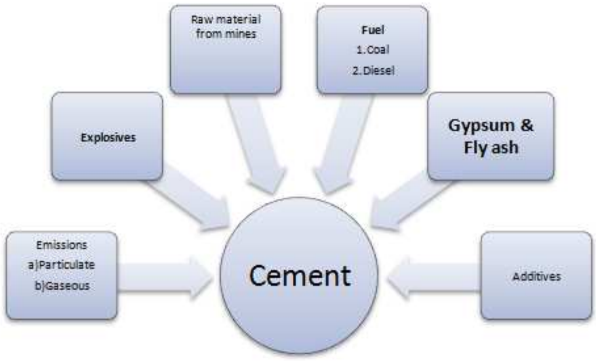

Figure 6

Material Balance

On average 1.66 t of raw materials are required to produce 0.95 t of clinker or 1.0 t of finished cement (refer to Figure. 6 for a material flow diagram of the manufacturing process). Non-fuel raw material consumption can be broken down into five major components that provide: (1) calcium oxides, (2) aluminum oxides, (3) silica, (4) ferrous oxides, and (5) calcium sulfate **[13, 14].**

In this assessment the raw materials and corresponding quantities outlined in Figure. 2 are assumed to provide the necessary chemical balance for the kiln feed. Figures.4 & 5 and Table 2 show the material acquisition, processing, and manufacturing.

Table 2: Material Balance of Product of JSCP

Material Balance				
Material Balance for JSCP			IN kg	OUT kg
S. No				
1	Clinker	C	****	1
2	Coal Ash	A	0.0647	****
3	Raw Mix to Clinker	B	1.4668	****
4	Co2 from Raw Mix	D	****	0.5316
5	Free H2O (i.e I.M from Raw Mix)		0.0029	0.0029
6	Return dust @8.00% of kiln feed		0.1276	0.1276
7	Free H2O (i.e. I.M from Kiln feed)		0.0003	0.003
8	Difference		0	
9	Sum		1.6623	1.6623

Materials & Products Flow Diagram

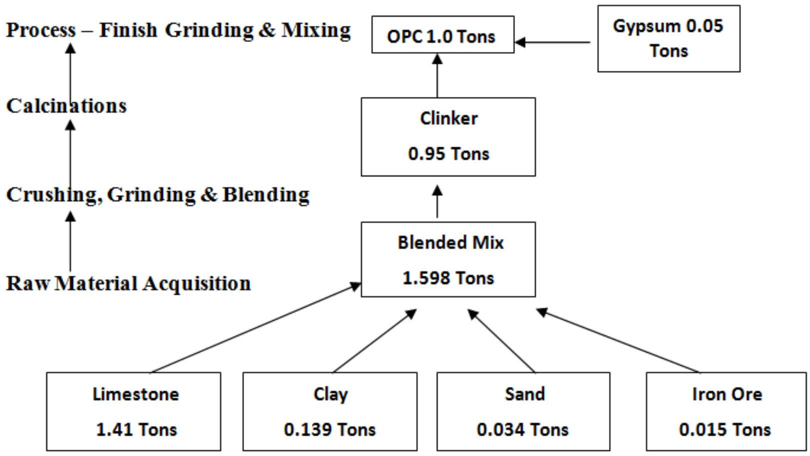

Figure 7: Material Balance of Product of JSCP

Energy Consuming Process in the life Cycle Stages of Cement Manufacturing

Cement Plants are energy intensive, in terms of both Thermal as well as Electrical. Thermal energy contributes around 90% of total energy consumption where as electrical energy contributes to around 10% of total energy. The total energy costs (Thermal & Electrical) make up about 30-40% of total production cost of cement. This is why efficient energy utilization has always been a matter of priority in cement industry. Following point has been taken well in study of LCA of product of industry.

Daily basis measurements of electrical & thermal energy were made in plant and analysis were made with the help of conditional monitoring of equipments. Energy consuming process in the life cycle stage of cement among different section is well shown in table 3.

Table 3: Energy Consuming Process in the Life Cycle Stages of Cement Manufacturing for F.Y 14-15

Energy Consuming Process in the life Cycle Stages of Cement Manufacturing. For F.Y 14-15			
S. No.	**Areas**	**Electrical Energy Consumption (Kwh/TClk)**	**Thermal Energy Consumption (Kwh/TClk)**
1	Limestone Crushing	1.03	****
2	Raw Mill drying & Grinding	30.85	****
3	Coal grinding & Drying	4.08	****
4	Clinkerisation & Clinker Cooling	25.37	****
5	Clinker Grinding- Cement Production	34.36	691.09
6	Conveying, packing & Dispatch	2.4	****

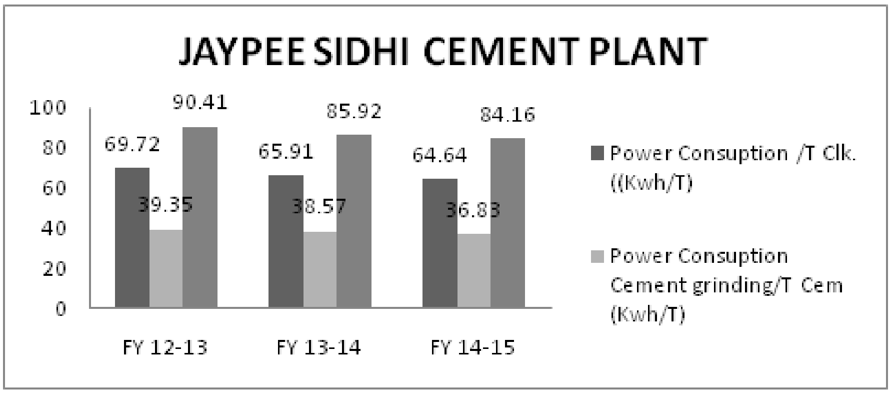

Figure 8: Energy Consuming Process in the Life Cycle Stages of Cement Manufacturing for F.Y 12-13 to14-15

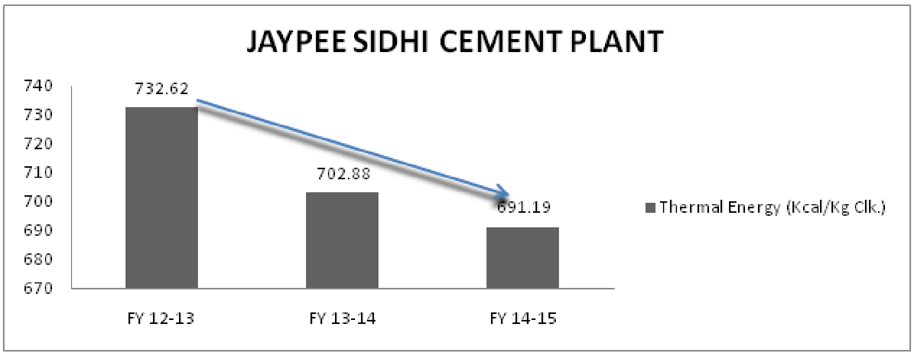

Figure 9: Thermal Energy Consuming Process in Cement Manufacturing for F.Y 12-13 to14-15

Particulate Emission

Table 4: Energy Consuming Process in the Life Cycle Stages of Cement Manufacturing for F.Y 14-15

Jaypee Sidhi Cement Plant						
Report of Stack Emission April -2014 to March - 2015						
Location ->	**Lime Stone Stack**	**Raw Mill Baghouse Stack**	**Coal Mill Baghouse Stack**	**Cement Mill Baghouse Stack**	**Packer Stack**	**Cooler -Esp Stack**
PARAMETERS ->	Dust Concentration Mg/Nm3					
AVERAGE ->	28.52	20.29	31.98	28.47	31.44	21.23
MPPCB LIMIT ->	50	50	50	50	50	50
Min.	16.94	18.09	23.95	21.99	22.06	18.91
Max.	35.93	22.1	39.87	33.96	42.11	23.86

JSCP Plant has installed highly efficient Air Pollution Control Devices APCDs, across major points results are well within statuary norms of SPCB & CPCB. Around 108 nos. Bagfilters are installed in major transfer points to control fugitive emissions.

4.5 Inventory Analysis of Water, Fuel Consumption (Process Plant) & Explosive in Mines

Table 5: Water consumption in the life Cycle stages of Cement Manufacturing for F.Y 14-15

Water Consumption Per Unit Product			
Sl. No.	**Inventory**	**Unit (Kl/Day)**	**Unit (Kl/T Cem)**
1	Industrial Demand	2550	0.255
2	Domestic Demand	1073	0.107
3	Total	3629	0.362

Table 6: Explosive & Diesel Consumption in the Life Cycle Stages of Cement Manufacturing for F.Y 14-15

Limestone Mines			
Sl. No.	**Inventory**	**Name of The Product**	**Consumption**
1	Explosives (Gm/t)	Limestone	260
2	Diesel (Lit/t)	Limestone	0.2
3	Total	3629	0.362

RESULTS

Life Cycle Impact Assessment

The environmental impacts of cement manufacturing can be local, regional, or global in scale. Local effects include noise, air quality, and natural disturbance (e.g., change in landscape, impacts to local ecosystem) of mining raw materials such as limestone, iron ore, and clay. Emissions such as sulfur dioxide (SO2) and nitrogen oxides (NOx) contribute to acid rain on a regional scale. Carbon emissions originating from the calcining process and combustion of fossil fuels (e.g., coal, natural gas, fuel oil) contribute to global climate change. The focus of this analysis is global environmental impacts, particularly global warming, and how alternative cement mixes and or processing technologies impact the overall global warming potential of cement production.

Table 7: Environmental Impact Score for Cement Products at JSCP

Environmental Impact Score for Cement Products				
S. no	**Pollutants Emitted from Cradle to Gate for 1 ton of Clinker**	**Clinker**	**Traditional Cement (OPC)**	**Blended Cement(PPC)**
1	CO_2 (Kg/ton -Cement)	812	789.264	547.288
2	SO_2	0.093	0.090	0.063
3	NOx	0.850	0.800	0.611
4	Total Greenhouse Effect (Kg Co2 Eq/ton)	812	789.264	547.288`
5	Total Acidification (Kg So2 Eq/ton)	0.7279	0.708	0.491
6	Total Eutrophication (Kg Po 4 Eq/ton)	0.11791	0.115	0.079
7	Total Photo –Oxidant formation (Kg C2H4 eq/ton)	0.045080.04	0.044	0.030

CONCLUSIONS

As per the review, EIA is the cumulative & best identified tool to cover all environmental impacts during the planning & designing phase of upcoming activity. It is the key to find out the mitigation measures to reduce the impact on Environment as it facilitates the design of monitoring programme by providing suitable opportunity to people for identifying problems. With other available tools, there are few constraints making them specific to one field only like with LCA the main constraint is, it cannot quantify actual environment effects for the upcoming project. Moreover the Ecological Footprint does not cover the entire industrial future impacts on the Environment, while EIA is best recognized tool as both of these constraints are undoubtedly solved by EIA. Mitigating sources of anthropogenic carbon emission will help to lower greenhouse gas levels globally. This study has addressed the environmental impacts associated with the alternative technologies for the cement manufacturing process. Environmental life-cycle assessment (LCA) is a valuable tool for understanding the environmental hazards of products and for optimizing the manufacturing process to reduce adverse environmental impacts. However, there are limitations to the study and it should be noted that data aggregation problems associated with secondary information sources may cause variation in impact values for replication studies. Much of the absolute environmental impact will depend on energy and heat input amounts that vary between processes.

Although the results of this LCA show that blended cements provide the greatest environmental savings, the reduction in GHG potential in blended over traditional cements.

REFERENCES

1. Huntzinger, Deborah N., and Eatmon, Thomas D., "A life-cycle assessment of Portland cement manufacturing: comparing the traditional process with alternative technologies" Journal of Cleaner Productions 17 (2009) 668-675.
2. ISO 14044: Environmental management—life cycle assessment—requirements and guidelines [S]. International Standard Organization, Geneva, 2006.
3. REBITZERA G, EKVALLB T, FRISCHKNECHT R, et al. Life cycle assessment (part 1): Framework, goal and scope definition, inventory analysis, and applications [J]. Environment International, 2004, 30:701−720.
4. HORNE R, VERGHESE K, GRANT T. Life cycle assessment: principles, practice and prospects [J]. Australia: CSIRO Publishing, 2009.
5. Neuwald A. Supplementary cementitious materials, part I: pozzolanic SCMs, what are SCMs and how can you use them to your advantage? Manufactured Concrete 2004:8–16.
6. Mihelcic J, Eatmon T, Muga H, Harris RA. Engineering sustainable construction materials for the developing world: a meta-discipline approach to engineering education. International Journal of Engineering Education 2007;23 (6):1116–25.
7. Harris RA, Eatmon T, Seifert C. Reconciling technological viability with social feasibility: the case of natural pozzolans for sustainable development. World Review of Science, Technology, and Sustainable Development 2008; 5(1):49–65.
8. International Organization for Standardization (ISO). ISO 14040: environmental management – life cycle assessment – principles and framework; 1997.
9. Allen DT, Shonnard DR. Green engineering: environmentally conscious design of chemical processes. Upper Saddle River: Prentice Hall; 2002.
10. Owens JW. Life cycle assessment: constraints on moving from inventory to impact assessment. Journal of Industrial Ecology 1997;1(1):37–49.
11. Curran MA. Environmental life-cycle assessment. McGraw -Hill; 1996.
12. Hunt RG, Sellers JD, Franklin WE. Resource and environmental profile analysis: a life cycle environmental assessment for products and procedures. Environmental Impact Assessment Reviews 1992; 12:245–69.
13. Van Oss HG, Padovani AC. Cement manufacture and the environment, part 1:, chemistry and technology. Journal of Industrial Ecology 2002; 6(1):89–105.
14. Van Oss HG, Padovani AC. Cement manufacture and the environment, part II: environmental challenges and opportunities. Journal of Industrial Ecology 2002;7(1):93–127.

15. United Nations, 1992 The Rio Declaration UN.
16. Bruhn-Tysk S. and Eklund M., 2001. Environmental impact assessment – a tool for sustainable development? A case study of biofuelled energy plants in Sweden.
17. Cashmore M., Bond, A., Cobb, D. 2007. The Contribution of Environmental Assessment to Sustainable Development: Toward a Richer Empirical Understanding.
18. Gibson R., Hassan S., Holtz S., Tansey J., Whitelaw, G. 2005. Sustainability Assessment Criteria, Processes and Applications, Earthscan Publications Limited, London, UK.
19. Bhatt R. and Khanal S., 2010. Environmental impact assessment system and process: A study on policy and legal instruments in Nepal.
20. Macharia S., 2005. A Framework for Best Practice Environmental Impact Assessment Follow-up: A Case Study of the Ekati Diamond Mine, Canada.
21. Green Guide to Environmental Impact Assessment Tools & Techniques, Green Recovery & Reconstruction: Training Tool kit for Humanitarian Aid.
22. A Guide to approaches, experiences & information sources- Life Cycle Assessment.1997. European Environment Agency
23. Micheal E., 2010. Environmental Assessment Tools as a Framework for Decision making: A Comparative Study between EIA Theory and Practice in Cameroon and Sweden.
24. Robert K., 2000. Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other?
25. Wikipedia on Life Cycle Assessment- http://en.wikipedia.org/wiki/Life-cycle_assessment.
26. Guidelines for Social Life Cycle Assessment of Products, 2009. United Nations Environment Programme.
27. Wikipedia on Ecological Footprint-http://en.wikipedia.org/wiki/Ecological footprint.