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METHODOLOGY USED FOR LIFE CYCLE ASSESSMENT (LCA) OF ELECTRICITY GENERATION THROUGH COAL-FIRED THERMAL POWER PLANTS IN INDIA- A REVIEW

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ABSTRACT

Coal is primary fuel for electricity production. It generates 42% of world's electricity and 68% in India. Burning of coal in thermal power plants produces many green house gases and other pollutants like carbon-dioxide (CO_2), sulphur-dioxide (SO_2), nitric-oxide (NO) and fly ash. With the increase in usage of coal to meet energy demands, these emissions are also increasing giving rise to climate change, global warming, pollution and resource depletion. Therefore, understanding these environmental implications of electricity production from coal is an important aspect of any plan to minimize total emissions and resource depletion. LCA of coal fired thermal power plants will give us details of all impacts produced on our environment from coal mining to transportation and finally to electricity generation. Analyzing these impacts data and processes through which these impacts are produced, one can give suggestions to reduce these impacts and interpret whether goal (electricity production) can be achieved in successful manner with minimum harm to environment. So, in this paper, we are going to review LCA methodology that can be used for environmental improvement, public policy making, strategic planning and eco-labeling in case of electricity generation through coal-fired thermal power plants.

Keywords: Life Cycle Assessment (LCA), Environmental Impact

1. INTRODUCTION

Technological advancements in manufacturing and production systems, changes in life style and social systems life style and increase in world populations have led to higher energy consumption. There are several approaches to provide possible solutions for current and future energy needs but among these approaches we need to select one having least environmental impacts. So, it is essential to perform environmental impact assessment before plant commissioning to ensure minimum risks on environment, health, and social systems. Accurate forecasting of environmental impacts will provide stakeholders and plant managers the adequate confidence to proceed with the production plans. To achieve such target, appropriate environmental measures are considered and optimized to reduce the impact on environment to minimum. This sequence is called "Cradle to Grave" assessment. These environmental measures are considered and quantified during the process of life cycle assessment [1].

2. LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is an instrument that can be used for environmental performance assessment [2]. In other words, LCA is a systematic analytical method to identify, evaluate and minimize the environmental impacts of a product through every step of its life from transformation of raw materials into useful products and the final disposal of all products and its by-products. It is also used to investigate and design factors that have direct and indirect environmental impact throughout the life cycle of the underlying product or service. In addition, LCA can be used to compare environmental impacts of two or more products or services that perform the same function. So, for a typical product, LCA takes into account mass and energy transferred and emissions occurred during extraction and processing of raw materials, manufacturing of the product, packaging, transportation/distribution of raw materials and product, intermediates and the product, use of the product and finally at disposal of the product after use.

The procedures of life cycle assessment (LCA) are part of the ISO 14000 environmental management standards in ISO 14040:2006 and 14044:2006[3].

The basic LCA tools used are dedicated software packages intended for practitioners like GaBi software developed by PE International, SimaPro developed by PR Consultants, and Umberto developed by Ifu Hamburg GmbH, and web-based solutions include Earthster and Linkcycle.

3. METHODOLOGY

The methodology used in conducting LCA is based on the standard three-component model set forth by the Society of Environmental Toxicology and Chemistry (SETAC, 1991). Interactions between environment and Thermal power systems are present, with different ways and intensities, along all lifecycle of systems. The life cycle of thermal power plant can be divided in the following main phases:

− Commissioning of the plant
− Functioning of the plant
− Decommissioning of the plant

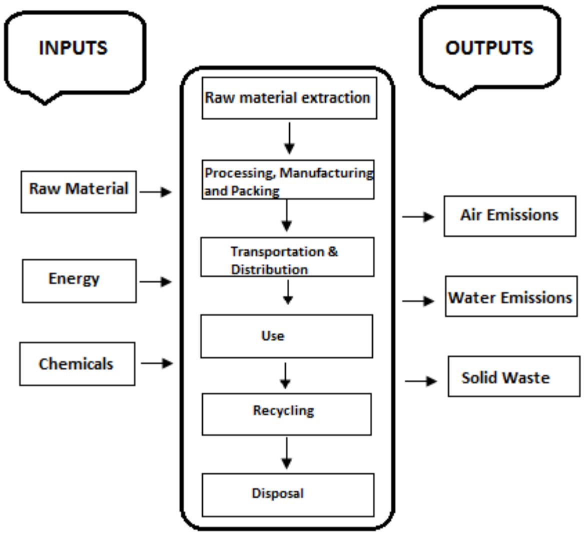

Fig 1: Systematic diagram showing Life Cycle Assessment Method

Figure 1 gives an overview of Life Cycle Assessment Method. Every phase of life cycle of thermal power plant have different impacts on environment: the commissioning phase causes land transformation, the functioning phase brings material use and waste production, and the decommissioning phase causes more land transformation that, considered the relative long life of power plants, is not so easy to know during most of the previous phases. In addition, it is important to note that, in most cases, a power plant is not decommissioned but, at the end of its life, substituted or re-powered rather site dismissed and removed [4]. The typical environmental impacts of this end life phase are similar to the commissioning phase ones.

In LCA study, a thermal power plant is examined at every stage by means of the four main phases detailed below:

3.1 Goal and scope definition

Here the characteristics of the system are outlined; the products/processes being studied are identified as well as their specific features [5]. The first step taken before starting the study is the selection of the functional unit, i.e. the reference unit of measurement that quantifies the performance of the outflows of the product system. The main purpose of the functional unit is to provide a benchmark to which the in and outflows can be linked. This unit is needed to make the results of an LCA comparable [6]. In case of thermal power plants the functional unit taken is 1 kWh of electricity produced. The initial boundaries of the system are defined. Within this boundary the study has to be carried out and the processes outside the boundary are neglected. Other than this, goal and scope also include any assumptions and limitations on the basis of data available, the allocation methods used to partition the environmental load of a process when several products or functions share the same process and the impact categories chosen [7]. The system is represented as a set of process units (e.g. production, distribution, transport, use etc) linked together by intermediary product flows which are then linked up to other systems and to the environment by entry flows (raw material, energy etc) and exit flows (emissions into the atmosphere, water and ground etc.

3.2 System boundary

In thermal power plants, the system boundary can comprises of all of the major processes necessary to produce electricity from coal such as coal mining, equipment manufacturing, transportation, and chemicals production for the mining and power plant operations. The material and energy flows of processes (figure 2) involved in the extraction of raw materials and the production of intermediate feedstocks (e.g., limestone used in the gas clean-up process at the power plant) as well as the disposal of wastes can also be included.

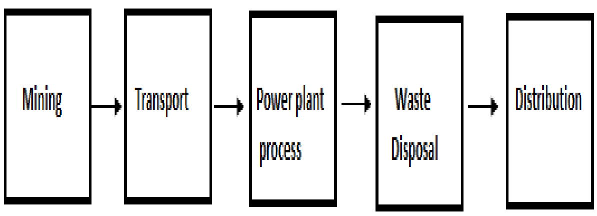

Fig 2: Processes included in System boundary

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3.3 Life Cycle Inventory - (LCI)

This phase involves creating an inventory of flows from and to environment for a product system. The data for inputs, emissions and wastes of energy and materials are collected and environmental load is quantified. Inventory analysis must be comprehensive in order to provide the data necessary to carry out the analysis correctly, and this is detailed in the standard ISO 14041. Inventory analysis is the most important point of an LCA in which a true-to-life model is built that is capable of representing all the exchanges between the individual operations belonging to the production chain [8]. In this phase the incoming and outgoing flows of a product system are identified over its entire lifespan. Inputs include materials, energy, chemicals etc. and Outputs include air emissions, water emissions, and solid waste.

3.4 Life Cycle Impact Assessment - (LCIA)

Life cycle impact assessment is described in the standard ISO 14042 [9]. Its aim is to estimate environmental impacts associated with the data relating to material and energy flow collected in the inventory. In this step the effects on health and the environment caused by a product during its life cycle are assessed. Life cycle impact assessment consists of the following mandatory elements:

I. Selection of impact categories, category indicators, and characterization models.
II. The classification stage, where the inventory parameters are sorted and assigned to specific impact categories.
III. Impact measurement, where the categorized LCI flows is characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total (table 1).

Table 1: Impacts Associated with Stressor Categories
(a) HH = human health, EH = ecological health.
(b) LO= local (county), RE = regional (state), GL = global [10].

Stressor categories	Stressors	Major impact category (a)	Area impacted (b)
Ozone depletion compounds	Cl atom, NO, OH radical,H atom, CFCs	HH, EH	RE, GL
Climate change & Greenhouse gases	CO_2 , CH_4 , N_2O_3, CFCs, O_3 ,CO and NO_x (indirectly), water vapor	HH,EH	RE,GL
Contributors to smog	NO_X , O_3 , VOCs, Particulates, SO_2	HH, EH	LO, RE
Acidification precursors	SO_2 (H_2SO_4 , H_2SO_3), NO_X (HNO_3), CO_2 (HCO_3^-), F^- (HF), CL^- (HCl)	HH, EH	LO, RE
Contributors to corrosion	NH_3 , NH_4^+ salts, SO_2 , H_2S, O_3, O_2 , H_2O, Cl, HCl, CL^- salts, alkali metals	EH	LO
Trace elements	Sb, Ar, Be, B, Cd, Cr, Co, Cu, Pb, Mn, Hg, Mo, Ni, Se, V	HH, EH	LO
Other stressors with toxic effects	NMHCs, CN^-	HH, EH	LO

The inventory data that can be linked with potential ecological and human health effects are placed into stressor categories. The association between the stressors and categories results from previously identified consequences of environmental emissions [10].

The general categories are ozone depletion potential, acid rain potential, photochemical oxidant impact, global warming potential, etc. Characterization involves the quantitative assessment of the impacts of the individual environmental items. It assesses the magnitude of impacts for each stressor category. In brief, it measures how intensely a specific input or output affects the environment. Table 2 shows the outline of Environmental Measures in Thermal Power Plants.

Table 2: Outline of Environmental Measures in Thermal Power Plants [1].

S.No	Items for Environmental measures	Details
1.	Air pollution prevention measures	SOx measures NOx measures Carbon measures Soot / Dust prevention measures
2.	Water pollution prevention measures	Internal drain measures Thermal effluent measures Leakage prevention measures
3.	Noise, Stink, and vibration measures	Anti-noise measures Vibration isolation measures Stink prevention measures
4.	Measures for the surrounding environment	Scenery measures Greening, Natural Resources Measures
5.	Management of chemical substance	Chemical release investigation PCB storage amount PCB harmless processing

3.5 Life Cycle Interpretation

Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment.

The results from the inventory analysis and impact assessment are summarized during the interpretation phase as shown in figure 3. The outcome of the interpretation phase is a set of conclusions and recommendations for the study. This part is dealt with by the standard ISO14043 [11]. The interpretation should include:

I. Identification of significant issues based on the results of the LCI and LCIA phases of an LCA.
II. Evaluation of the study considering completeness, sensitivity and consistency checks.

III. Conclusions, limitations and recommendations

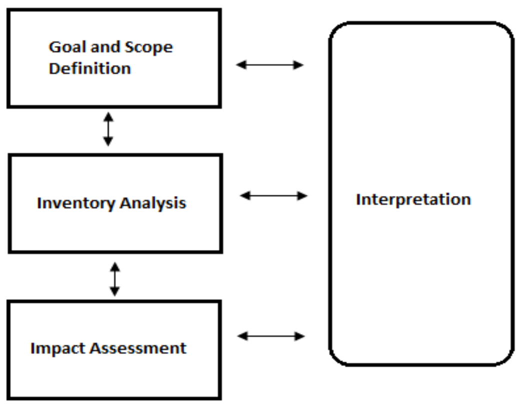

Fig 3: Steps in Interpretation

4. CONCLUSION

Combustion of coal accounts for the majority of utility power generation as a result, the additive environmental consequences of these systems can be quite large. In terms of total air emissions, CO_2 is emitted in the greatest quantity, accounting for 98-99 wt% of the total air emissions for all systems. The majority, greater than 93%, of the CO_2 is emitted from the power generation subsystem during coal combustion. Because this amount is so large, it overshadows the CO_2 from the other process steps within the life cycle assessment. Examining the resource consumption, energy requirements, and emissions from a life cycle point of view, including coal mining, transportation, and power production, can help to determine which areas have the greatest environmental burdens. It may then be possible to focus on improving process steps that have a large impact on the environment and human health. Current LCA applications to energy production needs to develop more accurate Life Cycle Inventories (LCI) databases in order to derive accurate results that permit to evaluate the possible electrical energy production plant impact.

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