Environmental Impact Study of Cement Factory using a Multi-Criteria Analysis: Evidence from Messebo Cement Factory, Ethiopia

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Abstract
Cement is a pillar to develop infrastructures in Ethiopia. At the same time, cement production affects the local environment and nearby communities. Therefore, this paper aims to analyse the local environmental impacts of the Messebo Cement Factory in Tigray, Northern Ethiopia, and to identify the consequences of these impacts. A multi-criteria analysis and community perception survey were used. Primary data were collected through key informant interviews with three purposefully selected management bodies to identify the main impacts. A structured questionnaire on ten purposively selected external experts helped to estimate the weighting factors. Moreover, sixty employees, who were selected through clustered random sampling for scoring the identified impacts, and 120 randomly selected households, were investigated for the perception survey analysis. Moreover, the study used secondary data from supplementary documents to complement the primary data. The study shows that the preparation of raw material and coal, and clinker production at the factory are the major sources of environmental impacts. Additionally, most environmental impacts of the activities in the crushing and raw milling and coal and kiln processing units are substantial and affect the surrounding communities and local environment. The local communities suffer most from the dust particles of processing materials, noise, odour, heat lost and storm water. The study recommends that the factory introduce impact reduction and prevention programs. Such programs will improve the environmental quality of the surroundings and safeguard local inhabitants.
Keywords: cement production, environmental impact analysis, impacts significant determination, environmental aspects, relative significance, Messebo cement factory and Ethiopia.

1. Introduction

Ethiopia is one of the fastest growing economies in Africa. Major sectors of the economy are agriculture, industry and service sector contributing 4.9 percent, 13.6 percent and 11.1 percent respectively (Geiger and Moller, 2013). The country aims to join the mid economy class countries by 2025 (Ministry of Finance and Economic Development (MOFED), 2011). The country's growth and transformation plan (GTP) provides vital attention to the manufacturing sectors as the basic driving force of the economic growth. The cement manufacturing industry is one of the sectors that are expected to significantly contribute to the success of this plan (MOFED, 2011). The geological characteristics of the country, the large limestone deposit, the fast growing infrastructural sector, and the massive demand for cement in the country incentivise the cement industry in Ethiopia. This also lead to increase in cement production, expand capacity of the existing factories and attracted investors to establish new factories in the country (Edwards, 2013). Moreover, an increasing of cement demands for real estate and other construction derived by an increasing population and the growth of businesses in the country. This situation has triggered to rapid development of new cement plants (Amin and Ali, 2010).

The Ethiopian government has planned to increase the cement production for domestic and foreign market in its five year GTP plan from the initial capacity of 2.7 million tons in 2009/10 to 27 million tons in 2014/15 and to meet annual cement per capita consumption of 300kgs (MOFED, 2011). The country's investment agency (2008) states that it has strengthened its effort towards the promotion and success of the GTP plan by motivating through several investment incentives for those who participate on potential cement raw material supply chain as well as for those who invest on new cement factories in the country. The International

Finance Corporation (IFC, 2007) indicates that cement and lime manufacturing projects result in air emissions, immense energy consumption, wastewater, solid waste generation and noise and recommends cement plants to install pollution prevention and control techniques. Furthermore, Kumar and Rawani (2012) show that in cement production process, environmental impacts are substantial for the emission of greenhouse gases. Moreover, clinker production demands major energy input and raw materials which is the major source of gas emission and toxic pollutants due to their physical and chemical reactions in the cement kiln system (EEA, 2009). In line with this, cement production contributes about 10% to the total global mercury emissions (Marquita, 2010).

Moreover, Van Oss and Padovani (2002) stated that the environmental issues of cement manufacturing is related to local, regional and global problems on their mining and mineral processing. The local problems include dust, ground subsidence, noise, vibrations, chemical contamination, tailings spills, scenic and local ecological degradation, and health problems among miners. Regional problems are acid rain and contamination of surface and/or groundwater, spills of processing chemicals and stream sediment loading. Global problems are effects of minerals use and anthropogenic greenhouse gases contributing to global warming. Cement factories are one of the major pollutants and unbalancing the environment (Darley, 1966). In relation to the processing units' pollution contribution, the quarrying process generally does not lead to significant problems (Van Oss & Padovani, 2002). On the one hand, dust emission sources are kiln, crusher, grinders, clinker cookers and material handling equipment, which are in crushing and pyro processing (Kumar and Armani, 2012). In addition, clinker manufacturing of pyro-processing is a considerable source of emission such as Cement Kiln Dust (CKD), gases like CO2, sulphur oxide, nitrogen oxide and dioxins (Van Oss & Padovani, 2002). This shows the crushing and pyro processing units of cement production are relatively the main source of pollutions among the other processing units. Accordingly, this study was focused on these two processing units because the crushing and Pyro processing units are a major source of impacts. They required more energy source and raw material, thereby released pollutants into the surrounding environment during their process.

2. Problem statement

Messebo cement factory (MCF) is one of the biggest cement factories in Ethiopia located in Mekelle city. The factory is founded in 2000 with a daily production capacity of 2000 ton clinker per day. The factory expanded its capacity to 5000 ton clinker per day in 2011 aiming to satisfy the domestic cement market. According to the company's report, the factory uses a heavy oil clinker furnace and recently introduced coal to boost energy. Recent studies indicated that the dust emitted from the factory is affecting the physicochemical properties of the soils in the surrounding area (Estifanos and Degefa, 2012). Moreover, the surrounding communities have been complaining about health and environmental impacts of the factory.

Though, the factory showed readiness to accept the complaints about the impacts of the factory from the surrounding community and the environment, it fully concentrated on satisfying the country's cement demands. This was due to lack of documented evidence on all environmental impacts of the factory. So far no research has been done on the significance of environmental impacts of the factory. This research gap initiated us to conduct this research, which was designed to identify and analyse the significance of the existing local environmental impacts and to propose workable recommendations on pollution control and waste management of the factory. Therefore, the main objective of the study was to identify and analyse the significance of the environmental impacts of the crushing and pyro-processing units of MCF and to recommend solutions to monitor and control the local impacts.

3. Methodology of the study

3.1 Framework of the study

This study framed on the integration of Multi Criteria Analysis (MCA) and perception survey analysis to collect and analyse data about local environmental impacts of the factory (Figure 1). This framework comprises the steps of the multi-criteria analysis of the study and how this integrates with perception survey analysis. The steps of the multi-criteria and the way of analysis are described hereafter.

Impact identification

The first step of the MCA for this study was local impact identification that comprises identification of activities and environmental aspects led to local environmental impacts. To identify the local environmental impacts considering the overall cement production processes of the factory are needed. It helps to determine the main activities performed to produce cement and their environmental aspects. Face to face interviews with the higher personnel of the factory and literature were the source of data for local impact identification. The higher personnel included two process managers from crush and raw mill (CRM) and coal and kiln (COK) processing units and a deputy general manager of the factory and they were selected purposively. The interviewees had 10 to 16 years of work experience in the factory. The key informant interview was integrated with site visits to understand the key activity of each processing unit and their environmental aspects and potential impacts. In addition, it was supported by structured questionnaire about overall pictures of the factory. The collected data about the impact identification compiled using the checklist. The checklist used to summarize the identified activities, environmental aspects and potential impacts. This illustration organized by integrating of the relationship of flow of process of activities and environment aspects that resulted in impacts.

Criteria identification

Criteria are necessary to determine the significance of impacts. Generally, criteria characteristics include the magnitude of the impact, duration, frequency, spatial distribution, reversibility, likelihood, nature and timing (Beanlands & Duinker, 1983; Sadler & McCabe, 2002). These characteristics are broad and could be used for any type of impact determination. This study adopted six criteria include magnitude, occurrence, impact, detection, controls and legislation adopted by Kumar & Armani (2012) to focus on local environmental impacts. These adopted criteria are easily understandable by local stakeholders and all fulfils the criteria requirements listed by Dodgso, et al. (2009). These requirements are completeness, avoids similarity and redundancy, selects important to judge option /impacts in this study/, gives priority for impact comparison and evaluation, alternatives are independent, avoids double counting, manageable criteria size. The criteria had a value ranged from one (minimum) to ten (Maximum) on the Likert scale that made easier the respondents to put their judgments about the local impacts numerically.

Weighting criteria

Next to adopting the criteria was weighting of the criteria which is defining the relative importance of the criteria to judge the local impacts. In this study weighting determined through ranking of the criteria by experts found in different sectors of the regional state, such as Tigray Environmental Protection, Land Administration and Use Agency (TEPLAUA), Bureau of Labour and Social Affairs (BoLSA), Bureau of Urban Development, Trade and Industry (BoUDTI) and Bureau of Health (BoH). The data collected in a structured questionnaire. Ten experts were selected purposefully from the sectors. These sectors are selected, because they have responsible experts to assess and control the factories in the Tigray regional state. Based on the characteristics of the experts, 80% of the experts were master degree holders in different field specialization. The experts' work experience was 60% 1-5 years, 40% above 5 years. The 90% of the experts were responsible to assess and control the factory, in relation to environmental issues. The ranks converted to weight using the formula specified in equation 1. The equation analysed weight using Rank Order Centroid (ROC) method (Barron & Barrett, 1996; Edwards & Barron, 1994). This is a process of converting the ranks given by the experts into weights[1] of each individual rank for each criterion, and then calculated the mean weight (W_i) for each criterion among each other.

$$W_i = \frac{1}{n}\sum_{k=i}^{n}\frac{1}{k} \quad i = 1, 2, 3, \ldots\ldots 6. \qquad \text{(Equation 1)}$$

Where W_i is the weight for each i[th] criteria, n is the number of criteria and **k** is a rank given by experts.

Scoring environmental aspects

After weighting, the next step was scoring to the identified environmental aspects. The source of data for this step was employees in the factory, and the data collected in a structured questionnaire. The employees selected using a cluster sample method by clustering them in three working shifts. Then, ten employees were selected using a simple random method from each shift which is a total of 60 employees (30 from CRM and 30 from COK) from the factory. The score given for each impacts by each employee is calculated its average by ratio method (RM). The RM calculated the average score using the sum of total respondents replied to each score multiplied by the value given in the Likert scale and divided by the total number of respondents participated in scoring (Equation 2).

$$Z_i = \sum_{k}^{n}\left(R_n V_i / R_T\right) \qquad \text{(Equation 2)}$$

Where Z_i is the average score of i[th] identified impacts, $\mathbf{R_n}$ is the number of respondents replied to the score of i[th] impact and V_i is the given value in the Likert scale of the i[th] criterion. $\mathbf{R_T}$ total number of respondents participated in scoring.

Cumulating outputs

The cumulative degree of impact of each activity calculated from the outputs of ROC and RM. They combined using relative significance (Equation 3) (Deng et al, 2011: Noah & Lee, 2003).

$$f(\mathrm{i}) = \sum_{k}^{n}(W_k Z_{i.k}) \qquad \text{(Equation 3)}$$

Where f (i) is a relative significance of impacts, W_k is the weight for i[th] criteria and $Z_{i.k}$ is the calculated average score of i[th] identified impact on the kith criteria. Note that the range of criteria 'legislation adoption' was

[1] Individual weight for the criterion ranked: first (1+1/2+1/3+1/4+1/5+1/6)/6; second (1/2+1/3+1/4+1/5+1/6)/6; third(1/3+1/4+1/5+1/6)/6; fourth (1/4+1/5+1/6)/6; fifth(1/5+1/6)/6 and sixth (1/6)/6. http://msdn.microsoft.com/msdnmag/issues/06/10/TestRun/default.aspx

modified to '1' for the average score 1-2, '2' for 3-4, '3' for 5-6, '4' for 7-8 and '5' for 9-10. It keeps the comparability of the criteria during taking the combined result of the product summation of the scores and weights.

For impact significance determination, benchmark setting is necessary to identify the degree of impacts as 'significant' and 'insignificant' by comparing results of relative significance against the stated benchmark. This helps to determine what and where improvements are needed. Accordingly, the study checked a benchmark by assuming the 30%, 50% and 70% range value of the criteria in the Likert scale are responded by all respondents as a score and calculated 1.8, 2.9 and 4.1 as benchmark respectively. When the 30% result is taken as the decisive value, all the environmental impacts will be significant. When the 70% result is also taken as the decisive value, all the environmental impacts will be insignificant. This shows the comparison cannot inform decision makers about their actions, and cannot give conditions to consider the community perception. The 50% result is better to indicate a balanced comparison between the employees' opinions and the stated benchmark. Therefore, the study decided to take the 2.9 as decisive value. When the combined result of the impacts equal or less than 2.9 it is insignificant and if the result is greater than 2.9 it is significant and needs further controlling and monitoring measures.

Perception survey analysis

This study did perception survey analysis to compare the community perception on the impacts with the results of the employees about the significance of the local environmental impacts of the factory. The study used local communities' households as a source of data to the survey analysis. In the survey a total of 120 local communities' from total population of 1122 households were participated and selected randomly. The Data was collected from the households using structured interview. Descriptive statistic (means, frequency, percentage and count) was used to analyse the collected data from the local community in the SPSS statistical package. Note that the community perception on environmental impacts assessed their agreement using 'disagree', 'not much' and 'agree'. However, the 'not much' count is included to 'disagree' count on the presented data, because it was perceived that similar explanation between 'not much' and 'disagree' during data collection.

Examine results

This is the process of impact significance determination from the overall collected and processed data. It is a step that determined the key environmental aspects and their consequence, and is identified the sources from existing activities' of the processing units. In addition, it is correlated to the results of other scholars and within the results of this study. In addition, it is the process of establishing the conclusion of this study.

4. Result of the study

4.1 Cement production in MCF

Pyro-processing is a system that changes the raw feed into clinkers by heating them at a high temperature in chemical and physical reactions. In MCF the Pyro-processing unit is known as COK. This processing unit includes the coal related process and kiln process. The clinker production comprises stages known as preheating, calcining, clinkering (sintering) and clinker cooling (Bye, 1999; Worrell et al., 2001). In clinker production the mill uses a black coal as a source of energy and consumed about 480 tons per day.

During the kiln process, the prepared raw meal in the crushing process burns in a kiln at a temperature of 1300 to 1500^{o}C and the materials inters and fused to form clinker. In this process, preheating of materials is taking place in a preheated through heat exchange between the exhausted gas comes from the cooler and the dry material. Then decarbonazation is taking place in the calciner. Then after, the decarbonized material moves to burner for clinkering in a kiln. Consequently, the coal preparation activities of the pro-processing are hopper, crusher, and belt conveyors, raw coal bin, coal mill grinder and fine coal storage (European Commission IPPC document, 2001). Generally the steps in coal preparation start in the hopper, it is a recipient of coal material for crushing in the crusher; then crusher grinds the coal and transported to raw coal storage via belt conveyor. In the raw coal storage, the raw crushed coal accumulated in the form of piles formed by stacking. The pile raw crushed coal load to belt conveyor by reclamer to transport to mill grinder. The mill grinder changes the raw crushed coal to fine coal. These fine grind coal stored in storage and injected to calciner and kiln by coal feeder.

The key informant interview data indicated that the total production amount and types of cement in the factory. Of the daily cement production of the factory 4500 blended types of cement (with Pozzolana or limestone), the rest about 2500 with maximum amount of clinker. The 64% of the cement to produce with less amount of clinker and 36% of the cement produced with intensive utilization of clinker. This implies the cement production system of the factory is concentrated on the direct use of additives that reduce the amount of clinker. This also can lead the factory to minimize the impacts from intensive utilization of clinker. Because, clinker production requires energy and resource consumption that can lead to environmental impacts. The interview result also showed about the storage and handling of materials of the factory during the production process. The pre-blended raw materials, cement and additives 100% stored in a closed storage. Whereas, 50% of coal and 30% clinker stored in an open area. According to the field visits, the coal and the Pozzolana are totally stored in an open area before entering to the preparation and production process. Recommended storage for coal and clinker is a closed or covered / closed bay or silos unless leads to particulate matter or coal dust emission. This indicates that the factory has a storage mechanism that can lead to emissions.

The factory's way of material handling, material transporting, install de-dusting devices and the actions taken to collect dusts. The materials in MCF handled in a simple linear condition and transported in closed belt conveyor. During material transportation, the factory reduced multiple transfer points that can lead to dust emissions. The de-dusting mechanisms of the factory are filter bags and ESP. This implies that the factory has no ways of transportation that can cause emissions due to multi transfer points and open transportation system. Regarding the factory's liquid waste management, the factory discharges about 30m^3 per day of wastewater to the surrounding environment. This discharged water is never checked by external bodies. It also is not treated properly. The factory's water utilization system is used and disposed way. It is use water for different purposes, and finally disposed the waste water. In addition, the factory installed runoff control canals to manage storm water coming through the factory. This reflects the absence of intention to the discharged water and there is no water treatment system in the factory.

4.2 Impact identification results

For the impact identification, we used checklists to contain the activities, environmental aspects and potential impacts categorized to the three processes (raw material preparation, coal preparation and clinker production) under the two CRM and COK processing units of the factory. The summary result of the interview with managerial bodies, site visits and literature review, the study identified eleven activities, seven environmental aspects such as dust emission, noise, material spillage, stack emission and oil leakage, and their potential impacts under the CRM processing unit of MCF. Almost all activities resulted in dust emission and noise. Moreover, the checklist of activities takes place under COK processing unit for coal preparation as a source of energy during clinker production in MCF. Based on the interview with managerial bodies, site visits and literature review, the study identified eight main activities and six environmental aspects suck as coal dust emission, noise, odour, material spillage, oil leakage and stack emission, and their potential impacts under COK for coal preparations. Dust emission, noise and odour resulted almost from all activities. Besides the checklist of activities that can be performed under COK processing unit for clinker production in MCF. Thus, the result identified by the study identified eight activities and seven their environmental aspects such as heat releasing, dust emission, resource, noise, oil leakage, gas emission and grease leakage, and potential impacts under COK for clinker production. The dust emission, noise, resource and heat release resulted almost from all activities.

4.3 Impact significance determination

This section includes all the steps of MCA next to impact identification. These are processes of determining significance of local impacts from the combined outcomes of the MCA steps such as criteria and its weighting, scoring and impact significance determination. A criterion weighting results are one part in MCA and tell the processes and results of weighting of the six adopted criteria and compared the weight calculated by ROC with the weighting of rating and ranking methods. Based on the rank given by experts, each expert ranked the criteria differently. In addition, they ranked to the criteria based on their educational background and experience, and from information that they have during their assessing and controlling programme. These ranks translated to weight using the ROC method. Based on the calculated mean weight, criterion impact has the highest weight followed by 'occurrence' and 'magnitude' of the identified impacts. The rest criteria are 'detection', 'control' and 'legislation adopted' respectively. Moreover, the study compared the weighting criteria of ROC by another method known as ranking and rating of the ranks. The rating method applied by giving a rating score of 17 to the least ranked criteria and 100 to the most important ranked criteria of the expertise's rank. Then, the relative weight of the criteria calculated by the sum of the given score to individual criterion and divided by the total rate given to each criterion multiplied by 100. The ranking method also applied by converting the experts' rank to the ranking score (1- 6 score) which is the 1st ranked gave a score of 6 and the 6th ranked gave a score of 1. The combined weight was calculated by the sum of the relative weights of ranking and rating and divided into two. The result is almost similar to the result of ROC. However, there is a variation in the weight calculated for impact. Note that all the results with ranking and rating is percentile and decreased to two digits and the results of the ROC is in the form of ratios and decreased to three decimal places.

4.3.1 Impact significance determination of raw material preparation

The process of scoring, calculating an average score and cumulative outputs, identifying the relative significance and impact significance determines for raw material preparation determined the relative significance and considerably of the impacts in CRM for raw material preparation. To show highlights about scoring results based on the six criteria characteristic dust emission in material storage and noise in belt conveyor from the crusher are scored 4. This implies it has a severe extent in the stated activities. The rest, environmental aspects received an average score of 2 and 3, and they refereed as a medium extent. Occurrence of noise in the hopper and crusher, and dust emission in crusher and material storage scored 5. This show, they are occurring several times a day. The rest, environmental aspects scored 3 and 4, and implies they are mainly occurring once a week and some once a day. In relation to the effect, there is no environmental aspect scored 6. This implies there is no identified aspect with fatal problems. Almost all are scored in the ranges belong to resource consumption and discomfort problems. However, dust emission in the hopper and material storage, and noise in crusher and raw mill scored 4 which have an influence on fauna and flora.

About the sensing time of the environmental aspects, almost all aspects have scored 3, this implies, their effect recognized within 8 hours. About controlling measures to control the impacts of the environmental aspects, most of the environmental aspects scored 2 to 3. This show they have control mechanism but it needs human intervention or it is a secondary controlling mechanism. In addition, the dust emitted from the hopper and noise in the hopper and raw mill is scored 4, and indicates it is with mechanism but not reliable. According to the status of the environmental aspects complying with standards or limits, the majority of the environmental aspects were scored 5 to 8. This implies the environmental aspects are not meeting on legislation or control limit. Some scored 3 and 4 that are nearest to in compliance with the standards. These results show the judgment of the employees on the impacts and are inputs for the rest of MCA steps to determine significance of local impacts of raw material preparation.

With regard to the relative significance of the identified environmental aspects of the activities in raw material preparation, most of the dust emission, noise and stack emission are relatively above the benchmark and are significant. This implies that the raw material preparation of the factory is a source of significant environmental aspects that is a consequence of environmental impacts. In the relative significance results, dust emission in the entire activities is significant takes place in the CRM processing unit. It scored 4.5 & 4.1 highest degree of impact in material storage and hopper. The rest activities for dust scored from 3.1 to 3.6. In addition, noise is significant in some of the activities such as hopper, crusher, surge bin, raw mill and screening. It scored highest degree of impact in raw mill and hopper with 4.2 and 4.0 respectively. In the rest activities, noise is closer or in line to the set benchmark. Moreover, material wastage is significant only in the activity of the hopper and is insignificant in a proportionate and material storage. Furthermore, the stack emission in crusher and raw mill is significant. This indicates that dust emission, noise and gas emissions are the environmental aspects that need further controlling and monitoring measures. However, when we compare relative significance results of dust and the other environmental aspects, dust emission occurred more significantly in all activities. For instance the highest and lowest value of dust is 4.5 and 3.1, and the highest value and the lowest value of noise is 4.2 and 2.5 respectively. Most of the activities for noise and the others are almost close to the set benchmark. Then, the dust needs further attention than the others and it is the main burden of the surrounding area.

4.3.2 Impact significance determination of coal preparation

This is a process of scoring environmental aspects, calculating an average score and individual cumulative outputs, identifying relative significance and impact significant determination for coal preparation, and determined the relative significance and considerably of the impacts in COK processing unit for coal preparation. The scoring results based on the six criteria characteristics, the extent of coal dust from hopper, coal crusher, coal storage and coal in raw mill, and odour and stack emission in hopper scored 4, and implies as severe extent. The rest of the environmental aspects scored 2 and 3 that is a medium extent. About the frequency of the environmental aspects, the coal dust in hopper, crusher, and storage scored 5, and implies the coal dust occurred several times a day in the above listed activities. The rest, environmental aspects scored 2 and 3. It indicates most of the environmental aspects in coal preparation occurred once a day or once a week. Concerning to the aspects' degree of effect, the dust from the hopper and storage is scored 5, some scored 4 and most scored 3 and 2. This implies the dust from the hopper and storage can produce an influence on health. In addition, the dust from some of the activities can influence on to fauna and flora. Moreover, the dust from most of the activities can produce an influence on resource consumption and discomfort. Based on the sensing time of the aspects or effect, all aspects are scored 3 and 2, and most of the environmental aspects are detected within one hour and few in one hour. The environmental aspects about the control criteria, most of them are scored 3 and 2 that are environmental aspect with human intervened or secondary controlling mechanisms. To comply with the country standards, 50% of the environmental aspects scored 5 to 8, and implies not meeting the standard or limit. The rest 50% also scored 3 and 4 which is nearest to be in compliance with the stated limit. In general, there is no environmental aspect that scored the maximum range of the criteria. As mention in raw material scoring, these results are shown the judgment of the employees on the impacts and are inputs for the rest of MCA steps to determine significance of local impacts of coal preparation.

The result showed most of the coal dust emission, odour and stack emission are relatively beyond the set benchmark and are significant. While few of the environmental aspects scored below the benchmark, the coal preparation result indicates that it is definitely a source of significant environmental aspects that can interact with the surrounding community and local environment. In the relative significance results shows dust coal emission is significant in all activities. It scored the highest value 4.8 in the hopper and lowest value 2.7 in the coal bin. In addition, noise is significant in some of the activities such as in hopper, crusher and coal mill. In most of the activities, noise is in line with the set benchmark, and is insignificant. It scored the highest value 3.1 and the lowest value 2.2. Moreover, odour is identified to selective activities, and is significant on these identified activities. It scored the highest value of 3.9 in crushed coal storage and the lowest value 2.7 in the coal bin. Comparatively, the coal dust emission is scored with higher value among the others, and odour is scored next to coal dust emission. This implies coal dust and odour are considered as a burden to the surrounding environment in coal preparation. Both environmental aspects need further attention to control and monitor.

4.3.3 Impact significance determination of clinker production

The process of scoring of environmental aspects, calculating an average score and cumulative outputs, identifying the relative significance and impact significant determination of clinker production of the study and the data determined the relative significance and considerably of the impacts in COK processing unit for coal preparation.

The scoring result showed that based on the six criteria characteristics, the extent of all environmental aspects scored 2 and 3 in all activities and this implies the environmental aspects are in a medium extent in clinker production. However, the noise in cooling and clinker crusher scored 4. This implies noise is severed in these activities. About environmental aspects' occurrence, heat lost in preheated and kiln and clinker crusher, and noise in a cooler and clinker crusher, and dust in clinker storage scored 5. This implies heat lost and noise is occurring several times a day on the above stated activities. The rest aspects of the activities are scored 4 and 3. This shows they are occurring once a day or a week. For the environmental aspects' degree of effect, most of the environmental aspects in all activities scored 4 to 3. This implies the majority environmental aspects are effects on flora and fauna and resource consumption. There are few environmental aspects scored 2 as discomfort effects. In addition, the dust from clinker storage scored 5 and it implies an effect on health. When we see the sensing condition of the effects, the environmental aspects in all activities scored 3 and 2. These shows all the environmental aspects are determined within 8 hours or 2 hours. The environmental aspects and their controlling criteria, almost all environmental aspects scored 2 to 3. This indicates the environmental aspects are with human intervened controlling mechanism or secondary treatment method. The condition of the environmental aspects to the stated standard or limit, the majority scored in between 2 and 4. Some like dust emission from preheated, calciner and kiln, gas emission from preheated and kiln, and heat lost in kiln scored 5 to 6. This implies in the dust, gas and heat lost are beyond the limit in the stated activities. These results are shown the judgment of the employees on the impacts and are inputs for the rest of MCA steps to determine significance of local impacts of clinker production.

The result showed that most of the identified aspects such as heat loss, noise and dust are scored above the set benchmark, and are relatively significant in clinker production. Some of the environmental aspects such as material wastage and oil leakage are scored below the set benchmark, and they are insignificant. This indicates that clinker production is also the main source of environmental aspects in MCF. In the relative significance results, dust emission is significant in most of the activities. It scored the highest 4.1 in clinker storage and lowest 2.8 in kiln and cooling. Similarly, heat lost is significant in all activities. The highest score is 3.6 in preheater and lowest is 2.9 in cooling. In addition, the gas emission is determined to preheater, claimer, kiln and clinker cooler, and is significant in all of these identified activities. It scored almost similarly with dust emission in preheater, calciner, kiln and cooler, and rated 3.8, 3.3, 3.2, and 3.1 respectively. In spite, resource consumption is scored below the benchmark and it is insignificant in all activities. This implies the dust emission and heat lost is the problem in the surrounding environment. While gas emission is significant on its determined activities, it is not a burden to the local environment. Generally, the three dust, heat lost and gas emission are the environmental aspects need further attention from the factory.

4.4 Perception survey analysis results

This part comprises the perceptions of the local community on dust and coal emissions, the liquid waste discharges and the factory's storm water, and their associated problems as well as the factory interventions in the community. The study revealed that 95% of the respondents observe continuous dust emissions and coal related problems from the factory. In addition, this study compared the local communities' response of 'disagree' versus 'agree' for the consequences of dust and coal emissions. Accordingly, most of the sampled households agree that dust and coal emission of factory cause to darkening (50%), farmland cover (70%), the plants covered (70%), house equipment cover (88.3%), respiratory problem (51.7%), skin problems and itching (53.3%) and domestic animal related problem (58.3%). However, about 73.3% and 72.5% of the respondents disagree that the dust and coal emission to be a cause of bad smell and vision problems, respectively. This indicated that the presence of dust that comes from the factory to the surrounding environment affect the surrounding community and their environment.

Regarding the perception of liquid waste, 97.5% of the local community continuously observed the liquid waste discharge into the environment from the factory. The discharged water was also reused by the local communities for irrigation (64.2%), hygiene (18.3%), and construction (13.3%) and not users (4.2%). This shows 95% of the inhabitants used the discharged water that might affect their health. However, the majority of the sampled households responded with their disagreement that the causes of the factory discharged liquid on their bad odour (82.5%), pollute drinking water sources (97.5%), condition of insect breeding (73.3%), human health like malaria/ diarrhoea (75%), effects on animal health (90%), pollution to water resource (80%) and discomfort (92.5%) (Figure 4.3 and Annex 7, Table 9.3). To the contrary, the local community agreed with the problems of skin and domestic animals related problems. This indicates that even though there is discharge water from the factory, the local community did not perceive the effect of the discharged water negatively.

Perception on storm water, the 70.8% responded observes continuous storm water comes from the factory to their surrounding environment during rainy season. Accordingly, the majority of the sampled households responded with their disagreement that the storm water to cause water logging (88.3%), water contamination (93.3%), and malaria (90.8%), and diarrhoea (96.7%). However, about 68.3%, 66.7% and 68% of the respondents strongly agree with the causes of the storm water related to soil erosion, gully formation and soil contamination, respectively. This shows that the majority respondents agree on the presence of storm water coming from the factory and its negative consequence to the community. This implies the local community is worried about the consequences of storm water.

The local community participant households were asked to prioritize the type of interventions that currently ensure by the factory to the community. The response options were educational support, water resource, health centre, transportation, water soil conservation, afforestation, compensation, employment and others. The result shows that the majority 89.5% respondents ranked educational support as first, employment (70%) as second and water source 65. 2% as the third supported by the factory. In addition, the community (100%) ranked the factory as poorer to take measures for the problems occurred due to the factory. This implies the weak interaction of the factory with the surrounding community to take measures.

5. Discussion

In general, the impact significance determinations of the three sub processes imply that most of the environmental aspects of the main activities for raw material preparation, coal preparation and clinker production are significant in MCF. This shows the sub processes are a source of significant environmental aspects in MCF. These environmental aspects are also currently interacting with the surrounding environment. This interaction is a concern to the factory to explore controlling and monitoring measures to the sources of significant environmental aspects.

In the impact significance determination of raw material preparation process, the significance of dust and noise in CRM is partly related to the results of Kumar & Rawani (2012). This relation is on dust in the hopper and crusher, and noise only in the crusher, but the result of this study shows a big difference on the significance of the environmental aspects of the rest of the activities. This indicates that the source of dust emission and noise to the surrounding environment in MCF does not restrict too few activities. In addition, MCF is threatened more than ACC cement plant in India to the surrounding environment (Kumar & Rawani, 2012). The highest score of dust for raw material preparation clearly described the burden of dust in MCF. In addition, the characteristics of the individual activities defined this condition. For instance, the dust presently emitted when the crushed raw materials piled by reclaimer inside the store. While the store built as big closed sheds, they are with bigger doors on both sides that allow the dust to emit during piling by reclaimer to the surrounding. In addition, when the hopper received raw materials from the track the dust emitted to the surrounding environment. There's no de-dusting mechanism in these activities. Moreover, there are de-dusting mechanisms in the other activities, but the score is above the set benchmark. In case of noise in this processing unit, it is scored higher value for most of the activities. When we see the nature of these activities, they have the ability to release noise. While the noise mostly in the production area of the factory is significant, it is not a burden of the community. The surrounding community responded that noise came from the factory has not adverse effect.

Impact significance determination in coal preparation, they are similar to the significance of raw material preparation. In MCF the coal dust, noise and odour are common environmental aspects of coal preparation. In all activities, the coal dust is a burden of the surrounding environment (European commission, 2001). The coal dust has almost the higher degree of impact. Particularly in crushed coal storage and hopper, coal dust is relatively scored the highest degree of impact. In these activities there are no de-dusting technologies and they are open or partly open sheds which are exposed to wind. This leads to emit the coal to the surrounding environment. In addition, these particulate matter emissions are associated with last materials handlings and storage mechanisms. It is due to open or uncovered storage of materials (IFC, 2008). Compared to the other processes, the coal dust emission in coal preparation has a higher score. This implies the factory has poor attention to manage the coal preparation than the other processes. Odour is also scored higher value on selected activities of coal preparation. It is true that burning of sulphur-containing fuels and/or use of sulphur-containing raw materials can lead to odour emissions (European Commission, 2001). This shows odour is another worrying environmental aspect of the factory that interact the environment during coal preparation. In the specified activities such as hopper and mill grinding of coal odour scored higher value than the others. During transferring the coal to material recipients and fine grinding, the coal has an ability to disperse its odour to the environment than the others. This is because, they are open and are conditioned to sulphur constituent black coal pass through open area. In the same process, noise is almost in line with the stated benchmark. It is not such a nuisance to the environment. However, some activities such as hopper, crusher and raw milling of coal are significant degree of impacts. It needs further attention to resolve it.

Impact significance determination on clinker production, dust, resource, gas emission and heat lost are common environmental aspects. In this study degree of impact of dust emission scored higher value in the activities of clinker storage and preheater in clinker production. This result is in contrary to Zeleke et al., (2010) where he concluded that, dust is emitted during calcining and blending. However, similar literature was mentioned that the dust emissions are caused by the factory's storage mechanism of clinker (IFC, 2008; European commission, 2001). In MCF, the 30% of the clinker is stored in an open area and the way of clinker transporting to open area storage are a cause to form dust emission. In addition, the preheater typically line one released dust through the chimney. The activities in clinker production have been de-dusting mechanisms such as filter bags and ESP, but in line one there is dust emission. This is due to the de-dusting technology found in line one. ESP reduces its function due to a reason of special conditions such as technical and electricity problems (European commission, 2001). The same is true for gas emission in preheater and in other selected activities such as in calciner, kiln and cooler. It scored above the benchmark. The de-dusting technology found in these activities needs for assessment. When we see the heat loss in the clinker production, it also scored higher than the set benchmark. The highest value is given on preheater among the others.

Most of the raw materials are heated through a heat exchange mechanism between the heat coming from the cooler and dry gas of the material from silos in the preheater. This may lead to release the heat to the environment. In general, the factory is better to give attention to the dust, heat and air mission. Dust is the main environment aspect that needs further attention because of all the activities are a source of emission and the storage mechanism of the factory leads to form dust. However, clinker production is not worrying about significant material spillage as resource consumption of the other processes. In all activities the value for resource consumption scored below the set benchmark. The significant environmental impacts to community perception, the results support the degree of impact of the MCF cement production activities. Mainly the particulate and coal dust emission observed by the local inhabitants is in line with the judgment of employees. The community assured that the presence of dust particulate (from cement raw material or coal) emitted continuously from the factory. This is comparable to the activities implemented in the factory during production. These may due to the material storage mechanism of the factory (Figure 3.4) and the nine months east west wind direction of Mekelle (Estifanos, 2014). In addition, this supported that fugitive particulate emission from a cement plant impacts to a nearby community (Abdul-Wahab, 2006).

The community explained these observed dust particulate and coal dust emission about its interaction with the surrounding environment. Accordingly, these emissions are a consequence of darkening to the surrounding environment, covering of farmland, plants found in the surrounding and house equipment by the dusts, and health problems like respiratory and skin. Similarly, the study Kusena, et al., (2012) justified that the dust coming from a cement plant has an influence on coughs and chest pains. In addition, local inhabitants evaluate air pollution by direct observations and personal experiences such as contamination of washed clothes, discoloration of snow and respiratory problems (Walker et al., 2006). Moreover, these practically held on covering of farmland by dust particulate and coal dust (Figure 3.3). These pictures shown the dust particulate and coal dust deposited on the farmlands. This deposition detected after a rainy time of the surroundings. The dust accumulated in the pockets of the farmland. Furthermore, the dust particulate and coal dust covered the plants found around the factory (Figure 3.3). Especially the coal dust accumulated on the leaf of the surrounding plants. Due this, the plants found to West direction of the factory changed their green color to black. This indicates that the dust particle and coal dust emissions are threatening to the surrounding environment, and they need critical attention to reduce and prevent.

In addition to agreeing on continuous dust emission from the factory, most of the local community households agree with the presence of continuous discharging of water and storm water from the factory. The discharged water is reused by the local communities for irrigation, hygiene and construction, and practically recognized in site visits. In addition, this water is discharged without treatments, and not checked by legal laboratories. It is openly discharged to the surrounding. Therefore, the factory and local inhabitant know nothing about the results of using these discharge waters. To the contrary, the local community households disproved the consequence of the discharged water on bad odour, pollute drinking water sources, condition for insect breeding, human health like malaria/ Diarrhea, effects on animal health and discomfort. In addition, the wastewater discharge from a cement plant is not a cause of water pollution rather limited to run off (European Commission IPPC, 2001). In case of the storm water coming through the factory causes soil erosion, gully formation and soil contamination. This implies the storm water is another threatened of the factory to the surrounding community. This is a continuous condition of the surrounding area during a rainy season. Differently, the local inhabitants agree to the storm water are not effect of water logging, water contamination, and health related problem like malaria and diarrhea.

Moreover, the local community household assures the absence of solid waste transported and dumped into the surrounding environment from the factory. This shows the absence of solid waste related problems of the factory on the surroundings. In addition, the local community households agree the intervention of the factory in education, employment and water source. However, they all ranked (100%) as poorer to the performance of the factory to take measures when factory related problems are found. Even some measures are taken through long time with disputes. This shows there is a poor relationship between the factory and the local inhabitants. This is contrary to the role of Sino cement factory in Zimbabwe, which is concerned with the development of the local communities through the improvement of infrastructure, health and sanitation as well as education (Kusena, et al., 2012).

6. Recommendations

The study forwarded the following possible ways and suggestions on reducing and controlling impacts, especially, on dust emission. The degree of impact and perception survey results show that the activities under the three sub processes are the source of dust emissions. These emissions also may be due to absence of mechanisms to prevent it, the inefficiencies of the existing mechanism or the conditions to transport the dust to the surroundings like the surrounding wind conditions. Therefore, the factory is better to implement reduction and prevention program that include introduction of effective dust emission control mechanisms.

The factory introduces prevention and reduction ways on the identified area. These are maintaining material moisture through spray, typically in the hopper, raw material storages of raw materials and coal, constructing sheds around open storage of coal, gypsum and additives, introducing sheets to the material not needed to spray water like the clinker stored openly, and building fences around the outlet of clinker to store openly. Moreover, to assure achievements on the prevention and reduction methods, the factory is better to set up a dust supervision system. This can help to show all spots and assess the introduced controlling methods.

MCF has installed filter bags and electrostatic precipitator (ESP) to control dust particulate. Typically, the dust control bags in the new line have maximum controlling efficiency. Comparatively, according the data from the employee and a community survey, there was a significance dust particulate impact to the surrounding environment. Therefore, it is better to rethink on the filter bag's performance. In addition, regular maintenance and quick replacement of filter bags is necessary. Practically the ESP found in the old line in addition to some filter bags has less performance on de-dusting. Dust emission is observed continuously due to malfunction of this device. Therefore, this ESP way of de-dusting is better to change or supported by the other de-dusting device. While the factory starts to investigate and allocate budget to improve the ESP; it is delayed to make sure it. It needs urgent decision-making to substitute it.

The results of this study show the presence of a poor coal management of the factory relatively to the other production processes. Therefore, the factory is better to design proper management mechanisms of coal such as closed the belt conveyors, sheds for the coal storages, and build fences on the storage. In addition, some sources of dust emission may be the way to handle accumulated materials such as pet coke and black coal. The factory transformed from pet coke and black coal coming from South Africa to use of local black coal. The study observed during the visit, some pet coke and black coal from South Africa accumulated without function and poor handling in the factory compound. It is better to take urgent measures on these transformed materials.

According to the data, most of the local inhabitants are illiterate. This shows that the local community is not able to mitigate or adapt the problems of cement production. In addition, the interaction between the factory and the local inhabitants is poor. Therefore, the factory better to focus on creating awareness and capacitating the local inhabitants, especially on health and hygiene, development of the local community and promoting the efforts of the factory on controlling the problems to make good relationship with the community. The development program mainly focuses on controlling the storm water by implementing integrated water and soil conservation activities surrounding the areas. These can solve the problems of storm water and can rehabilitate the surrounding areas.

Lastly, the factory is better to design its own environmental standards and policy. In addition, it should prepare and make an environmental management plan in the factory. By doing such policy and environmental plans, all the significant environmental aspects can get attention from the plant. In addition, the factory is better to capacitate the regulatory body of the factory. While the factory established environmental regulatory body as a division by its initiation since 2013, it is incapacitated and not a decisive body to bring environmental improvements in the factory.

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Figure 6: General framework of data collection and analysis methods of the study.