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HANDLING OF COAL DUST AT COAL HANDLING FACILITY IN COAL POWER PLANT USING SOFT SYSTEM METHODOLOGY (SSM) APPROACH

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Abstract -- *Currently, many coal-fired powers plants are built to supply electrical energy needs in Indonesia due to relatively inexpensive raw materials and abundant in Indonesia. Handling of coal is mostly done at the power plant using coal handling facilities consisting of ship unloaders, conveyor belts, stock piles, silos or bunkers. The problem that arises in the coal handling facility is dust from coal that fells or hovers in the air so that it can interfere with the environment and health both for workers in the Coal Power and residents around the Coal Power. The purpose of writing this paper is to eliminate the spread of coal dust that arises due to coal handling equipment that is not precise and imperfect. The method used is the Soft System Methodology (SSM), which is a systematic approach used to analyze and solve problems in complex and messy situations. This paper examines the benefits of applying SSM to knowledge management issues in handling coal dust at a power plant. Improvement is done by upgrading coal handling equipment (ship unloader, conveyor belt, stock pile) with the addition of dust suppression, proper sealing system, dust bag, and training to operators on the impact and handling of coal dust and coal handling equipment maintenance, so resulting in a significant decrease in the spread of coal dust, creating a working environment and the environment becomes clean, healthy and safe.*

Keywords: *Coal power plant; Coal handling; Belt conveyor; Coal dust; Soft System Methodology*

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INTRODUCTION

The coal power plant is a power plant that uses coal as its main fuel. Special handling is called the Coal Handling Facility to meet the relatively large amount of coal fuel needed. The Coal Handling Facility functions to handle starting from coal unloading from the unloading area to the landfill or storage area in the stock area or directly charging to the bunker in the power plant, which is then used for combustion in the boiler. Transportation used with conveyor belt systems. Belt conveyor is the most populous equipment in such system to achieve material flow from start to endpoint (Todkar et al., 2018).

Conveyors are widely used in the mining, power generation, and process industries for the transport of crushed particles from one location to another (Witt et al., 2002). On the way to transfer coal from the ship unloading to the bunker, there were many problems regarding coal dust flying in the air. Coal dust is generated in producing, handling, crushing, and transporting of coal, drill, blast, smash, self-weight transport, artificial gangue and other production processing are the main reasons caused coal dust (Du, 2018). Coal-handling properties add a layer of complexity to coal selection. Wet, sticky coal, plugged bunkers, and frozen coal in railcars, trucks, and barges can force plant deratings or outages if the problems are severe (Arnold, 2004).

In its series, Best Practice Environmental Management in Mining, Environment Australia, issued a report on dust control in 1998 (Reference 1 .2). The report analyzed the sources of airborne dust in various mineral processing plants. The report indicated that the primary sources of dust were as follows:

Crushing .... 1-15 percent
Screening .... 5-10 percent
Stockpiling .... 10-30 percent
Reclaiming .... 1-10 percent
Belt Conveyor Systems ....…..30-60 percent
(Foundations, 2016).

The dust has become one of the major issues that are produced in the course of coal production, transportation and storage, and so on, seriously affecting production safety and causing occupational hazards, environmental pollution and economic losses (Xi et al., 2014).

Soft System Methodology (SSM) is a systematic approach used for analysis and problem-solving in complex and messy situations. SSM uses "system thinking" in the cycle of research, learning, and reflection to help understand the various perceptions that exist in the minds of different people involved in the situation. The process is especially suitable for complex management systems and seeks to evaluate as many different choices as possible. This approach applies to minimize; environmental pollution caused by airborne coal dust, safety risk (fire) caused by coal dust, production losses, unplanned shutdown, dirty environment and cost of maintenance.

MATERIAL & METHOD

Material

The EPRI Coal Quality Development Center (CQDC; now CQ, Inc.) initiated a formal research project in 1989 to address coal-handling concerns based on comments by its advisory committee. An initial survey as listed in Table 1, of about 40 coal and power generation industry representatives pointed to plugged bins, plugged feeders, and hang-ups in bins as the biggest problems. In addition, a review of the North American Electric Reliability Council (NERC) 1982–1987 data for outages at coal-fired power plants was conducted. Problems with coal conveyors and feeders and bunker flow problems caused the most coal-handling troubles. The research was then focused on these problems (Arnold, 2004).

Table1. The Coal Handle ability survey result (Arnold, 2004)

Problem	**Rank**	**Weighted Rank**
Plugged bins	1	1.0
Plugged feeders	2	1.3
Hang-up in bins	3	2.0
Sticky coal on belts	4	5.7
Frozen coal in transport	5	5.9
Dusty coal on conveyors	6	6.0
Dusty coal in stockpiles	7	6.2
Frozen coal in storage	8	9.5
Spontaneous combustion	9	9.9
Cave-in storage	10	10.0

Method

Soft System Methodology, as described elsewhere (e.g., Checkland, 2011; Checkland & Haynes, 1994), SSM was developed in the 1970s in an action research program that began by investigating whether the by then the well-established methodology of systems engineering could be applied in problematical management situations. The systems engineering approach assumes that the system of concern can be named unequivocally and that its objectives can be defined with precision, allowing it to be engineered to achieve the objectives, using a range of well- tested (Checkland & Haynes, 1994).

In order to make sense of our experiences, I found it necessary to bring together several ideas: about human situations, about world views relevant to each situation, about purposeful activity, about systems models of purposeful activity, each built according to a declared world view. Given these ideas the rethought Systems Engineering emerged as a very different approach; it became known as SSM. Boldly stated the shape of SSM is as follows:

- Enter a situation deemed problematical and take part in improving it; in finding out about the situation think of world views relevant to it; based on the world views make some purposeful activity models, each based on a declared pure world view;
- Use the models to question the real world, thus structuring discussion and debate; use the discussion/debate to find accommodations among conflicting world views which would allow action-to-improve which is both (systemically) desirable and (culturally) feasible to be taken;
- Take action; and
- At a meta-level, continually iterate among the above as learning occurs (Checkland, 2011)

Soft Systems Methodology (SSM) can be used to analyze problems or situations, but most precisely where the problem "cannot be formulated as the search for efficient means reaches a determined end; a problem where the ends, goals, objectives are themselves problematic".

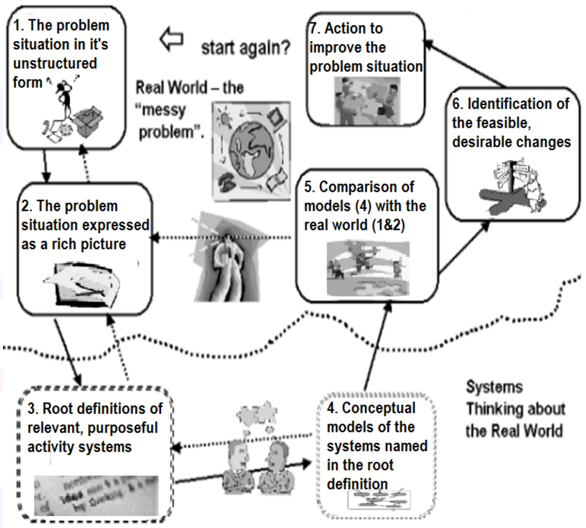

Figure 1. Summary os SSM as a seven-stage process (Checkland, 1999; Checkland & Scholes, 1990)

Soft System Methodology, in its ideal form, is described as a logical sequence of seven stages as shown in Fig.1.
Stage-1: The problem situation in its unstructured form.
Stage-2: The problem situation expressed as a rich picture.
Stage-3: Root definitions of relevant, purposeful activity systems.
Stage-4: Conceptual models of the systems named in the root definition.
Stage-5: Comparison of models with the real world.
Stage-6: Identification of feasible, desirable changes.
Stage-7: Action to improve the problem situation.

RESULTS AND DISCUSSION

Discussion

Stage-1: Identification of The Problem

Belt conveyors are widely used for transferring solid materials for various industrial applications, such as in the mining industry, in coal transport at power plants, and the cement industry. However, the use of belt conveyors often entails the environmental problem of dust emission. Belt conveyors emit dust primarily at points of material admittance and discharge, namely, at belt transfer points. Three sensitive zones exist at transfer points:
(1) at the point of particle discharge from the belt head pulley where emission is driven by turbulence and by a delayed detachment of particles from the belt;
(2) at the column of falling particles between hells, where small dust particles separate from the mainstream due to air turbulence;
(3) near the tail pulley, where a dust cloud is formed by the violent impact of the stream of falling particles and entrained at1 on the lower belt (Ullmann & Dayan, 1998).

At the transfer point of the belt conveyor, due to the combined effects of airflows such as belt traction flow, falling coal induced flow and sheared compressed flow, a large amount of dust is generated at the transfer point (Gao, Shen & Liang, 2018).

In its application in handling coal dust at the coal power plant, we can use this 5W1H Method as listed in Table 2 to collect information and analyze the problems that occur so that we can take the right solution to overcome them.

Table 2. 5W1H Method to analyze the coal dust problems at the coal power plant.

5W1H	Coal dust problems at the Coal Power Plant
WHAT	1. Dust can damage the coal handling system equipment. 2. Risk of fire. 3. Dangers to health (eyes, lungs, skin irritation). 4. Coal dust flying in the Coal Power Plant area and settlements around it.
WHERE	1. Coal Power Plant area, Coal Handling facility (ship unloading, conveyor belt, transfer tower). 2. The residential area around the Coal Power Plant.
WHEN	1. Since the government has built a lot of power plants from 2010 to the present. 2. Until now, the problem of dust in coal power plants is still a lot.
WHY	1. The design of a Conveyor Belt system that is less effective. 2. Dust collector/dust suppression equipment is not functioning properly. 3. Very minimal maintenance for conveyor belts.
WHO	1. Employee or Operator Coal Power Plant. 2. Residents around the Coal Power Plant. 3. The environment around the Coal Power Plant.
HOW	1. Installing dust collector equipment in the conveyor belt area. 2. Re-engineering belt conveyor equipment by CEMA standards. 3. Dust suppression installation in the area of ship unloads and stock pile. 4. Installation of Doom and wind-blocking nets in the stockpile area to minimize the spread of dust.

Stage-2: Rich Picture Diagram

Rich picture diagrams are one way that can be used to describe a particular situation. The picture Richard is a cartoon image that describes the entire complex system so that it is easy to read from various angles with all aspects contained in it instantly. A rich picture contains an overall picture of people, objects, processes, structures, and problems in the entire business process in the company as shown in Fig. 2. The usefulness of Rich picture is:

1. The ideal tool for communicating about complicated and problematic situations.
2. Linkages between elements and relationships that are interwoven, directly or not, are easier to see.
3. Facilitate identification of problem owners and help identify potential problems and conflicts.
4. Assist in making limits and scope of problems.

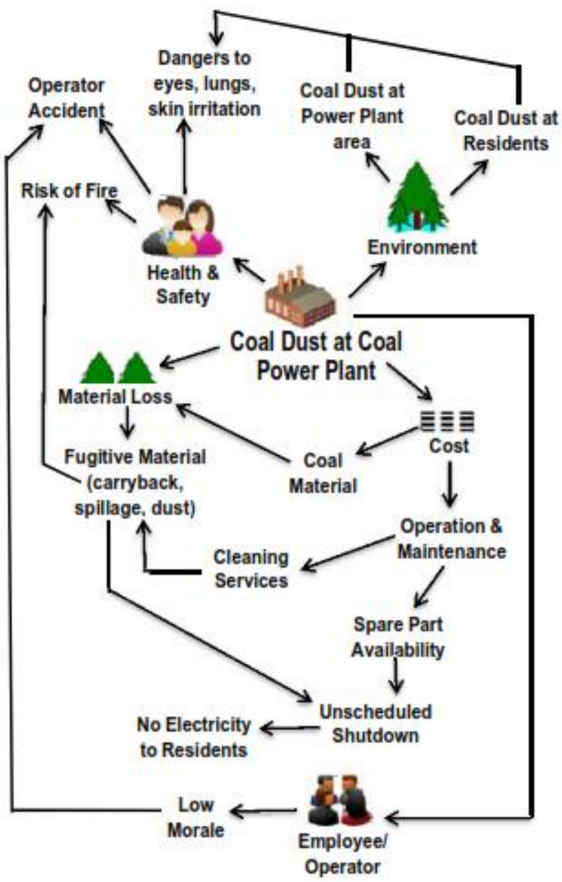

Figure 2. Application of Rich Picture Diagram of coal dust problems at the Coal Power Plant

Stage-3: Root Definition

Coal dust which flies and is widely found in the PLTU area as well as to residential areas is more dominant due to coal transportation activities from ship unloading, transferred through conveyor, passing some tower transfers and being temporarily placed in the stock pile area and then transferred to several equipment such as crusher and seizer to get to the bunker or silo area. Dust is a solid piece that is wide variety of shapes and sizes. Dust is caused by the disintegration of the materials in the ground into smaller pieces as a result of the mechanical processes (Atılmış & Tufan, 2019). Environmental controls are mandated by federal law: ventilation systems, water sprays, and other dust capture devices require continuous monitoring to ensure they operate as intended (Petsonk, Rose, & Cohen, 2013).

As a result of the spread of coal dust has a profound impact on health problems for workers and residents around the plant (breathing, lungs, eyes), safety or safety problems in the plant (work accidents, fire), cost loss problems (damaged equipment, cleaning service, coal material loss, sudden plant shut down) and environmental problems (pollution or air pollution that can damage crops or agricultural products). Coal dust has been shown to stimulate the release of cytokines that are important in lung inflammation and fibrosis, including tumor necrosis factor-a (TNF-a) and IL-1 (Petsonk, Rose, & Cohen, 2013). These include respiratory symptoms such as cough, aggravated asthma, the development of chronic bronchitis and decreased lung function, arrhythmias, nonfatal heart attacks, and premature death in people with heart or lung disease; the effects of absorption of toxic material; and allergic or hypersensitivity effects (Casleden et al., 2011). One of the major harms of coal dust is damage the health of practitioners, and another major harm of coal dust is spontaneous combustion and high explosiveness (Du, 2018).

Speaking of dust in port handling systems, dust emissions causes:

- Indirect costs related to the cleaning of surrounding areas
- Contamination of nearby urban areas with many nuisances
- Direct or indirect damages to other goods in ports and their installations (Zrnic et al., 2011).

This next step is to formulate root definitions. This stage is known as naming and selecting relevant systems, and we can formulate with CATWOE as listed in Table 3. This stage is like that determine because, at this stage, the core or root of the definition faced selected and named (selecting and naming). The CATWOE acronym is used to formulate root definition appropriately and relevantly. It is used to check that root definition has been well formulated. CATWOE is standing for: customer, actor, transformation, weltanschauung/worldview, owner and environmental constraint.

Table 3. CATWOE for element and question

Element	Question
Customers	Who are the system beneficiaries?
Actors	Who transforms inputs into outputs?
Transformation	What transformations exist?
Worldview	What is the reason for this transformation?
Owners	Who can stop or change this transformation?
Environment	What constraints are there in the immediate surroundings of this transformation?

[C] Customers: Coal Power Plant operators/workers, residents around the plant.
[A] Actor: Engineering department, maintenance department.
[T] Transformation: With three pillars discussing: Knowledge, Technology, And Commitment so that it is expected to overcome the difficulties of coal at the Coal Power Plant.
[W] Weltanschauung; To appreciate the feasibility of making improvements in handling coal dust at the Coal Power Plant, understanding the solutions to be taken is based on experience and knowledge about handling coal dust at the previous Coal Power Plant.
[O] Owner: Management of Coal Power Plant.
[E] Environmental Limits: Health, environment, costs, safety.

Stage-4: Conceptual Model

The conceptual model as shown in Fig.3, that originates is a method of analyzing the activities that need to be done to determine what the perpetrator must do to achieve transformation. Don't include activities carried out by anyone other than the actors you have named in the root definition (and if possible, Limit actors to one group of people - Monitoring activities are very complicated when more than one group is involved). Again, thinking discipline is needed — a list of activities needed to achieve the objectives of the system. Thinking discipline is also important to include activities that monitor the system and results of feedbacks, so that system activities can be carried out effectively.

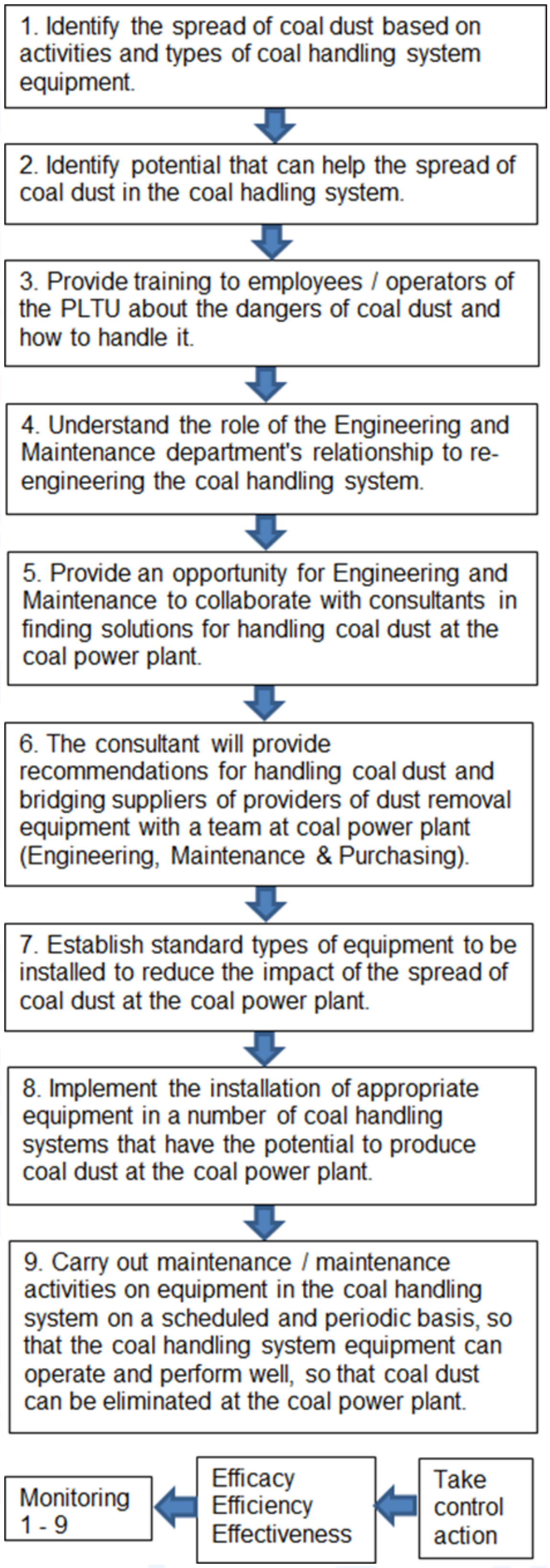

Figure 3. Application of Conceptual Model for handling coal dust at the Coal Power Plant

Table 4. The conceptual model compares with real-world and identification of feasible, desirable changes

Conceptual Model Activities	Real World	Identification of feasible, desirable changes
Identify the causes of coal dust based on activities and types of coal handling system equipment.	Workers at the coal power plant only see coal dust without identifying the cause of the coal dust.	Conduct inspections and investigate the causes of coal dust in the coal handling system.
Identify potential that can help spread coal dust in the coal handling system equipment.	It has never been thought of by coal power workers to identify potential that can help spread coal dust in the coal handling system equipment.	Conduct a study (book/literature, brainstorming/discussion) relating to the potential for coal dust to arise in the coal handling system equipment.
Provide training to employees/operators of the PLTU about the dangers of coal dust and how to handle it.	There has never been any training regarding the dangers of coal dust and its handling to coal power plant workers.	Do training by calling on expert trainers from outside parties to share knowledge about the dangers of coal dust and its handling to workers at the coal power plant.
Understand the role and relationship of the engineering and maintenance departments to re-engineering (refining) the coal handling system equipment and its maintenance.	There has been no synchronization between the engineering department and maintenance in handling coal dust at the coal power plant.	A special committee for handling coal dust was formed at the PLTU by declaring engineering to re-design the equipment and maintenance for maintenance of the equipment in the coal handling system.
Providing opportunities for engineering and maintenance teams to collaborate with consultants in finding solutions to handling coal dust at the coal power plant.	Workers at the coal power plant are still trying to deal with the dust problem itself, wherewith the limited knowledge of handling coal dust, and the handling is not maximal. Not yet implemented	Invite consultants/specialists (experts) to handle dust in the coal handling system.
The consultant will provide recommendations for handling coal dust and bridge the supply of equipment suppliers for handling dust with the engineering and maintenance team.	Not yet implemented	The report contains recommendations on the type of equipment that is right for dealing with coal dust and helps provide the right supplier for the procurement of this equipment.
Set the standard type of equipment that will be installed in the coal handling system to reduce the impact of the spread of coal dust at the coal power plant.	Not yet implemented	Together with a special committee (engineering and maintenance) team to make a standard type of equipment in the coal handling system for handling coal dust at the coal power plant.
Execute the installation of standard equipment in several places in the coal handling system that has the potential to generate coal dust at the coal power plant.	The equipment installed is not by the appropriate standards.	Re-install by replacing equipment that is not following the standard.
Conducting regular maintenance and maintenance activities for the installed equipment can perform well, and coal dust can be eliminated at the coal power plant.	Maintenance activities are carried out only occasionally and not scheduled.	Create a standard schedule for maintenance of coal handling system equipment by placing workers who are highly dedicated to performing
Monitor operational activities.	Not yet implemented	Management and its staff regularly scheduled meetings to discuss progress regarding the impacts that occur after the equipment is installed in the coal handling system.
Take control measures.	Not yet implemented	Evaluate and take action (repair and maintenance of coal handling system equipment) if the problem of the spread of coal dust still occurs in the coal power plant.

Stage-5 and Stage-6: Compare Models with The Real World and Identification of feasible, desirable changes.

The next step is where we return to the real world and compare the reality that we experience with those captured in the model. The purpose of the comparison is to start a discussion from which changes to improving the situation that can be identified. This approach uses a model to provide a means of understanding different views of reality by testing assumptions that may exist but are difficult to implement. The approach is the difference between what happens in reality and a logical model that raises questions that will eventually cause change.

The way we do this step is to build a table with three columns as listed in Table 4. The first contains activities in the conceptual model. The second contains what happens in reality and the third what we can do to bring reality closer to the conceptual model that can be maintained logically

Stage-7: Action to improve the problem situation.

To control dust spread at belt conveyor transfer points, it is common to enclose the transfer points in containment structures that extend from the head pulley to the tail pulley (Ullmann & Dayan, 1998).

The following steps have been implemented by the coal power plant management:

1. Hire a material handling consultant to assess of the distribution of coal dust to the area of coal handling facilities (unloading vessels, stock piles, and conveyor belts at the transfer point area), and the results of the assessment from the consultant which will be used to repair the coal handling facility equipment as shown in Fig.4.

Figure 4. Assessment of coal handling facility by consultant

2. Continuing training for employees of coal power plants (operators, maintenance, engineering, and other staff) about the hazards and impacts caused by coal dust for safety and health as shown in Fig. 5.

Figure 5. Training the hazards and impacts caused by coal dust for safety and health

3. The management of the coal-fired power plant conducts counseling to residents around the coal-fired power station about the dangers and effects of coal dust on health (eye and skin irritation, respiratory, and lung disorders).

4. improved coal handling facilities, including:

a. Installing dust suppression equipment in the ship unloader area, where this equipment will eliminate the spread of dust when transferring material from the tanker to the hopper as shown in Fig. 6. Suppressing the generation of coal dust during the production process is the most important work (Du, 2018).

The use of water sprays over the years has established the following facts:

- For a given spray nozzle, the collection efficiency for small dust particles increases as the pressure increases.
- At a given pressure, the efficiency increases as the nozzle design are changed to produce smaller droplets.

The conclusion is clear: smaller droplets are more effective in knocking small dust particles out of the air (Xie et al., 2007).

Figure 6. Dust suppression at ship unloader

b. Modify the equipment in the transfer point area on the conveyor belt, namely:

- Install the right sealing system (rubber skirt uses a double-lip type as shown in Fig. 7.

Figure 7. The sealing system with double lip

- A dust bag is installed to reduce the speed of the wind and the spread of dust in the transfer point area as shown in Fig. 8. The heart of fabric filter technology remains the bag itself, which acts as a matrix on which the dust cake is formed. Several variables, among them fabric, weave, finish, and construction affect collection efficiency and bag life (Carr, 1986).

Figure 8. Dust bag at transfer point area of belt conveyor

- Install a rubber curtain inside chute at transfer point area as shown in Fig. 9. In general, reducing air velocity can reduce dust generation (Chen et al., 2010).

Figure 9. Rubber curtain inside the chute

- Install tailbox extension at the transfer point area as shown in Fig. 10.

Figure 10. Tailbox extension at transfer point area

c. Installing equipment dust boost in the area of stock pile and stacker reclaimer, where this equipment will eliminate the distribution of dust during stacking and material reclaiming to and from the stock pile as shown in Fig. 11.

Figure 11. Dust boost at stock pile area

5. Monitoring the spread of coal dust starting from unloader ships, stock piles, and conveyor belt area transfer points. At the transfer point of the belt conveyor, due to the combined effects of airflows such as belt traction flow, falling coal induced flow, and sheared compressed flow, a

large amount of dust is generated at the transfer point (Gao, Shen & Liang, 2018).
6. Carry out monitoring and maintenance of equipment to continue.
7. ISO 14000 prescribes voluntary guidelines and specifications for environmental management. The program requires:
- Identification of a company's activities that have a significant impact on the environment.
- Training of all personnel whose work may significantly impact the environment.
- The development of an audit system to ensure the program is properly implemented and maintained regulatory (Foundations, 2016).

RESULT AND DISCUSSION

The result is the comparison before and after improvement the method. It can be seen the differences visually. At belt conveyor - transfer point area as shown in Fig. 12, before improvement the condition is extremely dusty and compare with after improvement is dust free.

a. Before Improvement (extremely dusty)

b. After Improvement (dust free)
Figure 12. Coal dust at belt conveyor - transfer point area

Also, at belt conveyor – coal bunker area as shown in Fig. 13, before improvement the condition is extremely dusty and compare with after improvement is dust free.

a. Before Improvement (extremely dusty)

b. After Improvement (dust free)
Figure 13. Coal dust at belt conveyor – coal bunker area

Table 5 shows a category of dust level based on comparing a visual inspection with ranges of conditions broken down into categories and illustrated with relevant photos.

Table 5. Survey of category for coal dust level before and after improvement

Survey	Level	Remarks
Before Improvement (Fig. 12a & Fig. 13a)	Extremely Dusty	- More than 10 milligrams of dust per cubic meter. - Opacity is greater than 30 percent. - Able to see less than 15 meters (50 feet) through the dust. - Unable to breathe without a respirator. - Eyes irritated and constantly watering.
After Improvement (Fig. 12b & Fig. 13b)	Dust-Free	- Less than 1,2 milligrams of dust per cubic meter. - Opacity 0 to 10 percent. - Able to see more than 100 meters (300 feet) through the dust. - Able to breathe without a respirator. - Eyes not irritated.

(Swinderman et al., 2013)

CONCLUSION

After implementing seven stages in the soft system methodology (SSM), a very significant result was obtained, namely the reduction in the distribution of coal dust in the belt conveyor area, where the conveyor belt is a very large contributor to coal dust. From the results of the survey of coal dust levels before improvement of visual conditions around the conveyor belt is extremely dusty, but after the improvement of the coal handling facility equipment, the visual conditions around the conveyor belt are dust free. And this also will reduce of risk of air pollution caused by airborne coal dust, hazardous risk (fire) caused by coal dust, production losses, unplanned outage, dirty environment and cost of maintenance.

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