Design of a material handling system that feeds bagged powder into polyvinyl acetate paint disperser as a Cleaner Production option

Winnie Mutenhabundo, Ngoni Chirinda, Tauyanashe Chikuku

Abstract - This project is about designing a material handling system that feeds bagged powder into the disperser as a Cleaner Production, (CP) option. Initially, waste streams were identified; the levels of dust emissions were assessed as well as their impacts to humans and environment. The researchers set their objectives seeking to reduce these negative effects. Attempts were made to recognize potential sources of airborne dust using Cleaner Production Assessment and assess the dust load upon workers in several process stages by comparing observations with standard values assigned by American Conference of Governmental Industrial Hygiene, (ACGIH). Loading pigment material generates dust which can cause serious health problems as reported in Material Safety Data Sheets. The new technology option of CP in form of a design led to a reduction in dust emissions thus reducing potential health hazards and also a reduction in material consumption. The researchers therefore recommend this design to enable Cleaner Production.

Key Words: Cleaner Production, Material Handling, Paint manufacturing, Pollution

1 Introduction

The raw materials used in polyvinyl acetate, (PVA) paint manufacturing include pigments, medium (water) and additives, ''SAPMA [1]''. The pigments are white or coloured fine, solid particles, insoluble in the liquid or solid medium in which it is dispersed for paint production to provide colour and opacity. The medium is the liquid or solid material in which the pigment is dispersed and suspended to produce the complete formulation of the coating and for the PVA paints, water is used as a medium. Additives are a wide variety of ingredients added in small amounts for a variety of purposes

During production, a forklift carries pigment bags such as of Amorphous Silica, Titanium oxide, dolomite, chromium oxide and kaolin from the storeroom, elevate them to a 4metre height (tank height) and then deposit them at a floor surrounding the disperser tank rim. Two people will take a bag (40 or 25kg in weight) and had it over to other two people who will open them up and pour into the mixer.

The empty bags are piled on the empty pallet and then taken by a forklift to the waste bin.

As the operators load powders into mixing vessels, a lot of dust is emitted and some spillages occur as well. There are a number of potential hazards associated with handling these pigments. Some pigments are not toxic neither do they irritate, but they influence the body on a more subtle level to produce cancer. These pigments are called carcinogenic. Many carcinogenic materials are not toxic in the sense that if you eat a mouthful you don't show symptoms of poisoning within a few hours; in fact, no symptoms may appear for a number of years but can build up cancer.

Some pigments such as silica are not toxic but are nevertheless harmful. These pigments have an irritating action which the body responds to much more slowly than to a really toxic material, but in a very undesirable fashion. When silica in its finely divided form is inhaled into the lungs, it causes an inflammatory reaction which makes the lungs virtually useless and this disabling disease is called silicosis, ''NIOSH [2]''. Material Safety Data Sheets, (MSDS) states that titanium dioxide can cause some lung fibrosis at fifty times the nuisance dust, ''Stryker [3]''. Lungs may be affected by repeated or prolonged exposure to chromium oxide, resulting in fibrosis, chronic bronchitis, and pneumoconiosis, ''NIOSH, [4]''. Occupational exposure to kaolin may cause pneumoconiosis whilst for its toxicities inhalation may predispose miners to pulmonary diseases, ''Kluwer, [5]''.

Reduction in dust creation through modification of the disperser feeding process as a Cleaner Production option ensures a clean and safe working environment.

2 Methodology

2.1 Data collection

Work orders were used to get historical data on production. Interviews were done with stakeholders to get the story behind the participant's experiences. Questionnaires were distributed to operators to collect 'baseline' information which would then be tracked over time to examine changes. Literatures were reviewed in search of

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information pertaining to the problem at hand and see how other people have solved it.

2.2 Cleaner Production Assessment

Walk through inspection

It was done to understand operations so that the process flow diagrams could be generated and have inputs and outputs identified.

Material balance

With an established focus, a material balance was done on the key processes which were raw material measurement, pigment feeding and dispersion to see how inputs and outputs tallied and identify waste streams.

Pollution Audit

An air pollution audit was done and this included the sampling of airborne dust concentration for the area as well as personal dose. The sampling points that were used are presented in Table1 that follows;

TABLE1. DUST EMISSIONS AUDIT

Section/Stage	Type of dust	Number of samples
Storage area	Mixed dust	5
Pigment measurement	Mixed dust	5
Disperser loading	Mixed dust	5
Dispersion	Mixed dust	5

Cause Assessment

- An Ishikawa diagram was used to identify possible causes of dust emissions.

Cleaner Production opportunities

- With the causes of dust generation identified, some cleaner production opportunities were suggested.

Feasibility Analysis

- Technical, economic and environmental feasibility analysis of the options was done and the overall effective rating was given. The option that scored highest was recommended for development, ''Tuong Anh, [6]''.

2.3 Experimental design

Multiple solution generation

Three possible designs were identified and the best solution was chosen basing on functionality, product safety, cost, manufacturability and maintainability.

Experimental techniques

- Formulae were used to calculate conveyor capacity
- Prototyping and simulation was done using Autodesk Inventor

3 FINDINGS

3.1 Environmental Issues of the plant

The raw material storage area and the disperser area have pigment dust. There is no dust extractor at the master mix to extract some of the dust workers prefer working without masks.

3.2 Material balance

After focus was established, detailed material balance for raw material measuring, premixing and dispersion process were done and is as in Fig1 that follows.

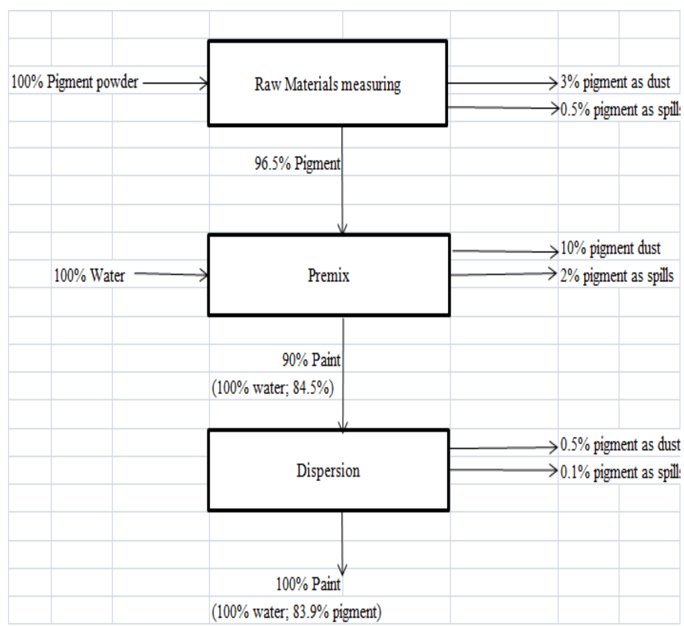

Fig. 1. Material balances

3.3 Pollution Audit of the plant

The amount of mixed dust concentration during disperser loading is above the threshold value of 5mg/m3 according to American Conference of Governmental Industrial Hygiene, (ACGIH), both for area concentration and personal dose. The observed dust concentrations are in Fig2 that follows.

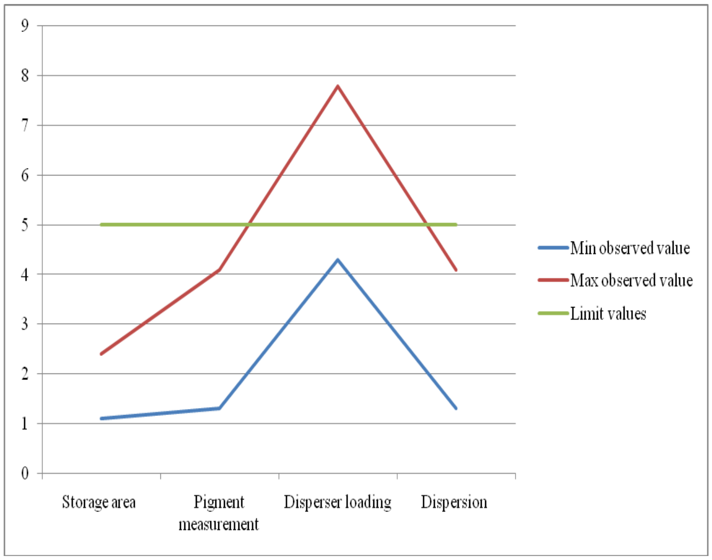

Fig. 2. Observed dust concentrations

In the storeroom and during the dispersion process, the dust concentration is more prone in the environment whilst the person is more exposed during pigment measurement and disperser loading as shown in Fig3 that follows.

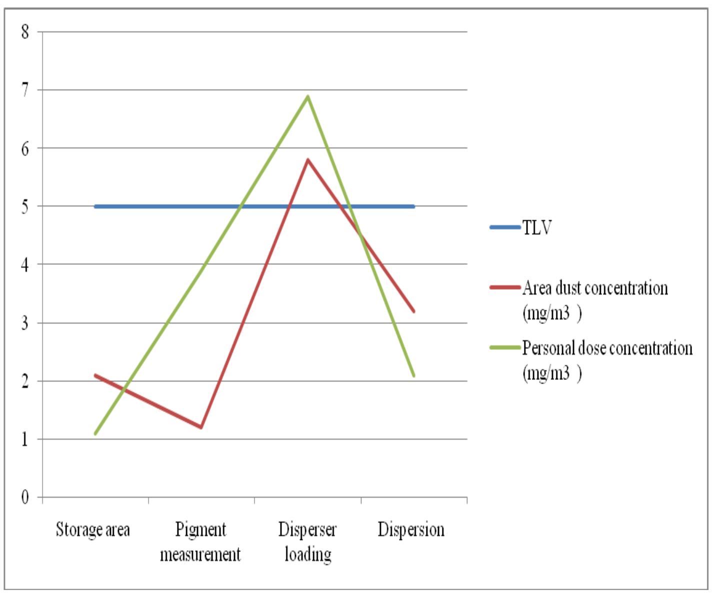

Fig. 3. Area dust concentration vs personal dose

3.4 Causes of Waste Generation

From the Ishikawa diagram, it was found that the various causes of dust generation in the plant are as follows;

i. Poor process and equipment design
- The way of disperser feeding through direct pouring of pigments in the disperser tank creates a lot of dust.
- There was no dust extractor at the disperse unit that could have minimized the amount of dust that is released into the environment.
- The spillage of powders was seen to be as a result of poor feeding technique as well as poor workmanship.

ii. Poor Housekeeping:
- Untidiness was seen in the form of pigment spills on the disperser feeding area floor
- Equipment is not wiped off of dust emissions that would have accumulated on them
- The emptied raw material bags were thrown on the pallet after emptying resulting in dust creation on the floor.

iii. Wrong Raw Material
- The pigments that are used are in the form of powders which can easily fly out as dust

iv. Poor workmanship
- The emptied raw material bags were thrown on the pallet after emptying resulting in dust creation on the floor.
- The concentration of dust emission is not monitored neither is it measured.

3.5 Cleaner Production Opportunities

Some cleaner production opportunities were identified and these are presented in Table2. These identified options were rated according to their feasibleness, technically, economically and environmentally as presented in Table3 that follows.

TABLE2. CLEANER PRODUCTION OPPORTUNITIES

Cleaner Production Measures	Anticipated Benefits	Technical requirement	Economic Viability	Environmental Impacts	Remark
Good housekeeping					
1. Frequent cleaning of floors	* Reduction in respirable dust	* None	Unquantified	Marginal reduction in pollution load	Easy to implement
2. Frequent wiping off of dust on equipment and walls	* Reduction in respirable dust *Prolonged equipment life	* None	Unquantified	Marginal reduction in pollution load	Easy to implement
3. Load empty bags into a drum to avoid spillage of left over materials.	* Clean working area *Reduction in respirable dust * Reduction in	*Equipment	Not quantified	Marginal reduction in pollution load	Fairly easy to implement
Poor process and equipment design					
4. Design of a material handling system to reduce dust emissions and spillages during for disperser feeding.	* Clean working area *Reduction in respirable dust * Reduction in material	*Equipment *Technology	*Initial Capital intensive	Marginal reduction in pollution load	Difficult to implement
5. Installation of a dust extractor		*Equipment	Not very expensive	Reduced pollution load	Fairly easy to implement
Wrong Raw Material					
6. Use pigments in paste form	* Reduction in respirable dust	Not Available	Not quantified	Reduced pollution load from dust only VOCs can be there	Very difficult to implement
Poor workmanship					
7. Measure and monitor dust emissions in the plant	*Pollution monitoring and control	Available	Not quantified	Pollution control	Fairly easy to implement

The option of designing a material handling system to reduce dust emissions and spillages during pigment loading ranked best as shown in Table 3 that follows. This option falls into the *new technology* category of CP options. Adopting and transferring new technologies can often reduce resource consumption, minimize wastes, as well as increase the throughput or the productivity. The new technology option is also often capital intensive, but can lead to potentially high benefits. Designing of a material handling system helps to reduce dust emissions and spillages.

TABLE3. RATING OF CLEANER PRODUCTION OPTIONS

Cleaner Production Opportunity	Feasibility			Total point	Overall Rank
	Technical 30	Economic 20	Environmental 50		
1	25	5	10	40	6
2	25	5	5	35	7
3	20	18	15	53	4
4	15	10	40	65	1
5	20	10	25	55	3
6	0	20	40	60	2
7	25	5	12	42	5

4 OPTION SYNTHESIS

4.1 Multiple solution generation

Identified option must reduce dust emissions, improve environmental performance, reduce environmental burden. Possible solutions to dust eradication include the use of the following techniques;

i. Vibratory Feeding
ii. Screw feeding
iii. Pin feeding, ''www.labman.co.uk [7]''.

A decision matrix identified a screw conveyor to be the best for the desired application.

4.2 Detailed design steps

1. Establishing the characteristics of the material to be conveyed.
2. Locating conveyor capacity (conveyor size and speed) on capacity tables.
3. Selection of conveyor components.
4. Calculation of required horsepower.
5. Checking of component torque capacities (including selection of shaft types and sizes), 'www.screwconveyor.com, [8]'.

TABLE4. DESIGN SPECIFICATIONS

Material	Dolomite (crushed)
Weight kg/m³	1281- 1602
Material Class	$90C_{1/2}36$
Component Group	2D
H.P Factor	2
Degree of trough loading	30%
Screw diameter (cm)	50.8
Maximum RPM	40
Capacity @ max RPM	70.8
Capacity @ one RPM	1.8

Capacity required: 2.600TPH [Tons per Hour]
Length of conveyor: 4.47m [Inlet Center to Outlet Center]
Inclination angle = 63.5^0
Capacity = 2.07 m^3/hr
Capacity = 73.03 cubic feet per hour
Screw diameter = 510mm
Pitch = 390mm
Smaller diameter is 500mm
Pipe diameter is 88.9mm
Conveyor overall length =5250mm

Horse power required
H.P. = 0.236
Brake horse power (B.H.P) = 0.555 = required motor H.P

Flutes
Conveyor length = =5250mm
No. of flutes = 13.4 flights
Thickness of flute = 3.18mm
Material = Mild steel

Couplings (flange)
Cold hardened steel couplings used with hard iron bearings
Coupling diameter = 76.2mm

Troughs
Heavy troughs to be used
Trough thickness = 5mm
Trough thickness = clearance between screw flight and trough.
Cover thickness = 3mm

Inlet and outlet
They are squared with dimensions of 400mm.
The inlet and outlet centers are at a distance of 4.47m and are pitch distance away from respective ends.

Bin/Hopper
Base area is 400 x 400mm
Top area is 600 x 600mm

Illustrations

The screw with its 13flutes is shown in the drawing that follows in Fig 4.

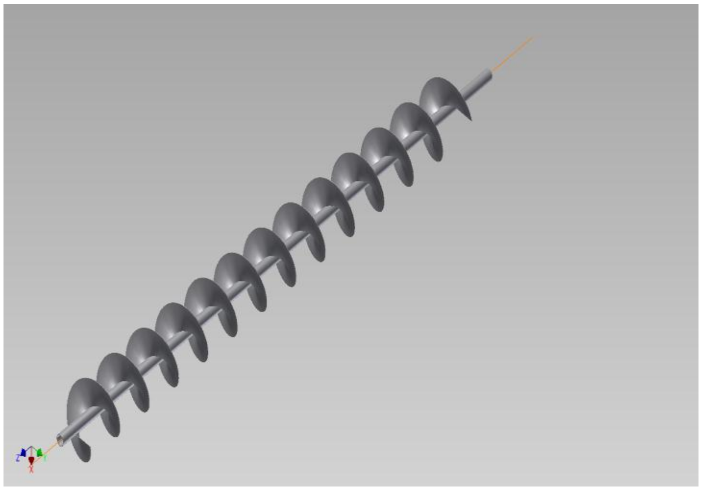
Fig. 4. Screw

The assembled drawing is shown in the pictorial view in Fig 5.

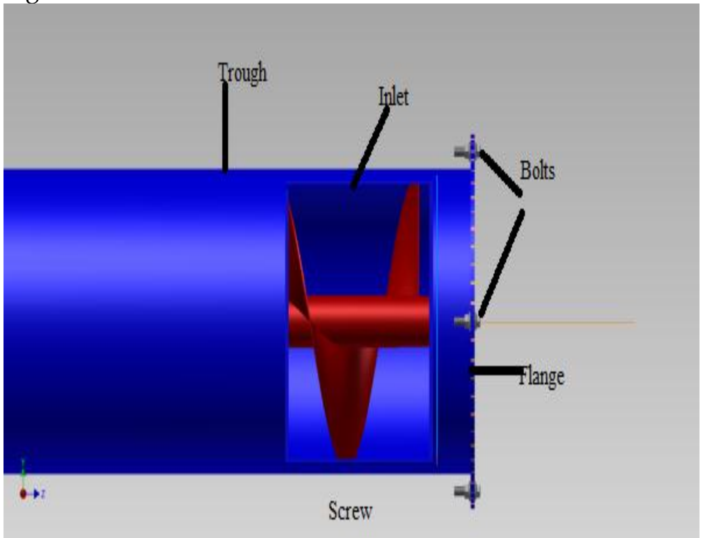

Fig. 5. Assembled Drawing

Financial implication of the design

Total cost of the design (Initial investment) = US$3000
Labour cost savings = US$900/mnth
Material cost savings = US$20/mnth
Total Savings = US$920/mnth
Payback Period =3.26months

5 Conclusions and Recommendations

The designed conveyor for material handling reduces in dust emissions in the plant. This in turn eradicates pollution thereby reducing potential health hazards to the human and the environment. Apart from dust reduction, the new feeding technology also increases the throughput and reduces direct costs.

5.1 Recommendations

Directly implementable options
Those simple options that are obvious should be implemented straightaway. These include

- ✓ Frequent cleaning of floors
- ✓ Frequent wiping off of dust on equipment and walls
- ✓ Load empty bags into a drum to avoid spillage of left over materials
- ✓ Measuring and monitoring dust levels

For these options there is no further detailed feasibility analysis that is required. Furthermore, their immediate implementation gives management real, tangible benefits in a short period, which makes them more comfortable with the Cleaner Production Assessment.

Dust extractor
There are other options such as the installation of a dust extractor which are not as easy to implement but are of outermost importance. This option cannot stand on its own but can support the usefulness of other options.

Paste pigments
Use of paste pigments is an option that can be considered for the design of the future plant as it requires consultation with raw material suppliers which makes it difficult to implement right away.

Acknowledgment

The authors wish to acknowledge the support offered by the management of the case company. They also wish to thank Mr Mugwindiri of the University of Zimbabwe for his unwavering guidance in this work.

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