Comparative Content of Harmful Substances Contained In the Raw Material for Various Types of Printing Ink

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***Abstract*—Printing ink is one of the chemical industry that can be considered as a high risk industry due to it is a manufacture industry that involved all kinds of chemical materials. Thus, reliability data is important for the environmental safety in chemical industries. This study aims to compare the hazardous substances in raw materials for various printing ink production and propose the control measures in the ink production process. Three types of printing ink raw material i.e sheet-fed ink, cold-set ink and heat-set ink were considered in this study. This study was conducted by using a quantitative approaches. Data were collected through Material Safety Data Sheet (MSDS). Hazardous substances were identified from the Chemical Abstract Service (CAS) registry number of the raw materials. The result of the study shown that there are eight hazardous chemical substances in sheet-fed ink, cold-set ink and heat-set ink. The hazardous raw materials identified are mainly from the category of pigment, solvents and additives. From the study of the three types of ink printing, sheet-fed inks contain harmful chemicals that are the lowest of 33.27%, followed by thermal ink-set of 41.73% and cold-set inks of 61.86%. The results also shown that solvents are identified to contribute highest percentage as hazardous chemical substances in the printing ink, followed by additives and pigment. The results of the research shown that the production workers in the printing ink production process are at highly exposed to the hazards. The hierarchy of hazard control based on Department Occupational Safety and Health (DOSH) are proposed to control the hazardous chemical substances. The recommended control measures of possible hazards and risks based on the work activities are elimination, engineering control, administration control and personal protective equipment. This research is very important as it will enhance the precautions and safety knowledge of the employer and employee in handling the chemical substances in the printing ink production process.**

***Keywords*- Safety and Health, Material Safety Data Sheet, Control Measures, Printing Ink, hazardous chemical substances**

I. INTRODUCTION

Printing inks are the coloured liquids or pastes that formulated to transfer a reproduce image from the printing surface for the purpose of convey message, give decorative effect and it provides protection to a substrate surface [1]. The printing surface may involve wide range of papers, boards, plastic, and glass. Printing inks can be grouped into sheet-fed, cold-set and heat-set lithographic inks. The printing inks category is depends on the drying properties of the ink [2]. Sheet-fed drying process is oxidizing of the solvent and slight absorption of the ink into the substrate [3] and it is mostly use in high quality printing job. However, cold set ink drying property is by the penetration onto an absorbent substrate and it is apply to newspaper and some book production print[2]. It is usually high speed printing and low cost printing. For heat-set printing, the drying process dry at elevated temperature of 120ºC to 140ºC and it involve evaporation process up to 90% of the solvent content.

Printing ink consist dispersions of insoluble colorants or solutions of dyes in a varnish or vehicle system resulting in the combination forms of fluid which can distribute and transfer on the printing press. The composition of the sheet fed ink, cold-set ink and heat set ink are different from the content of additives and the different boiling range of the solvents based on the drying properties of the inks and its application. In the printing ink production process, two steps of the main processes are involved. The printing ink production processes are varnish manufacturing and the pigment grinding [4].

Hazard is an event that could cause harm [6]. Hazards is defined as the sources that potentially cause harm to human health, property and environment [7]. Hazards can cause many human health problems that developed slowly over time and under certain conditions hazards lead accidents to happen [7].

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Papadopoulos *et al.* (2010) mentioned that the identification and prioritising of the essential hazard is vital and manage the hazard through preventive measure is necessary to mitigate and prevent accidents and emergencies. The hazards are sources of potential harm to human and hazard leads accident to happen[7]. Accidents happened unpredictably and caused severe injuries and losses [6]. All kind of hazards exposure in the chemical industries namely sharp surface, moving parts, equipment, tools, industrial trucks, pressurized system, electromechanical system, noise vibration, environment conditions, chemicals and etc. [6].

In the printing ink production process, significant of physical and chemical hazards are exposed. The physical hazard is imposed due to the heating tanks, various size of mixer and blenders in the production process [4]. Besides that, chemical hazards exposed due to various types of raw materials such as pigments, solvents and others are largely used in the production process. Chemicals hazards that most likely to give adverse effect on the workers' health are the black or coloured pigments, varnish system, volatile solvents and cleaning solvent[9]. The emissions of the dust, vapours, fumes and spills are exposed to the workers are hazardous. Carbon black pigment contain the chemical substances such as titanium dioxide, calcium carbonate, zinc oxide and clay. However the coloured pigments can be inorganic or organic. Organic coloured pigments are mostly synthetic colorants of aromatic hydrocarbon such as benzene, naphthalene and anthracene. Inorganic coloured pigments contained metals such as lead, chromium, copper, mercury, iron and others [9]. Besides that, the major composition of the varnishes system is a homogeneous solution in volatile solvents such as aliphatic ester, aromatic hydrocarbons, alcohols or ketones. Moreover, the cleansing solvents emitted volatile organic compound (VOC) is the great concern to the health of the printing ink production process workers [9].

The common cleansing solvents are kerosene, glycol ether, ether alcohols toluene, hexane and special formulated blends of solvents. Major sources of the VOC emissions exhausted when the production worker clean up the machines manually with wetted rags. Inhalation or skin contact to the chemicals can cause adverse effect to health and the diseases may develop are dermatitis, irritation, central nervous system depression and respiratory tract[9]. Furthermore, central nervous system depression can cause the inattention, in coordination, impaired balance and drowsiness. Upon long term of chemicals exposure, the printing ink workers may develop damage of the internal organs such as liver, kidney, lungs and others. The handling of dangerous substances in the manufacture of printing inks is important to eliminate unnecessary of hazard chemical contact. This is because chemical hazard may cause health effect over long time exposure [7]. For that reason, the objective of the study is to compare the hazardous substances in raw materials for various printing ink production and propose the control measures in the ink production process.

II. METHODOLOGY

The study is conducted in a selected printing ink manufacturer. This research study is carrying out in the production department of the printing ink. The production plant of the manufacturer involved the production processes of three types of inks namely sheet-fed ink, cold-set ink and heat-set ink. For the raw materials study, material safety data sheets (MSDS) were collected for the regulatory review on the safety of the raw materials application in the ink. From the chemical abstract service (CAS) registry number of the raw materials, hazardous substances for each type of printing ink raw material were identified. The results obtained for the hazardous chemical substances were discussed and studied thoroughly.

The health adverse effect of the hazardous chemical substances were analyzed accordingly based on the regulation of the hazards statements of the relevant literacy references namely Regulation (EC) No 1272/2008 (CLP), International Agency for Research on Cancer (IARC), GHS Hazards statements, American Conference of Government Industrial Hygienists (ACGIH), Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) (USECHH) Regulations (2000), and Occupational Safety and Health (Classification, Labeling and Safety Data Sheet of Hazardous Chemicals) (CLASS) Regulations 2013[10]. The comparison of each type of printing ink raw materials is then being compared and analyze.

III. RESULT AND DISCUSSION

The raw materials of the printing inks are studied through the printing ink formulation. The sheet-fed ink raw materials ratio compositions are as per Table 1. The cold-set ink raw materials ratio compositions are as per Table 2 and the heat-set ink raw materials ratio compositions are as per Table 3. The hazardous raw materials in the printing inks are identified based on the relevant literacy references as per Table 4, Table 5 and Table 6. The raw materials safety data sheets (MSDS) for each of the hazardous raw materials are collected and studied throughout. For sheet-fed ink, the hazardous chemicals substances consist of total 33.27%.

There are 7 hazardous chemicals substances are identified based on the regulatory references. The hazardous chemical substances identified in the sheet-fed ink are namely carbon black (16.5%), petroleum distillates hydro-treated light (8.75%), petroleum distillates hydro-treated middle (7.04%), 2ethylhexanoic acid (0.53%), petroleum distillates hydro-treated light naphthenic (0.31%), 2,6-Di-tert-butyl-4-methylphenol (0.08%) and starch (0.06%). In sheet fed ink the highest ratio compositions of hazardous chemical substances is carbon black and the lowest ratio compositions of hazardous chemical substances is starch.

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Table I. The Sheet Fed Ink Raw Materials Composition Ratio

No.	Chemical Substances:	CAS number	Ratio Compositions
1.	Modified Rosin Esters	Confidential	19.30%
2.	Linseed Oil Modified Alkyd Resin	67700-81-6	1.70%
3.	Rosin Polymer with Formaldehyde, 4-(1,1,3,3-tetramethylbutyl) Phenol and Glycerol	119209-70-0	0.11%
4.	Rosin Polymer with Formaldehyde, glycerol, pentaerythritol and (1,1,3,3-tertramethylbutyl)phenol	68512-70-9	0.03%
5.	Benzene, mono C12 13 Branched Alkyl Derivatives	151911-58-9	1.54%
6.	Carbon Black	1333-86-4*	16.50%
7.	Pigment Blue 61	1324-76-1	1.05%
8.	Petroleum Distillates Hydro-treated Middle	64742-46-7*	7.04%
9.	Petroleum Distillates Hydro-treated light	64742-47-8*	8.75%
10.	Petroleum Distillates Hydro-treated Light Naphthenic	64742-53-6*	0.31%
11.	Gilsonite	12002-43-6	1.65%
12.	Linseed Oil	8001-26-1	22.79%
13.	Tung Oil	8001-20-5	0.01%
14.	Soybean Oil	8001-22-7	5.43%
15.	Palm Oil	8002-75-3	5.17%
16.	Fats & Glyceride Oils Fish, Oxidized	68187-75-7	0.90%
17.	Calcium Carbonate	471-34-1	5.05%
18.	2-Ethylhexanoic Acid, Manganese Salt	15956-58-8	0.74%
19.	2-Ethylhexanoic Acid	149-57-5*	0.53%
20.	Aluminium	14782-75-3	0.33%
21.	Polyethylene	9002-88-4	0.30%
22.	Cobalt Bis(2-Ethyhexanoate)	136-52-7	0.27%
23.	Sulfonic Acids, Petroleum, Sodium Salts	68608-26-4	0.15%
24.	Tripropylene Glycol	24800-44-0	0.11%
25.	Toluhydroquinone	95-71-6	0.08%
26.	2,6-Di-tert-butyl-4-methylphenol	128-37-0*	0.08%
27.	Starch	9005-25-8*	0.06%
28.	Hexametaphoshate Sodium Salt	10124-56-8	0.01%
29.	Water	7732-18-5	0.01%
Total			100.00%

Refer to Table 2, in the cold-set ink, the hazardous chemicals substances consist of total 61.86%. There are 3 hazardous chemicals substances are identified based on the regulatory references. The hazardous chemical substances identified in the cold-set ink are namely carbon black (16.00%), petroleum distillates hydro-treated light (16.86%), and extracts, paraffinic solvents (29.00%). In cold-set ink the highest ratio compositions of hazardous chemical substances is extracts, paraffinic solvents and the lowest ratio compositions of hazardous chemical substances is carbon black.

Table II. The Cold Ink Raw Materials Composition Ratio

No.	Chemical Substances	CAS number	Ratio Compositions
1.	Petroleum Resins	64742-16-1	14.08%
2.	Carbon Black	1333-86-4*	16.00%
3.	Petroleum Distillates Hydro-treated light	64742-47-8*	16.86%
4.	Extracts, Paraffinic Solvent	64742-04-7*	29.00%
5.	Tung Oil	8001-20-5	13.00%
6.	Calcium Carbonate	471-34-1	8.00%
7.	Gilsonite	12002-43-6	2.56%
8.	Bentonite	1302-78-9	0.28%
9.	1-Octadecaaminium	112-03-8	0.22%
Total			**100.00%**

Refer to Table 3, in the heat-set ink, the hazardous chemicals substances consist of total 41.73%. There are 3 hazardous chemicals substances are identified based on the regulatory references. The hazardous chemical substances identified in the heat-set ink are namely petroleum distillates hydro-treated light (40.93%), petroleum distillates hydro-treated light naphthenic (0.49%) and 2, 6-Ditert-butyl-4-methylphenol (0.31%). In heat-set ink the highest ratio compositions of hazardous chemical substances is petroleum distillates hydro-treated light and the lowest ratio compositions of hazardous chemical substances is, 6-Di-tert-butyl-4methylphenol.

Table III. The Heat-Set Ink Raw Materials Composition Ratio

No.	Chemical Substances	CAS number	Ratio Compositions
1.	Phenol Modified Ester Rosin Resin	Confidential	28.6%
2.	Linseed Oil Modified Alkyd Resin	67700-81-6	2.85%
3.	Petroleum Resins	64742-16-1	0.61%
4.	Rosin Polymer with Formaldehyde 4-(1,1,3,3,tetramethylbutyl) phenol and Glycerol	119209-70-0	0.13%
5.	Petroleum Distillates Hydro-treated Light	64742-47-8*	40.93%
6.	Petroleum Distillates Hydro-treated light Naphthenic	64742-53-6*	0.49%
7.	Pigment Yellow 3	5102-83-0	12.0%
8.	Soy Bean Oil	8001-22-7	0.26%
9.	Palm Oil	8002-75-3	11.6%
10.	Linseed Oil	8001-26-1	0.05%
11.	Tung Oil	8001-20-5	0.01%
12.	Benzene	151911-58-9	1.07%
13.	Aluminium	14782-75-3	0.59%
14.	Polytetrafluoroethylene (PTFE)	9002-84-0	0.30%
15.	2,6-Di-tert-butyl-4-methylphenol	128-37-0*	0.31%
16.	Toluhydroquinone	95-71-6	0.10%
17.	Calcium Carbonate	471-34-1	0.07%
18.	Hexametaphosphate, Sodium Salt	10124-56-8	0.02%
19.	Water	7732-18-5	0.01%
Total			100.00%

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There are total 8 hazardous raw materials identified from the sheet-fed ink, cold-set ink and heat-set ink. The hazardous raw materials identified are mainly from the category of pigment, solvents and additives. From the identification, among the three types of printing ink, sheet-fed ink consist of lowest hazardous chemicals substances by ratio compositions (33.27%), followed by heat-set ink (41.73%) and cold set ink consists highest ratio compositions of hazardous chemicals (61.86%).

Refer to Table 4, the 8 hazardous chemical substances consist of 1 pigment, 4 solvents and 3 additives are identified with total percentage of 32.50%, 103.38% and 0.98% by category respectively. Hazards contribution of the hazardous chemical substances, solvents are the highest. It followed by additives and pigment. Among the 8 hazardous chemical substances, Petroleum Distillates Hydro-treated light (64742-47-8) consist the highest percentage by 66.54% from total three types of ink. Whereas, starch (9005-25-8) is the lowest hazardous chemical substances with total 0.06% from sheet fed ink. From this data, solvents are identified to contribute highest percentage as hazardous chemical substances in the printing ink, followed by additives and pigment.

Refer to Table 5, Table 6 and Table 7, the justifications of the hazards statements are refer to the relevant literacy references namely Regulation (EC) No 1272/2008 (CLP), International Agency for Research on Cancer (IARC), GHS Hazards statements, American Conference of Government Industrial Hygienists (ACGIH), Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) (USECHH) Regulations (2000), and Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) (CLASS) Regulations 2013.

According to the regulatory references, among the 8 hazardous chemical substances identified, there are 7 of the hazardous chemical substances are listed as the carcinogen chemical by International Agency for Research on Cancer (IARC). The hazardous pigment identified is Carbon Black (1333-86-4). This chemical substances can cause skin corrosion and skin irritation. Carbon Black is slightly irritate to the respiratory system. It is an aspiration hazard that can cause fatal if swallowed. This chemical substances give narcotic effects, cause drowsiness and dizziness. Carbon Black is carcinogenic and total hydrocarbon vapour can absorbed through skin. The hazardous solvents identified are Petroleum Distillates Hydro-treated light (64742-47-8); Petroleum Distillates Hydro-treated Middle (64742-46-7); Extracts, Paraffinic Solvent (64742-04-7) and Petroleum Distillates Hydro-treated light Naphthenic (64742-53-6). The hazardous solvents can cause skin corrosion and skin irritation. It is also slightly irritate to the respiratory system and it can cause fatal if swallowed due to aspiration hazard. These hazardous solvents give narcotic effects and cause drowsiness and dizziness. These hazardous solvents are carcinogenic and can cause skin dryness. The hazardous additive identified is 2,6-Di-tert-butyl-4-methylphenol (128-37-0). It is acute, chronic and carcinogen hazards. Starch (9005-25-8) is another additives identified as high-polymerized carbohydrate that can cause respiratory system irritated.2-Ethylhexanoic Acid (149-57-5) as hazardous additives identified is harmful chemical substances to skin, it can caused serious eye damage and damage to the fertility system.

Table IV. The Total Hazardous Chemical Substances Identified From Sheet-Fed Ink, Cold-Set Ink and Heat-Set Ink By Total Percentage

Raw Material Category	No	Hazardous Chemical Substances	Chemical Abstracts Service (CAS) Number	Sheet-fed Ink	Cold-set Ink	Heat-set Ink	Total percentage by chemical substances	Total by category
Pigment	1	Carbon Black	1333-86-4	16.5	16	0	**32.5**	**32.50**
Solvent	2	Petroleum Distillates Hydro-treated light	64742-47-8	8.75	16.86	40.93	**66.54**	**103.38**
	3	Petroleum Distillates Hydro-treated Middle	64742-46-7	7.04	0	0	**7.04**	
	4	Extracts, Paraffinic Solvent	64742-04-7	0	29	0	**29**	
	5	Petroleum Distillates Hydro-treated light Naphthenic	64742-53-6	0.31	0	0.49	**0.8**	
Additives	6	2,6-Di-tert-butyl-4-methylphenol	128-37-0	0.08	0	0.31	**0.39**	**0.98**
	7	Starch	9005-25-8	0.06	0	0	**0.06**	
	8	2-Ethylhexanoic Acid	149-57-5	0.53	0	0	**0.53**	
Total percentage by Ink				**33.27**	**61.86**	**41.73**		

Table V. The Hazardous Chemical Substances In Sheet-Fed Ink By Ratio Compositions Based On The Regulatory References

Chemical Substances	CAS Number	Ratio Compositions	Regulatory References					
			CLP	IARC	ACGIH	GHS	USECHH	CLASS
Carbon Black	1333-86-4	16.50%	√	√	-	-	√	√
Petroleum Distillates Hydro-treated light	64742-47-8	8.75%	√	√	√	-	-	-
Petroleum Distillates Hydro-treated Middle	64742-46-7	7.04%	√	√	-	√	-	-
2-Ethylhexanoic Acid	149-57-5	0.53%	√	-	-	-	-	-
Petroleum Distillates Hydro-treated light Napthenic	64742-53-6	0.31%	√	√	-	-	-	-
2,6-Di-tert-butyl-4-methylphenol	128-37-0	0.08%	-	√	-	-	√	√
Starch	9005-25-8	0.06%	-	-	-	-	√	-
Total		33.27%						

Table VI. The Hazardous Chemical Substances In Cold Set Ink By Ratio Compositions Based On The Regulatory References

Chemical Substances:	CAS Number:	Ratio Compositions:	Regulatory References					
			CLP	IARC	ACGIH	GHS	USECHH	CLASS
Carbon Black	1333-86-4	16.00%	√	√	-	-	√	√
Petroleum Distillates Hydro-treated light	64742-47-8	16.86%	√	√	√	-	-	-
Extracts, Paraffinic Solvent	64742-04-7	29.00%	√	√	-	√	-	-
Total		61.86%						

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Table VII. The Hazardous Chemical Substances In Heat-Set Ink By Ratio Compositions Based On The Regulatory References

Chemical Substances:	CAS Number:	Ratio Compositions:	Regulatory References					
			CLP	IARC	ACGIH	GHS	USECHH	CLASS
Petroleum Distillates Hydro-treated Light	64742-47-8	40.93%	√	√	√	-	-	-
Petroleum Distillates Hydro-treated light Naphthenic	64742-53-6	0.49%	√	√	-	-	-	-
2,6-Di-tert-butyl-4-methylphenol	128-37-0	0.31%	-	√	-	-	√	√
Total		41.73%						

In daily production process activities, the most frequent group exposed to the hazardous raw materials are the production workers. In order to control the hazardous chemical substances health adverse effect to the production workers, the risk management control measures of the hazardous chemical substances proposed are based on the hierarchy of hazard control (Department of Occupational Safety and Health, 2008).

According to the hierarchy of hazards of control, the control proposed are elimination, substitution, engineering control, administration control and personal protective equipment (PPE). The most effective hazard control is elimination, and the least effective hazard control is application of Personal Protective Equipment (PPE). This is because the chances to eliminate the hazards completely are usually impossible. Whereas, application of personal protective equipment (PPE) minimize the hazards exposure to the production workers to avoid serious workplace injuries or illness. In order to control the hazardous chemical substances, the proposed risk management control measures by hierarchy of control are discussed.

Carbon Black (1333-86-4) is the hazardous colour pigment powder identified from the printing ink raw materials. It is impossible to eliminate this pigment due to it is the main source of colourant to the printing ink. Thus, to control this hazardous chemical substances, the carbon black pigment powder can be substituted with the black paste. Besides that, from the engineering control, the production process of the weighing and premixing section can be redesigned and replaced by the auto pumping in a closed system. This is because the production workers on manual handling of the carbon black pigment at the weighing and pigment section are highly exposed to the hazardous chemical substance. The semi-manual premix process also initiate the pigment to contaminate the entire section. On the administration control, the production workers should be trained on the safe operating procedures and the personal protective equipment (PPE) correct method application. By educating the production workers, they should be trained intensively to handle the carbon black pigment powder carefully in order to avoid the carbon Black irritate the respiratory system and other health adverse effect. The appropriate Personal Protective Equipment (PPE) should be provide to the production workers such as nitrile rubber gloves with minimum thickness of 0.11mm and suitable size, air-purifying respirators with full-face particle type P3 (EN143) respirator cartridges and safety glasses with side-shields conforming to EN166. The production workers should always put on their Personal Protective Equipment (PPE) when handling the carbon black pigment.

The hazardous solvent identified are Petroleum Distillates Hydro-treated light (64742-47-8), Petroleum Distillates Hydro-treated Middle (64742-46-7),Extracts, Paraffinic Solvent (64742-04-7) and Petroleum Distillates Hydro-treated light Naphthenic (64742-53-6). Elimination of the solvents in the printing ink is not possible, this is because the solvents play an important role as dissolution in the printing ink. However, the solvent can be substituted by other organic product such as natural vegetable oils, palm oils, soy oils and etc. Substitution of the solvents to organic oil required reformulation of the composition of the organic oil in the printing ink, this is because the chemical properties of the organic oil is different from the solvents, thus, the substitution can be in 1:1 ratio. On the engineering control, the manual handling of the solvents in the weighing and premixing section can be redesigned and replaced by the auto piping system. The auto piping system can avoid the production workers contact to the chemical substances in manual handling. On the administration control, the production workers shall be trained on the safe operating procedures and correct method in use Personal Protective Equipment (PPE). Safety instruction shall be brief to the production workers before they start handle the solvents. The Personal Protective Equipment (PPE) to provide are the hand gloves (tested to EN374), nitrile rubber, PVA or Viton gloves, respiratory equipment with gas filter, type A2, safety goggles or face shield in case of splash risk and the production workers are required to wear antistatic material overall (full cover) when handling the solvents.

The hazardous chemical substances identified from additives in the printing ink are 2,6-Di-tert-butyl-4-methylphenol (128-37-0), Starch (9005-25-8) and 2-Ethylhexanoic Acid (149-57-5). 2,6-Di-tert-butyl-4-methylphenol (128-37-0) are the additives that serve as the antioxidant function in the printing ink. Elimination of 2,6-Di-tert-butyl-4-methylphenol (128-37-0) from the printing ink is not possible, this is because antioxidant play a role in the drying property of the printing ink. However, substitution of the 2,6-Di-tert-butyl-4-methylphenol (128-37-0) is not application. This is due to non-hazardous antioxidant are not available. Thus, to control this hazardous chemical substances, engineering control can design an auto piping closed system to replace the manual handling procedures. Moreover, on the administration control, the production workers shall be trained well in safe operating procedures and the personal protective equipment (PPE) training. The production workers shall put on the full-set of the personal protective equipment (PPE) when handling this hazardous chemical substances. The Personal Protective Equipment (PPE) are namely nitrile rubber

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gloves with minimum thickness of 0.11mm in suitable size, air-purifying respirators with full-face particle type P3 (EN143) respirator cartridges, and safety glasses with side-shields conforming to EN166

Starch (9005-25-8) is function as anti-se-off additives in the printing ink. Due to the starch is served as layer separator and insulator powder, thus elimination of the starch from the ink formulation is not possible. However, substitution of the starch powder can be replaced by the liquid coating. This required coating technology and knowledge on the coating film on the printed material to avoid set-off problem. Engineering control can control the starch from irritate the production workers respiratory system by handling the starch powder in closed system. The production workers shall be trained well with the safe operating procedures and the personal protective equipment training under administration control. Personal Protective Equipment (PPE) to provide to the production workers are nitrile rubber gloves with minimum thickness of 0.11mm in suitable size, air-purifying respirators with full-face particle type P3 (EN143) respirator cartridges and safety glasses with side-shields conforming to EN166.

2-Ethylhexanoic Acid (149-57-5) is function as catalyst for polymerization. It is important to control the drying properties of the printing ink. Thus, elimination of 2-Ethylhexanoic Acid (149-57-5) from the ink formulation is not possible. However the substitution of the equivalent non-hazardous catalyst in the ink also not available. The engineering control can reformulate the composition of 2-Ethylhexanoic Acid (149-57-5) to lower concentration. Besides that, redesign and replace the manual handling of 2-Ethylhexanoic Acid (149-57-5) to the auto pumping in the close system can minimize the hazards exposure. The production workers have to be trained intensively to handle this hazardous chemical substances. The training involved the safe operating procedures and the personal protective equipment training. The appropriate Personal Protective Equipment (PPE) to wear when handling this hazardous chemical substances are nitrile rubber gloves with minimum thickness of 0.11mm in suitable size, air-purifying respirators with full-face particle with multi-purpose combination type ABEK (EN 14387) respirator cartridges, and tight fitting safety goggles or f ace shield (8-inch minimum).

IV. CONCLUSION

This study identified the potential hazards and risks from the chemical substances and the production process of the printing ink manufacturer. The findings found that the hazards and risks are contributed equally from the chemical substance and the production process. This findings provide useful information for the management to control the potential hazards and risks in order to provide safe workplace to the production workers. The results shown that the hazards and risks shall be control comprehensively to avoid accidents in the plant.

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