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Jerkovich, Tyler D. ***An Analysis of Methods and Applications to Reduce the Hazardous Waste Generation of Paint Related Materials in a Manufacturing Setting***

Abstract

The purpose of this study was to evaluate the hazardous waste management system of Company XYZ and assess the systems that are currently in place in order to identify opportunities to minimize hazardous waste paint related materials from a source, process streamline and disposal perspective. Data was gathered as well as analyzed in relation to waste management associated systems and then presented in a matrix that shares the current status, the potential net gain / cost, a process improvement assessment, and ranking in which Company XYZ may receive the most benefit. The findings of this study provided the basis for both engineering and administrative recommendations for Company XYZ. In the mentioned matrix, providing customer-based incentives to increase the utilization of the powder coating application method may provide the preferred results to decrease the extent of hazardous waste paint materials since the waste powder is not considered to be hazardous. The remainder of the systems analyzed also were assessed to improve overall organization profitability and included the development / acquisition of a paint purchasing program, increasing the utilization of electrostatic spray painting, heightening employee training, employing a previously-purchased solvent recycler, and improving current formalizing hazardous waste disposal practices.

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Table of Contents

Chapter I: Introduction

The generation of hazardous waste is a situation that numerous organizations encounter from the processes rendered to manufacture a product. In order for a material to be considered a hazardous waste, per the Resource Conservation and Recovery Act (RCRA) Subtitle C regulations, the substance must have a harmful effect on human health or the environment (Environmental Protection Agency [EPA], 2019). The RCRA's role with hazardous waste provides the EPA the authority to ensure the hazardous waste management process of "cradle-to-grave" occurs (EPA, 2017). When an organization generates hazardous waste, it is the responsibility of the company to dispose of such materials properly. Furthermore, the company takes ownership of said waste for a lifetime from generation to transportation, treatment, storage, and disposal. Such disposal can be a burden with consequences such as regulated fines and storage-related expenses if companies do not recycle or treat the hazardous waste that is generated (EPA, 2017).

Company XYZ, a designer and manufacturer of industrial fans, can be compared to other manufacturing facilities since the generation and disposal of hazardous waste is part of the organization's manufacturing process. Company XYZ faces an excess paint inventory issue due to overordering and storage of three hazardous types of paint which is purchased and used for fan-related products. The three types of hazardous paint that Company XYZ has in its inventory include enamel, polyurethane, and epoxy. Company XYZ creates custom commercial and industrial fans and the corresponding plant is recognized as being unique because it is a custom shop. Customers may request any modification on the requested fan including the paint that is desired, which means that any excess paint Company XYZ purchased to complete a certain job is then transferred into storage. When Company XYZ no longer has a use for the excess paint, it is

then declared to be a hazardous waste. Company XYZ must follow applicable hazardous waste storage and disposal-related regulations which are set forth by the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), and The Resource Conservation and Recovery Act (RCRA).

Company XYZ's excess paint accumulation is derived from its current painting practices. The four issues which contribute to the organization's excess paint and storage situation include overordering of paint, facility and quantity-related storage regulations of the Occupational Safety and Health Administration, hazardous waste regulations under the Environmental Protection Agency, and a lack of standard operating procedures. The excess paint storage area approaches the maximum capacity because this facility permits the customer to specify the color and type of paint for the ordered product. Consequently, the excess paint is transferred to storage with an approximate expected shelf life of 12 months. Company XYZ has already enacted steps to reduce the paint used in the process through improved ordering and manufacturing practices. Additionally, an emphasis in quality throughout the fan manufacturing process has decreased the amount of rework needed for the product to be repainted. Also, the organization's engineers are ensuring that new fan designs focus on accuracy when assembling the product to decrease the amount of paint needed for a touch up coat. Company XYZ offers a variety of colors that the customer can choose from, but since the customer can order special colors, leftover paint tends to remain from each specific job. This company has also reconstructed an ordering system for paint per job to be specific for usage or storage. Thus, a failure to refine the hazardous waste generation and disposal practices at Company XYZ places the organization at risk of failing to maintain the "small quantity generator" status which will cause additional financial burden to the organization.

Purpose of the Study

The purpose of the study is to assess company XYZ's excess paint storage and hazardous waste disposal practices.

Goals of the Study

The goals of the study are as follows:

- Identify the weight of paint which is disposed of as hazardous waste in previous years.
- Identify the specific types and amounts of solvents that are annually disposed of as hazardous waste.
- Assess Company XYZ's hazardous waste handling practices and storage limitations.
- Identify cost-effective methods to decrease the need for shipping hazardous excess paint waste.
- Examine and compare the previous waste paint disposal system with identified efficient methods of disposal.

Background and Significance

Company XYZ operates in South Dakota and is responsible for following Federal regulations which have been developed by OSHA and the EPA. South Dakota does not have additional state regulations at this time. Company XYZ is currently near capacity with regard to the amount of flammable solvent-based paint that is within its designated storage area. OSHA requires that the conditions for flammable liquids meet certain requirements for capacity and fire rating of storage facilities. Since the maximum size of Company XYZ's storage is 150 square feet and necessary fire protection and controls are provided, the organization may have a total allowable quantity of four gallons per square foot of floor area (OSHA, 2016). Company XYZ

must also comply with standards applicable to generators of hazardous waste which is the EPA's Title 40 Code of Regulations Part 262. In the same manner, the EPA defines a hazardous waste, the specific storage and disposal requirements, and the amount that may be generated for each location pertaining to a granted license/permit.

Currently, Company XYZ is permitted under the South Dakota Department of Environmental and Natural Resources (SD DENR) to generate no more than 2,200 pounds of hazardous waste per month for being a small quantity generator. With the current situation, Company XYZ can apply for an episodic event through the EPA which allows the organization to dispose of all hazardous waste in order to maintain the status of being a small quantity generator. This allows for Company XYZ to maintain a small quantity generator status which can be a planned event such as a chemical clean out or an unplanned event such as a spill (Office of the Federal Register, 2019). Without the episodic disposal event option, Company XYZ may violate the small quantity generator criteria and thus become a large quantity generator of hazardous waste. A large quantity generator results in an increased amount of fees and payments due to the elevated amount of hazardous waste which is created. This also includes additional inspections and training criteria that must be met. The planned episodic event option can only be established once a calendar year as well as have 60 days to complete this transaction. Company XYZ is periodically utilizing the episodic event option and the excess paint system poses a problem for being a higher generator of waste than what the organization is permitted.

A number of Company XYZ's assets are negatively impacted by the organization's paint storage system. There is a significant cost that's associated with shipping as much hazardous waste as the company is allowed as a small quantity generator and the additional annual purge process. Also, the legal aspect coincides with environmental risk regarding the storage space

that the hazardous waste paint requires and the permits which detail how much waste Company XYZ's facility can produce. Another issue is the employee labor it takes to account for all of the waste paint and to store such in drums for monthly removal. The time that keeps employees from working designated positions because of hazardous paint waste needs is costly. Being that the excess paint's shelf life eventually expires and is thus determined to be a hazardous waste, all the paint is essentially wasted material. These and potentially other assets are negatively impacted by the current system that may be improved to decrease the overall amount of loss that Company XYZ experiences due to generation and disposal of paint-related waste.

Assumptions of the Study

The following are study-based assumptions:

- The Federal OSHA and EPA regulations regarding storage and disposal of hazardous waste will remain constant throughout the study.

Limitations of the Study

Following are limitations of this study:

- Company XYZ's manufacturing operations are limited to the state of South Dakota.
- This study is limited to the time frame of 12/1/19 through 12/7/20.

Definition of Terms

Following is a list of defined terms that are used throughout this study:

Episodic event. "An activity(s), planned or unplanned, that does not normally occur during generator operations, resulting in an increase in the generation of hazardous wastes that exceeds the calendar month quantity limits for the generator's usual category" (Legal Information Institute, n.d., p. 1).

Hazardous material. "Any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors" (Institute of Hazardous Materials Management, 2019, p. 1).

Hazardous waste. "..Waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment (Environmental Protection Agency, 2019, p. 2).

Large Quantity Generators. "..Facilities that generate greater than 1,000 kg of hazardous waste per calendar month (approximately 2,200 lbs) or greater than 1 kg of acutely hazardous waste per calendar month (approximately 2.2 lbs)" (EPA, 2017, p. 12).

Odds Ratio. "An odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. Odds ratios are used to compare the relative odds of the occurrence of the outcome of interest (e.g. disease or disorder), given exposure to the variable of interest (e.g. health characteristic, aspect of medical history). OR=1 Exposure does not affect the outcome, OR>1 Exposure associated with higher odds of outcome, OR<1 Exposure associated with lower odds of outcome" (Szumilas, 2010).

Planned episodic event. "An episodic event that the generator planned and prepared for, including regular maintenance, tanks cleanouts, short-term projects, and removal of excess inventory" (Legal Information Institute, n.d., p. 3).

Small quantity generator (SQG). "(SQG) are defined as those facilities that generate between 100 kg (Approximately 220 lbs) and 1,000 kg of hazardous waste per calendar month

and accumulate less than 6,000 kg (approximately 13,200 lbs) of hazardous waste at any time" (EPA, 2017, p. 12).

Chapter II: Literature Review

The purpose of the study was to assess Company XYZ's excess paint storage and hazardous waste disposal practices. This chapter reviews the nature of solvent-based paints as well as the implementation of recycling solvents and solvent recycler case studies examples that involve other companies. Other items to be reviewed include practical paint reduction practices, waste reduction methods, and the application of associated recovered solvents from recycled systems.

Solvent-Based Paint

Solvents are chemical compounds that dissolve or disperse other substances in liquid form and are comprised of a solvent and solute solution which can be as simple as water and salt (Deziel, 2019). Water itself is a solvent because it may dissolve a multitude of substances that align with its polar-based chemical components. The polarized hydrogen and oxygen atoms allow the molecules to be highly attracted to other types of molecules such as salt, which break the bond that holds sodium and chloride together which then dissolves (United States Geological Survey [USGS], 2020). Molecular polarity, however, is not the only method of categorizing solvents. Solvents may be classified by chemical composition such as organic and inorganic properties. Organic solvents are those that contain carbon and oxygen and thus are oxygenated in common chemicals such as alcohols, ketones, and glycol ethers (Deziel, 2019). Hydrocarbon solvents are those that contain only carbon and hydrogen and include gasoline, benzene, toluene, or hexane. Halogenated solvents are those that contain halogen chemicals such as chlorine, fluorine, bromine, and iodine. The remaining category of solvents are chemical compounds that do not contain carbon. These compounds are inorganic solvents which include water and ammonia (Deziel, 2019).

By definition, a solvent-based paint means that it does not contain water, but it may contain organic solvents such as toluene, xylene, or other mineral spirits (Deziel, 2019). Solvents help to dissolve and disperse the components of paint to provide the consistency desired without chemically changing either the solvent or other materials in which the solvent was added ("Solvents," n.d.). Once paint is applied to a given surface, the solvent rapidly evaporates which leaves the resin/pigment to produce a desired coating. The solvents in paints promote a higher quality and durable glossy coating which is able to withstand a variety of environmental conditions (American Chemistry Council, n.d.). Given certain properties, solvents may be classified as a hazardous material by various state and federal regulations.

Hazardous solvents may require the applicable end-user to follow regulations such as storage and disposal of hazardous wastes, occupational-based exposure limits, transportation, and release into air, land, and water ("Solvents," n.d.). Various federal-based regulators oversee separate entities of regulations that must be followed when handling solvents. The Environmental Protection Agency (EPA) regulates how solvents may be disposed and the Department of Transportation (DOT) regulates how solvents may be transported. Lastly, the Occupational Safety and Health Administration (OSHA) regulates both human exposure limits and how solvents may be stored in the workplace.

Solvents may have multiple acute and chronic health-related hazardous properties such as neurotoxic (i.e., nervous system) effects on human health (Dick, 2006). Exposures typically consist of inhalation of the vapor, but dermal exposure may also occur which represents a high burden on workers' bodies in industries such as painting (Dick, 2006). Additionally, organic solvents may negatively impact the central nervous system with multiple acute health effects ranging from eye, nose, and throat irritation to headache and dizziness; progressing to severe

effects such as unconsciousness, seizures, and death. (Dick, 2006). In fact, fatalities still occur around the world where substandard working practices and conditions exist due to the use of solvents (Dick, 2006).

Worker health-related reports indicate that employees' long-term exposure to solvents may contribute to a variety of cancers, with certain cases proving to be more concrete than others. For example, benzene has been correlated with leukemia and with scleroderma or "systematic sclerosis", which is a rheumatic connective tissue disease that affects the autoimmune system (Scleroderma Foundation, n.d), and renal cancer has been associated with exposure to chlorinated hydrocarbons (Dick, 2006). It is difficult to assess the direct correlation between certain diseases and solvents because of the elaborate variety of solvent and material mixtures which makes it increasingly difficult to pinpoint the direct effects that a solvent may have on worker health (Dick, 2006). A similar difficulty to determine which solvent directly affects neurodegenerative diseases holds true; although not proven, several studies attempt to correlate association between such diseases and solvents.

A study in Germany, for example, explored etiological relevance of Parkinson's disease (PD) with rural factors of farming, well-water drinking, animal contact with exposure to pesticides, wood preservatives, heavy metals, and solvents (Seidler et al., 1996). The study consisted of collecting data from personal interviews of 380 patients from nine different clinics, 379 neighborhood control subjects, and 376 regional control subjects to gather statistics on the correlations between solvents and PD. The results of this study found that individuals diagnosed with Parkinson's disease had a significantly high odds ratio for exposure to organochlorides found in pesticides as well as exposure to solvents, heavy metals, vehicle exhaust vapors/gases, and carbon monoxide (Seidler et al., 1996).

Another epidemiological study investigated the relationship between organic solvent exposure and Alzheimer's disease. The study consisted of 193 individuals who experienced symptoms of dementia and 243 individuals who served as the control who were free of any dementia and neurological disease-like symptoms. The subjects were randomly selected out of 23,000 individuals of the age of 60 or higher from a health maintenance organization in Seattle, Washington that fit these criteria (Kukull et al., 1995). Furthermore, the subjects explained relevant historic information such as solvent exposure and job descriptions in a comprehensive risk factor interview intended to provide the statistical background needed to assess the correlation. The study found that exposure to one or more solvent groups throughout the individual's occupational career yielded an odds ratio for Alzheimer's disease of 2.3 and 6.0 for males and thus suggests that organic solvents may be causing such debilitating disorders (Kukull et al., 1995).

An epidemiological case-control study based on the 1970 census in Norway explored the causation of Multiple sclerosis (MS) based on environmental factor. Three groups of 11,542 painters, 36,899 construction workers, and 9,314 food processing workers were identified from the census and followed until 1986 for identification of registering for disability pensions (Riise, Moen, & Kyvik, 2002). Of these groups, the results presented nine painters, twelve construction workers and six food processors had received disability pensions from being diagnosed in MS and painters exposed to organic solvents have a relative risk of 2.0 with a confidence interval of 95% between 0.9 and 4.5 compared to painters who were not exposed to organic solvents. The supporting data from this study indicated with a 95% confidence that the relative risk of the incidence of multiple sclerosis in painters exposed to organic solvents is higher compared to non-exposed painters. Furthermore, the relative risk of 2.0 between the intervals of 0.9 and 4.5

suggest that organic solvents may also be a risk factor for multiple sclerosis (Riise, Moen, & Kyvik, 2002).

Although there may be correlation to such diseases, solvent-induced neurodegeneration may only be a factor in the comprehensive assessment on why certain individuals suffer from such illnesses. Solvents also have been proven to cause other health effects such as a decrease in the senses of taste, sight, hearing, and smell. For example, a meta-analysis performed by Paremei Meyer-Baron, and Seebar (2004) evaluated 39 different studies on solvent exposure conditions with the intent to assess mild color vision loss induced by occupational exposure to organic solvents. Of the 39 studies, 15 were assessed given the information on color discrimination and 13 eventually indicated a positive effect for mild color discrimination from occupational exposure to toluene, styrene, and other organic solvents (Paramei, Meyer-Baron, & Seebar, 2004).

Solvent exposure may lead to other adverse health effects including mild cognitive impairment. The correlation with neurodegenerative diseases is less clear; nonetheless it is likely to be a reasonable component to workplace related illnesses with exposure to solvents. Not only may the central nervous system be damaged, but also the liver, kidneys, heart, blood vessels, and bone marrow may be at risk with negative impacts on the body (International Labour Organization, 2004).

In addition to the health-related hazards being of concern with solvents, the physically hazardous properties such as flammability/combustibility, reactivity, and corrosivity also pose significant human, property, and environmental risks. Most organic solvents are extremely flammable, highly combustible, and/or are distinctly volatile, and thus the reasons for solvent-based paint to be considered a hazardous chemical (International Labour Organization, 2004).

For reference purposes, the preferred source of information on chemicals is directly from the corresponding safety data sheets that are developed by the company that manufactures a given solvent or paint. For instance, a general safety data sheet on a xylene-based compound created by Val-Tech Diagnostics Inc. (2015) indicates that this solvent is considered to be a flammable liquid because of its low flashpoint at 25 degrees Celsius. The safety data sheet also warns of the explosion hazard that the chemical presents when vapors are in high concentrations and thus be ignited by sparks or flames. The corresponding permissible exposure limit (PEL) given forth by OSHA is 100 ppm for this chemical compound (Val-Tech Diagnostics Inc., 2015). Solvents, like many chemicals, can also become hazardous when exposed to other substances and thus result in violent reactions. For example, nitric acid that contacts the organic solvent benzene may lead to the release of hazardous nitrous vapors and thus result in an explosion (Bretherick, 2016). Therefore, the fire as well as reactivity-based volatile nature of needs to be considered when such are being incorporated in industrial processes.

On-Site Solvent Recycling

Solvent recycling has become an option in which companies have found success. A case history at Compressor Systems, Incorporated elaborates on the cost and environmental factors on the implementation of a solvent recycler, the regulations associated with the materials, and the process of the machine itself (Lee & Fouche, 2003). The Compressor Systems Incorporated case study indicated that used solvent is a hazardous waste and must follow Environmental Protection Agency (EPA) disposal-related guidelines and regulations. A solvent recycler used for reclamation replaced Compressor Systems Incorporated's need to dispose the solvent as hazardous waste and thus result in both environmental and financial benefits (Lee & Fouche, 2003). Due to the instituted reclamation process and a decrease of generated hazardous waste

solvent, the company became classified as a small quantity generator which meant that it could legally generate between 220 and 2,200 pounds of hazardous waste per month (EPA, 2017).

The EPA requires hazardous waste generating organizations to categorize each waste in order to track such through the disposal process. The Resource Conservation and Recovery Act of 1976 utilizes a "cradle-to-grave" process for hazardous wastes that organizations produce. Thus, a company that generates hazardous waste must oversee the proper disposal of such waste and document all relevant activities (EPA, 2019). Furthermore, if a company mismanages this waste disposal process, it may become a problem in the future with all liability falling on the organization that generated the hazardous waste (EPA, 2019). Regardless of how much waste is generated, it is the responsibility of the generating organization to properly dispose of such materials in accordance to the relevant regulations.

Considering further information regarding the aforementioned Compressor Systems Inc. case study, the company was paying nearly the same amount to dispose of clean-up thinner as what was spent to initially purchase the unused product. In addition, the company was also paying for the time required to manage the waste as well as complete the necessary documentation required by the EPA (Lee & Fouche, 2003). These hazardous waste disposal costs lead Compressor Systems Inc. to consider the implementation of a solvent recycling system. A solvent recycler is an apparatus that distills liquids in a manner similar to the process of distilling alcohol-based spirits. Heat is used to vaporize a liquid which travels through a coil to be reliquefied in another container (Lee & Fouche, 2003). Essentially, liquid containing the solvent heats up, vaporizes, and the solvent distills in another container that separate from the original liquid. Once the solvent is heated, vaporized, and reliquefied, the leftover constituents remain in the original container and become solid. The solids can then be disposed of in

accordance with local jurisdiction in a conventional manner provided that such materials are no longer considered hazardous (Lee & Fouche, 2003).

The results of the Compressor Systems Inc. case study indicated that recycling the cleanup thinner reduced various hazardous waste disposal costs within the organization's Paint Department (Lee & Fouche, 2003). Not only did the solvent recycler provide a cost reduction in regard to the amount of raw materials that were purchased, but being that the machine was not complex, it also allowed typical maintenance personnel to provide the necessary upkeep of the machine and thus eliminated the company's need to employ a specialized technician to maintain the solvent recycler (Lee & Fouche, 2003). Based on information provided within the proposal to purchase the machine, the company's Paint Department typically purchased approximately 200 gallons of paint thinner per month which resulted in a general hazardous waste disposal fee of roughly $2,200 per month. The proposed solvent recycler was projected to provide a 90% recovery of solvent in the recycling process and thus result in a substantial decrease of disposal fees which were lower than the original $5.90 per gallon to dispose of waste paint thinner (Lee & Fouche, 2003). Altogether, the use of the solvent recycler decreased the monthly hazardous waste disposal bill by $1,650 per month with a return on investment of 6 months (Lee & Fouche, 2003). In this case study, the solvent recycler proved to benefit the company by decreasing hazardous waste disposal as well as raw material purchasing costs and thus promote organizational profitability and environmental protection.

Legal Concerns of Solvent Recycling

The EPA considers the treatment of hazardous waste to be illegal unless such a process is exempted by this agency. The EPA actually encourages recycling practices and consequently excludes specific materials from the definition of solid waste which in turn renders certain solid

wastes to not meet the definition of a hazardous waste (EPA, 2019). Three categories of recycled materials are specifically exempt from the definition of a solid waste and include waste used as an ingredient, a product substitute, and is returned to the production process (EPA, 2019). The process of recycling solvent from paint applies to placing the recycled solvent directly back into the production process. The solid material from a solvent recycler must first prove to be nonhazardous by performing a Toxicity Characteristic Leaching Procedure to determine if the solid falls under the definition of a hazardous waste (EPA, 2020). Once the waste is deemed nonhazardous, the contents may be disposed of in a landfill and thus not be subject to certain hazardous waste disposal requirements (EPA.2019). Additionally, a material is considered to be recycled if it can be used, reused, or reclaimed in accordance with EPA regulations 261.1(c)(7)(2001). A material is reclaimed if it is processed as a usable product or it is regenerated from spent solvents (261.1(c)(4); EPA, 2001). The reclamation of solvents from paints is considered to be recovered and thus be a usable product in the organization's processes.

Solvent Recycler Cases

A number of companies have experienced moderate success as it relates to solvent recycling practices to save money as well as reduce hazardous waste. Companies such as Ford have implemented a solvent recycling program which permitted 38 million gallons of paint solvent waste to be recycled (Johnson, 2004). Ford started its recovery program at a single plant 20 years ago and has expanded to 19 different facilities by creating a closed loop recycling program. The closed loop recycling program entails not only reclaiming paint solvent and thinner, but also using sludge as fuel as part of the production process. This type of a closed-loop recycling program is exempted by the EPA which allows secondary materials from a process to be cleaned and returned back into production without being regulated in relation to

EPA regulations 40 CFR 261.4(a)(8). In the past 15 years since the program has been established, the company has saved nearly $75 million and approximately 225 million pounds of hazardous material from being landfilled (Johnson, 2004).

The manner in which paint is applied to a product may significantly affect the total efficiency of the paint's ability to adhere to a desired surface. For example, Trailboss Trailers Incorporated routinely experienced difficulties in complying with EPA requirements regarding volatile organic compound (VOC) emissions from painting operations (Kline, 1999). The company established a goal of reducing the amount of paint use and waste generation while increasing production. Before changes were made, the company's paint system consisted of an air-assisted airless system that was used to pump a single-component protective coating from a five-gallon pail to spray guns inside paint booths (Kline, 1999). The old system also consisted of a single-component paint spray gun which eventually led to a change in the type of spray gun used to paint the products.

The new painting system that Trailboss Trailers, Inc. implemented involved the installation of electrostatic spray guns. Electrostatic spray paint systems work on the principle of a charged electrostatic field. The paint is negatively charged through the spray gun and is attracted to the positively charged metal surface which prompts the paint to be drawn towards (i.e., wrap-around) and thus adhere to the product (Cook, 2019). The equipment purchased by Trailboss Trailers, Inc. included an air-assisted airless electrostatic spray gun. The wrap-around effect is a result of the charged paint being able to coat areas on the opposite side of the object being painted. The guns provided a desirable wrap of the material being sprayed which increased the paint transfer efficiency (Kline, 1999). The paint gun to target distance may be further than conventional spray guns since the overspray is able to wrap-around as indicated in

the aforementioned procedure. Thus, this capability from the electrostatic spray process decreases the amount of waste paint due to minimizing overspray (Mannouch, 1995). The new spray guns also led to a 10% decrease in VOC emissions because of the switch to a two-component paint that also contained a catalyst. This paint contained increased solids which ultimately reduced the amount of paint that is needed to coat a product as well as the amount of time the paint needs to cure (Kline, 1999).

The final part of Trailboss Trailers, Inc. VOC emission reduction initiative involved the use of a variable ratio proportioner which mixes and combines the two-component paint through a pump to the electrostatic spray guns which nearly eliminated waste, mess, and paint application inaccuracy (Kline, 1999). The three components of electrostatic guns coupled with the two-component paint and variable ratio proportioner within Trailboss Trailers, Inc. paint system decreased the amount of paint being used, increased the output of products, lowered VOC emissions, reduced operation costs and increased the overall quality of the final product.

Worker Paint Use Reduction Practices

The proper use and practices of a spray gun also contribute to the total amount of paint waste generation. The physical process of how paint is applied correlates to the percentage of paint which adheres on the desired surface versus the percentage of paint that is wasted. Efficient paint spraying is derived from proper application techniques in order to achieve preferred results. Part of the proper application technique involves the stroke or pass of the gun as it sprays across a given surface. Proper spray gun stroke is achieved by moving the gun parallel to the work and perpendicular to the surface (Mannouch, 1995). The type of spray gun determines the distance from the material the user should maintain. For example, conventional air atomizing guns should be at a distance of six to eight inches. As these strokes move across

the surface, 50% of the stroke should overlap the last application as the user spray paints down the material (Mannouch, 1995). Inconsistency with the strokes and overlapping will result in uneven coating thickness and poor aesthetics. If the gun is spraying too closely to the surface, the paint may become too heavy and tend to sag, thus forcing the paint to drip down with the possibility of solvent entrapment. Similarly, situating the gun too far away while spraying causes a sandy or abrasive appearance finish with excessive dusting (Mannouch, 1995). Such an undesirable finish occurs when the spray gun is not positioned at the correct distance and thus waste occurs either through dripping when spraying too close to the surface or dusting while being too far away.

Proper spray gun technique also includes how the gun is held. Maintaining the spray gun at a right-angle so that the tool is perpendicular to the surface results in a preferred coating. Tilting the gun up or down gives an uneven spray pattern and material deposition (Mannouch, 1995). This technique must be performed when spraying low and high surfaces, even when it requires more effort by the user. If a 90-degree right angle is not maintained, the uneven spray will cause heavy and light application bands with a visible deformed paint pattern on the surface (Mannouch, 1995).

The manner in which the operator controls the trigger directly affects transfer efficiency because the speed of the paint flow exiting the fluid tip determines the quantity of material emitted (Mannouch, 1995). As the trigger is pulled, the paint flow increases, and continuous adjustment of the fluid flow is often necessary when spraying difficult pieces. Becoming familiar with the spray gun and its trigger flow will prevent blotching or creating irregular patches of paint on the sprayed material. Thus, the operator's familiarity of the trigger

contributes to the reduction of paint waste and contamination of the spray area (Mannouch, 1995).

The structure of the piece being painted also determines how the operator should spray. When spraying a panel structure, the stroke must begin off the work and the trigger should be pulled when the gun is moving and ready to pass over the edge. The trigger must then be released when the other edge of the work is reached while the stroke is continued a few more inches and then reverses direction to perform the next stroke across the panel (Mannouch, 1995). Spraying the exact shape and maintaining full coverage will contribute to minimizing paint waste from reduction of overspray (Mannouch, 1995). Spray painters also use an "end stroke" to further reduce overspray and waste. An "end stroke" entails the operator spraying a vertical stroke at the edges of the panel so that when the operator sprays horizontal strokes, the stroke stops when it hits the vertical stroke on the edge and thus eliminate overspray while still maintaining complete coverage of the panel (Mannouch, 1995).

A variety of painting-related techniques depend on the geometry of the object being painted. When spraying horizontal surfaces, the operator should start at the near edge to avoid depositing dry spray on already coated work so that the overspray falls on uncoated work (Mannouch, 1995). When painting box structures, the edges and corners must be sprayed first and directly at the corner so the spray catches both surfaces and therefore leave the remaining surface area to be sprayed like a panel to minimize the amount of overspray (Mannouch, 1995). Inside corners are different and should not have direct spray, although if the corner is not visible, directly spraying on a corner resulting in an uneven coating may be satisfactory (Mannouch, 1995). Spraying the individual sides of the corner with a vertical spray provides an even coating across inside corners and the remaining work a standard spray (Mannouch, 1995). Round

surfaces should be sprayed like any other plane-surface, but the user must also conform to the surface which forces an increase in the angular movement of the gun. This prevents the paint from running or sagging from a heavy spray while limiting overspray and overlapping strokes to receive an even coat all around the structure (Mannouch, 1995).

Spray gun technique largely impacts the amount of waste paint that is generated in any paint operation. The greatest contributor to the occurrence of wasted paint is the operator and his/her spray technique which influences transfer efficiency. Consequently, the manner in which the operator chooses to paint may cause transfer efficiency to vary by up to 50 percent (Washington State Department of Ecology, 2002). In some cases, the skill of the painter may be more efficient than the equipment being used. Furthermore, worker training and experience are crucial factors for such skill development to occur (Washington State Department of Ecology, 2002). Efficient methods of spray gun movements and strategies to eliminate overspray result in less paint waste and an even as well as aesthetically pleasing coating of paint (Mannouch, 1995).

Administrative Paint Reduction Approach

An additional approach to reducing paint waste generation involves only purchasing the type and necessary amount of a desired material. One of the most efficient ways to limit waste is to generate less in the first place (Environmental Protection Agency, 2018). A paint calculator estimates the quantity of paint required for the surface area to be painted. Purchasing only the necessary amount of product to cover the surface area will reduce the amount of paint that is not utilized. Paint calculator tools that are provided by certain organizations estimate the correct amount of paint for the job. These tools are useful to minimize paint waste, but various calculators produce different results for a given job (Paintcare, n.d.). The variations depend on the type of paint being used, its application, and the surface area of the object being painted. All

in all, purchasing the correct amount of paint for the job and thus eliminating over-purchasing will decrease the amount of leftover paint and therefore minimize the creation of hazardous waste.

Additional Paint System Waste Reduction Options

Painting operations may create costly forms of waste for organizations that paint for aesthetic and technological purposes. Environmental and health regulations have forced many manufacturers to reassess painting operations (Kirsch, Looby, and Kirk, 1993). Certain manufacturers are able to switch from using solvent-based paints, but others cannot due to processes and applications which require the capabilities of solvent-based paint. The following four case studies represent methods which were employed by manufacturing companies to reduce waste and minimize paint volume (Kirsch et al., 1993).

Company One. The company produced more than 2.5 million car and truck mirrors a year with three distinct processes of injection molding, painting, and assembly (Kirsch et al., 1993). The paint processes used by this company consisted of spray-painting the product with guns in booths and utilizing water curtains which surrounded the process to capture excess paint overspray. This process created approximately 21,000 gallons of paint sludge per year which does not include other paint lost throughout the process. The waste paint typically collected in the paint booth sump floated to the top of the water and removed by manually scooping the sludge out. The waste paint disposal cost of this operation was approximately 1.2 million dollars per year (Kirsch et al., 1993). The implemented solution to the aforementioned waste removal situation was the installation of hydro clones to remove the paint solids which accumulated in the paint booth's water curtain drainage system. The hydro clones use centrifugal force to coagulate and separate the solids which allows the water to recirculate back into the process (Kirsch et al.,

1993). This strategy not only decreased the amount of paint waste for disposal, but it also reduced water consumption. The gathered sludge was then sent to a drying service which was turned to a powder and the empty paint cans were sent to a steel-can recycler which saved additional money as compared to when such containers were originally placed in a dumpster (Kirsch et al., 1993). The implementation of the hydro clones saved the company $179,900 with a payback of $26,000 for the installation of hydro clones, the sludge drying service saved $24,300, and the recycling of empty paint cans saved $7,200 per year (Kirsch et al., 1993).

Company Two. This plant also produced mirrors for vehicles with a production rate of three million per year and the current waste management practices accumulated expenses of $103,000 annually with even larger costs for the raw materials in relation to the generated waste fees (Kirsch et al., 1993). The painting process consisted of electrostatic solvent-based painting and dip painting for coating galvanized steel, zinc die-cast, and plastic parts that consist of the mirror itself. Before painting occurs, materials were cleaned in a five or nine staged washer process that produced multiple streams of waste including contaminated water, paint vapors, spent ion exchange columns, and overspray of paint (Kirsch et al., 1993). After a waste generation assessment was performed, the company installed electrostatic powder coating and electrostatic spray painting of the metal assembly parts. This invested cost roughly $236,000 with a payback within 2.1 years which in turn saved $113,418 in raw materials per year (Kirsch et al., 1993, p. 4). This new system allowed $25,000 to be saved per annum from a decrease in the amount of contaminated wastewater that was generated with the washer process (Kirsch et al., 1993).

Company Three. The manufacturing facility produced approximately 12,000 furniture units per year to military specifications. The furniture was constructed from heavy density-

particle board, steel frames and other hardware (Kirsch et al., 1993). The materials were cut and sized, partially assembled, cleaned, painted, completely assembled, and then shipped. The paint process required the metal parts to be spray or dip painted (Kirsch et al., 1993). The company installed a new electrostatic powder coating and spray gun system. The investment of $151,000 for the installed electrostatic powder coating system saved $50,000 annually at the conclusion of a three-year payback period for replacing a portion of the conventional spraying and dip painting process because it eliminated the evaporation of paint solvent and toluene as well as paint laden air filters within the paint booths. This process change eliminated the need for 3,400 gallons of paint which, in turn, avoided the disposal of 7,500 gallons of paint solids (Kirsch et al., 1993). The organization also reinstalled an electrostatic spray-painting system from a different product line for a cost $67,000. The new electrostatic spray-painting system was more efficient than the manually mixed paint with solvents that the company was previously using with a savings of $40,000 per year for an overall payback period of 1.7 years (Kirsch et al., 1993).

Company Four. This facility was the largest and most elaborate product producing plant assessed. The plant annually created 36 million pounds of aluminum extrusion from virgin and scrap materials. The first part of the process entailed aluminum and other alloy metals to be melted in a furnace where the molten metal was then cast into logs with a hydraulic casting system (Kirsch et al., 1993). The logs were then heat treated and extruded into shape, sheared, heated treated once more, and sent to be buffed, anodized, and finally painted. Approximately 21 million pounds of the extrusions were painted by manually being hung on a conveyor system which entered a succession of spray booths for pretreatment and painting (Kirsch et al., 1993). The first booth cleaned the parts with a recirculated heated alkaline cleaner and the wasted cleaner that dripped off the parts was routed into the plant's chromium wastewater treatment

system. The inefficiency of the chromic acid surface treatment process caused the associated collection tank to never be cleaned and the waste hexavalent chromic acid was pumped to treatment tanks. The extrusions were then spray-rinsed with a chromic acid surface treatment to increase adhesion of the paint on the product and conveyed through an oven and rinsed twice before being spray painted (Kirsch et al., 1993).

Plant four's original paint system utilized 180 different colors which used two electrostatic solvent-based paint booths. Polyester and acrylic paints were thinned with solvents involving methyl isobutyl ketone and toluene which were pumped through lines to clean before changing colors in the booth. The other type of paint used was fluorocarbon-based to attain the chosen color (Kirsch et al., 1993). The paint booths had air filters that were changed when needed, and plastic sheets covered the floor to absorb excess paint. The used air filters and waste plastic were dispersed of in a landfill when dried. The toluene that was contaminated in the paint lines for cleaning was collected in barrels and disposed of as hazardous waste and the toluene also evaporated in the plant's atmosphere which may have created employee exposure issues (Kirsch et al., 1993). The painted products were then routed through a bake oven one last time to dry before shipping. If the product was not up to paint quality standards, the extrusion went back to the melt oven and used as scrap charge. Paint-covered hooks in the conveyor system were put through an oven for paint removal by incineration where the leftover ash was also disposed of as non-hazardous waste (Kirsch et al., 1993).

The aforementioned manufacturing system that the company used provided many opportunities for cost-savings. Specifically, the eventual implementation of an electrostatic powder coating process rather than the conventional solvent-based painting eliminated the need for approximately 15,000 gallons of toluene and 7,000 gallons of other solvents, reduced the

generation of dried paint on used plastic sheets and filters by 50,000 pounds per year, provided increased surface coating efficiency on the product and the ability to collect and reuse overspray (Kirsch et al., 1993). The company's implementation of a powder coating system along with other methods to reduce wasted paint-related materials saved an estimated one million dollars annually in comparison to the prior metal treatment methods (Kirsch et al., 1993).

Powder-Coating Systems

As previously mentioned, powder coating is a surface finishing option which consists of a polymer resin material that is combined with curatives, pigments, leveling agents, flow modifiers, and other additives. The ingredients are then melted, mixed, cooled, ground into a uniform powder, and incorporated into an electrostatic spray deposition process that attaches the powder to a metal substrate (Powder Coating Institute, n.d.). The process uses a spray gun that adds negative electrostatic charge to the powder particles. Once the part is positively charged, the negatively charged particles are attracted to the part (Powder Coatings Institute, n.d). After the powder coating application, the sprayed materials are cured in an oven which allows the coating to chemically react and produce extensive molecular chains. The molecular chain contains a high cross-link density which causes the polymer-based finish to be extremely resistant to break down (Powder Coatings Institute, n.d.).

An aircraft powder coating application study focused on two central goals of achieving a high first-pass transfer efficiency and a powder layer that was uniform throughout the surface. Paint-oriented processes are unable to move from utilizing a solvent based paint to a powder coat medium because of the need to consistently change colors in the painting process (Sims et al., 2001). If the first pass of powder coating transfer efficiency is greater than 90%, this approach may eliminate the need for recycling overspray, which is common if the user was to recycle the

overspray sludge that accumulates over time. In this study, the company had different parameters pertaining to powder coating aircraft. The goal was to have a high first pass transfer efficiency in order to result in less defects and to minimize paint thickness coating and thus achieve the least amount of weight as possible. The company also desired the aircraft powder coating to be resistant to corrosion, ultraviolet radiation, and temperature extremes (Sims et al., 2001). Experimental studies were performed to determine the highest possible first pass transfer efficiency with minimal surface imperfections. The results of the study indicated that the preferred coating appearance involved powder being applied with 100 kilovolts of static electricity with a slow heated-based cure which allowed the paint to achieve its full strength and desired hardness (Sims et al., 2001).

Applications of Recovered Solvents

A majority of solvents that are used within industrial operations are contaminated with other materials and thus require disposal when such contamination levels reach criteria limits (Salvesen, 1989). With a solvent recycler in place, many companies will eventually reuse the material that was recovered. Recycling materials that contain solvent is only a part of the process. The next step is to configure how the recovered solvent will be disposed of and/or utilized. Industrial operations may use the recovered solvent as a cleaner or reaction media (Salvesen, 1989). Although the composition of used solvents varies, it is reasonable to believe that recycling and reusing solvents is applicable to many processes and industries.

When recycled solvent is being reused, there is the potential for the substance to become degraded and contaminated. Solvents that are continuously used over time and contaminated with other materials may eventually be unusable and incapable of fulfilling the intended use (Salvesen, 1989). The types of solvents are also derived from different materials. Hydrocarbon

solvents used for cleaning may be a derivative from petroleum, coal tar, and other natural resources which contain carbon and include aromatic naphtha, toluene, xylene, isoparaffinic solvents, and the most common being turpentine (Salvesen, 1989). Paint thinners also differ in the composition to suit the paint that is applied. These solvents may also contain petroleum or coal tar naphtha, isoparaffinic solvents, toluene, xylene, ketones, esters, alcohols, and ethers (Salvesen, 1989).

A common application of used solvents is for cleaning purposes. This is because the cleaning of equipment and parts is often performed prior to painting. Paint contamination is minimized by cleaning with solvents to remove material such as dirt, water, fuels, oil, or paint (Salvesen, 1989). Four common types of non-vapor solvent cleaning methods exist. The first involves wash stations where the solvent is circulated by a pump and the part is washed with a constant stream of solvent. As the liquid becomes contaminated, screens and filters are often implemented to remove the solids related portion of contamination (Salvesen, 1989). A spray booth which also contains filters and screens can remove solid-based contaminants. The solvents in the process aspirate from a container and air is combined to clean the part that is sprayed. The solvent is then recirculated to continue cleaning; the vapors created during this process are typically removed via a powered ventilation system (Salvesen, 1989).

Dip tanks are another form of non-vapor cleaning. This is a large container of solvent in which the part to be cleaned is immersed in the tank, and mixers are often applied to accelerate the cleaning process. Contaminants and solids may settle at the bottom, or an accumulation of insoluble materials occurs that can also be removed from the tank (Salvesen, 1989). The last and most straightforward form of cold cleaning is where an operator simply uses brushes and cloth to clean the parts or equipment manually (Salvesen, 1989). This form of cleaning would also

require the operator to wear appropriate personal protective equipment such as chemical resistant gloves and a respirator due to the potential for entry into the body via routes of skin absorption or inhalation.

The other form of cleaning using solvents involves vapor degreasing. The parts being cleaned are suspended above the liquid solvent and are then cleansed by warm vapor that condenses on the part. The condensation and contaminants on the parts then drip down into a reservoir that collects such contaminants. This process is continuous as vapors clean the parts to a satisfactory level. The solvents in this process are only replaced when a buildup of contaminants and sludge accumulate and thus disrupt the amount of vapors being created. Additionally, certain degrease vapor systems also have distillation equipment for the solvent as part of the process (Salvesen, 1989), which would likely minimize the overall amount of hazardous waste that's necessary for the respective organization to properly dispose of.

Summary

The focus of this study was to identify and evaluate practices to dispose hazardous paint waste as well as paint reduction practices to reduce waste. The literature describes not only different possibilities of waste reduction and recycling but case studies that have represented success with implemented waste management systems along with cost savings and payback periods. Although not all applications may be viable and/or applicable to Company XYZ's current processes, a better understanding of the options available and practiced in the manufacturing industry has proven to represent promising outcomes that may be beneficial to companies that have experienced similar hazardous waste disposal cost burdens. A full understanding of Company XYZ's current waste disposal practices and limitations will assess opportunities that may benefit the organization. The succeeding chapter will explore the

approach to defining the Company XYZ's waste disposal requirements, the use of a formula generated from a paint calculator that coincides with the expected amount of paint required to paint Company XYZ's products, the approach of utilizing solvent recycling methods, and applying relevant painting techniques as a means to further reduce the generation of hazardous waste.

Chapter III: Methodology

The purpose of this study was to assess Company XYZ's excess paint situation and hazardous waste disposal practices. The goal of this study includes:

- Identify the weight and cost of paint which has been disposed of as hazardous waste in previous years and use as a cost justification for process improvements.
- Assess Company XYZ's hazardous waste handling and disposal methods.
- Identify cost-effective and efficient methods to minimize waste paint that is generated as well as to decrease the cost of disposing of such materials.
- Examine paint application techniques as another form of metal surface protection.

Company XYZ's excess paint and hazardous waste disposal cost indicates opportunities for improving the organization's hazardous waste management system. The previous chapter explored various topics on how Company XYZ may improve its hazardous waste management practices which include hazardous waste reduction methods, disposal practices, and recycling incentives. This chapter provides information regarding data sources, collection, as well as analysis, procedures, and the limitations of this study.

Subject Selection and Description

This study does not analyze employee behaviors or related data and therefore will not involve human subjects. Information regarding Company XYZ will entail current management practices, policies, and procedures pertaining to waste disposal, paint purchasing, recycling, and application techniques. The information that is gathered and analyzed will be from calendar years 2019 and 2020 to-date. The author of this study is an employee of Company XYZ and thus has full permission to access and as well as analyze data/information that will be assessed.

Data Collection Procedures

The previous chapter described various opportunities to reduce the extent and thus cost of hazardous waste-based paint. In order to achieve the purpose of this study, the author developed a matrix to assist in outlining and assessing Company XYZ's paint processes and hazardous waste management system. Column one in the below-provided matrix consists of the different paint systems, processes, and disposal methods that were described in the previous chapter. This column includes purchasing programs, electrostatic spray painting, powder coating, employee training (paint applications), waste handling disposal, and a solvent recycler. The next column will describe the current status of each the systems listed above. The third column will attempt to distinguish the potential financial impact for each of these systems in regard to being a net gain or loss. The fourth column will analyze a process improvement that Company XYZ may want to consider. The last column is a final ranking on where Company XYZ stands to receive the greatest benefit from each system that was assessed.

System	Current Status	Potential Net Gain / Cost	Process Improvement Assessment	Cost / Ranking
Purchasing Programs				
Electrostatic Spray Painting				
Powder Coating				
Employee Training				
Solvent Recycler				
Hazardous Waste Disposal				

Figure 1. Paint and waste management system analysis matrix

Data Analysis

The data analysis will be based on information gathered from Company XYZ's current processes relating to the systems listed in Table 1. A total of six different approaches of reducing paint and hazardous waste were analyzed in Company XYZ's processes in relation to the topics that were reviewed within the Chapter II Literature Review. A significant portion of this analysis process will be based on the overall financial costs and benefits for the analyzed approaches/activities.

Limitations of the Study

Stated below are the limitations to this study.

- Data collection of the weight of hazardous waste and cost of disposal is restricted to calendar years 2018 and 2019.
- This study and remainder of data was collected from calendar-years 2019 and 2020.

Chapter IV: Results

Hazardous waste generation presents challenges for disposal of such material in a manner that is both appropriate and efficient. The purpose of this study was to assess the hazardous waste generation and how it can be appropriately dealt with from the source, streamline, and disposal perspectives; all of which present practices for ordering, purchasing, application, and disposal. New technology has been implemented into Company XYZ's processes along with other aforementioned applications which were mentioned in Chapter II of this paper. These processes entail the magnitude of the hazardous waste management system that is currently active, and this chapter shares the results of the reduction methods, disposal practices, and recycling incentives within that system. The goals of this study include:

- Identify weight and cost of paint which has been disposed of as hazardous waste in previous years and use as a cost justification for process improvements.
- Assess Company XYZ's hazardous waste handling and disposal methods.
- Identify cost-effective and efficient methods to minimize waste paint that is generated as well as to decrease the cost of disposing of such materials.
- Examine paint application techniques as another form of paint reduction.

The Table 1 Matrix in Chapter III was used to collect various forms of data/information and assist to meet the above-stated goals.

Presentation of Collected Data

The collected data was matched with each system which also aligned with the name of the subsequent headings of this chapter. In order to first assess each system, it was necessary to determine the amount of hazardous waste that Company XYZ previously disposed of. Tables 2 and 3 below contain data from Company XYZ's manifests from two separate points of removal

which indicate how much waste was disposed of in the 2019 fiscal year along with the associated costs. Calendar-year 2019 was selected to represent a full year of hazardous waste disposal and the associated costs for Company XYZ.

Table 1

2019 Hazardous Waste Disposal and Costs One

Month	Hazardous waste (in lbs.)	Cost ($)
January	2,000	1463.64
February	1,800	1114.00
March	1,636	1092.70
April	2,000	979.80
May	1,064	Data not found
June	3,000	1303.56
July	2,000	1053.75
August	5,500	4187.46
September	5,500	3048.23
October	0	0
November	3,000	1734.15
December	0	0
Total	27,500	$15,977.29

Table 2

2019 Hazardous Waste Disposal and Costs Two

Month	Hazardous waste (in lbs.)	Cost ($)
January	0	0
February	0	0
March	5,580	3,136.43
April	0	0
May	900	407.50
June	450	176.88
July	1350	740.18
August	0	0
September	1200	353.75
October	900	353.75
November	1350	777.45
December	0	0
Total	11,730	$5,945.94

During the 2019 fiscal year, Company XYZ paid $15,977.29 to dispose of 27,500 pounds of hazardous paint-related waste. Making note of the EPA regulations, a small quantity generator can dispose of hazardous waste that was generated within a one-month time frame and dispose of such within 180 days. Also, within the 2019-year, Company XYZ applied and was accepted to partake in an episodic event between July 15, 2019 and September 13, 2019. This explains the reason for 7,500 pounds of hazardous waste which was disposed of in a two-month period. An

episodic event also generates additional costs for the company to dispose of more waste than what is outlined in the permit of a small quantity generator. Company XYZ also disposed of 11,730 pounds of waste paint at another facility that utilizes the identical ordering system. In total, Company XYZ disposed of 39,230 pounds of waste or an estimated 5,000 gallons of paint.

Knowing the amount of hazardous waste is only beneficial if an individual understands the overall efficiency of the production that the paint stream was used. Company XYZ purchased approximately 90,000 to 120,000 gallons of paint throughout the year for approximately $1,446,700. At any given time, there are approximately 3,000 to 6,000 gallons in storage of leftover paint. Overall, between the paint that has been disposed and what will be placed in storage amounts to approximately 10,000 gallons. Being that Company XYZ purchased approximately 90,000 gallons of paint and disposed of 10,000 gallons of this material, one could conclude that the process efficiency of using such paint is 88.9%. This simple calculation indicates that approximately one-tenth of the purchased paint cost $160,743.05 in excess raw material expenditures during calendar year 2019. When combined with the $21,923.23 which is derived from Tables 2 and 3 for the cost of hazardous waste disposal, the total cost of paint purchased, and disposal amounts to $182,666.28. If this calculation were to include the additional 5,000 gallons of paint that is currently in storage and will eventually be disposed of as hazardous waste, then the estimated disposal cost would exceed $200,000 for the 2019 calendar year. The $200,000 total disposed cost represents the overordering/purchasing issue that Company XYZ currently faces. It should be noted that this is a conservative approximation of the total gallons of paint purchased and the correlating cost of the data mentioned for one year. Such costs may amount to $400,000 given variations of purchased and stored hazardous waste paint materials . The remainder of this chapter will examine each major

process within Company XYZ that relates to the generation of hazardous waste paint as well as potential reduction measures.

Purchasing Programs

Purchasing programs are a useful because such track the initial stream of paint which enters the building and is introduced into Company XYZ's process for eventual application to a product. This program is extremely useful to provide material control for the purchaser and therefore the company. The current status of a purchasing program for Company XYZ is subjective in that paint is ordered by the department that uses such material and is derived by what has been used in the past. With that being said, it is a common practice to order more paint than what is required so as to minimize the risk of running out before the production has been completed. However, this liberal purchasing approach leaves the company with excess paint that builds up over time and eventually needs to be disposed of as hazardous waste. Part of the challenge that Company XYZ faces with regard to implementing an efficient purchasing program is that not all product has the square footage noted on the respective customer order. To have an effective system for ordering, the first step would be denoting the square footage required to paint the product. Once the square footage is established, Company XYZ may specifically develop a paint ordering system based on a formula from the stated square footage which will in turn, decrease the excess paint that is unused per order. The current ordering system is the forefront on how Company XYZ initially creates excess paint that later must be disposed of as hazardous waste. Company XYZ's ability to adopt a proper paint purchasing formula for paint per order and thus increase the efficiency of decreasing the amount of excess purchased paint by 5%, may result in an annual savings of $72,000. Including the savings from a

decrease in the associated disposal fees would potentially result in $100,000 savings benefit per year.

Electrostatic Spray Painting

In 2019, Company XYZ invested in a new electrostatic spray paint system. The reason for this investment was to utilize a system that has a higher transfer efficiency compared to conventional spray painting. The higher transfer efficiency of electrostatic spray painting is derived from the negatively charged paint being sprayed with an electrostatic paint gun which is sprayed to a positively charged surface and thus prompts a "wrap-around" effect that decreases overspray and the amount of paint wasted in the process. This electrostatic paint application system should increase efficiency, although it is currently not being utilized throughout the entire facility since Company XYZ also uses the conventional paint spray application method.

At the current time, it is difficult to determine whether or not the recently installed electrostatic spray painting has proven to be beneficial for there has not been any data collected to cost justify such to be more efficient than the conventional method of spray painting. Thus, the potential of assessing the net financial gain as a result of decreasing the amount of paint that is used and therefore purchased with the implementation of the electrostatic spray painting has not been be determined. A part of Company XYZ's process improvement plan should be to analyze the amount of paint required to paint product with electrostatic versus the conventional spray methods.

Powder Coating

Company XYZ also uses the powder coating technique for a portion of its products. What determines if a product is powder coated or sprayed with liquid paint is based on the request of the customer. Powder coating utilizes static electricity to negatively charge particles

that attract to the positively charged surface. The leftover powder is not required to be disposed of as hazardous waste. This system would likely decrease the amount of hazardous waste being that such powder may be disposed into a landfill. Company XYZ allows the customer to pick any type of paint that is desired, whether it be powder or liquid based. Given current practice of allowing powder coating to be used at the decision of the customer, it may beneficial to explore the practice of promoting this system more often to minimize the amount of liquid paint used and thus decrease the generation of hazardous waste.

Employee Training

Training is often a leading indicator for the success of the employee to learn as well as gain experience to become efficient in the skill that is being trained upon. Company XYZ's current status of how employees are trained utilizes mentoring painters within the company to train novice employees on effective painting techniques. The potential benefits of developing formal training on the preferred practices and techniques to paint with quality and efficiency may reduce the amount of paint that is applied to a product. Paint application plays a major role in both quality and efficiency in relation to the technique being used. Thus, effective manual painting strategies are likely to achieve preferred results while maintaining the highest efficiency of paint that adheres to the product and therefore limits the amount of paint generated waste due to heavy application or overspray-based loss. Developing and training such techniques may result in less paint being used and therefore decrease the amount of painted purchased to paint product.

Solvent Recycler

In 2019, a solvent recycler was purchased by Company XYZ to assist in disposing of paint as well as recover solvents within such materials and contaminated thinners. The current

status of the purchased solvent recycler is that such is currently not in use. Company XYZ has experienced difficulties to achieve the correct temperature and time for the recycler's recovery cycle to be effective and thus receive the desired results. The aforementioned difficulties resulted in the company to only utilize the solvent recycler several times throughout the year.

The potential net gain of fully utilizing the solvent recycler as part of the day-to-day process would be beneficial to Company XYZ. Utilization of the equipment would assist in decreasing hazardous waste and also reuse solvent-based product that can integrated into the respective processes. The recovered thinner can be used for cleaning purposes such as purging paint lines that are involved within the paint booths. Integrating reclaimed solvent back into the process would assist in decreasing initial costs for solvent and paint thinners. Ultimately, the recovered solvent wouldn't be disposed of hazardous waste and therefore minimize purchasing costs.

In 2019, Company XYZ purchased approximately 4000 gallons of solvent and thinner which amounted to roughly $52,000. The utilization of the solvent recycler combined with reusing the recovered solvent may contribute to purchasing less virgin solvent and/or thinner. If the solvent recycler supplied half of the organization's solvent needs, then Company XYZ may potentially save $25,000 per year.

Hazardous Waste Disposal Process

The need for hazardous waste disposal is reasonably connected to the occurrence of employee training since there is not a defined process which controls the disposal of hazardous waste. A defined process would prompt painters to know what is acceptable to become hazardous waste and what is not. Furthermore, any employee working with hazardous waste must be trained according to the EPA, but the disposal process itself is what Company XYZ is

lacking. Currently, Company XYZ has an internal standard which states that paint may be shelved for one year and then must be disposed of as hazardous waste since a majority of a paint's shelf-life is 12 months. Without a defined disposal process, any type of paint may be placed into a hazardous waste barrel. The only time a paint may be placed into a hazardous waste barrel is when it is a two-part catalyzed product which cannot be shelved and reused after being mixed. Other single-part paint material may be placed back into the original container and shelved for later use.

Discussion

Table 3 below provides the results of the six different systems which were reviewed within Chapter II of this paper. All of the systems outlined within the Paint and Waste Management System Analysis Matrix provide opportunities to assist in strengthening a hazardous waste management system. In the case of Company XYZ, a likely approach to improving the waste management system is increased utilization of powder coating which is currently only applied at the request of the customer. Although, powder coating limits the generation of hazardous material, such waste does not require to be disposed as hazardous material which in turn would significantly decrease Company XYZ's disposal costs. Utilizing the powder coating method rather than conventional or electrostatic spray painting may be most beneficial for the waste powder does not require hazardous waste disposal and therefore be the most cost-effective from a financial perspective. The second approach to improving Company XYZ's waste management system would be to identify and implement improvements in the organization's purchasing system. Minimizing the amount of paint that is initially purchased may provide a significant cost savings in relation to all the systems mentioned. The third preferred waste management system in the ranking involves the use of the electrostatic spray-

painting method. The transfer efficiency of the electrostatic method is higher than that of conventional spray painting which is predominantly used throughout the facility. Tracking how much paint that is required for the electrostatic versus conventional application methods may provide the evidence needed to determine the preferred method. The next two systems are contingent on each other and involve the need to define a process on how to dispose of hazardous waste materials as well as to strengthen the level of employee training regarding the preferred techniques that will limit over painting and overspray. The last system noted within the matrix would be to fully utilize the solvent recycler. The consistent utilization of the solvent recycling equipment provides costs savings due to a reduced need to purchase thinner as a result of reclaimed material being integrated back into the painting process.

System	Current Status	Potential Net Gain / Cost	Process Improvement Assessment	Cost / Ranking
Purchasing Programs	Subjective system	Large potential gain for only purchasing what is needed, increase efficiency by 5%, potential savings of $100,000 per year	Establish proper paint purchasing formula to reduce overbuying	2
Electrostatic Spray Painting	System installed, opportunity to fully utilize	Track the amount of paint it takes to paint a product in electrostatic painting versus conventional spray painting	Start to track how much paint it takes to paint a product with electrostatic spray	3
Powder Coating	Only used at customer request	Not required to dispose of as hazardous waste	Provide incentives for customers to use powder coating products	1
Employee Training	No formal training, shadow employees on painting process	Decrease amount of paint required to coat product by decreasing over painting and overspray.	Establish regular training schedule on relevant paint techniques	5

Solvent Recycler	Implemented but not utilized	Potentially save $25,000 per year	Denote proper formula to utilize solvent recycler	6
Hazardous Waste Disposal	No defined process	Decrease amount of hazardous waste that is not needed to be disposed of as hazardous waste	Define process of what can and cannot be disposed of as hazardous waste	4

Figure 2. Paint and waste management system analysis matrix results

Chapter V: Conclusions and Recommendations

Company XYZ's hazardous waste control practices were analyzed and assessed to identify opportunities to minimize the generation of such waste materials. Furthermore, this study was performed to identify how hazardous waste generation can be appropriately dealt with from the source, streamline, and disposal perspectives; all of which involve practices for ordering, purchasing, application, and disposal. In order to perform the analysis, the following goals were developed:

- Identify weight and cost of paint which has been disposed of as hazardous waste in previous years and use as a cost justification for process improvements.
- Assess Company XYZ's hazardous waste handling and disposal methods.
- Identify cost-effective and efficient methods to minimize waste paint that is generated as well as to decrease the cost of disposing of such materials.
- Examine paint application techniques as another form of paint reduction.

The methods to achieve above goals involved an assessment of Company XYZ-based information in relation to opportunities to reduce the extent and thus cost of hazardous waste-base paint which was gathered from various product coating processes. The researcher developed a matrix that consisted of the current status of a variety of waste management associated systems, the potential net gain / cost, a process improvement assessment, as well as ranking in which Company XYZ may most benefit from the associated waste reduction approach.

Conclusions

The systems that were presented in the literature review chapter represent findings of other companies' success in minimizing waste and thus served as the foundation for this research paper. Each system was then assessed and analyzed in relation to Company XYZ's processes

with the intent to outline opportunities to assist in strengthening the organization's current hazardous waste management system. The findings of each system are as follows:

- Powder coating is a surface finishing method of application used in Company XYZ's application methods which is only used at the customer's request. Excess and waste powder is not required to be disposed of as hazardous waste and therefore, Company XYZ may experience the most profitability from the decrease in hazardous waste generated if powder coating is predominantly used.
- Company XYZ lacks a proper paint purchasing program. The current ordering system is subjective because the amount of paint is determined by the department and thus is based on historical use figures. Paint is over-ordered to decrease the chance running out during the application process and therefore an overabundance of paint occurs.
- Company XYZ has installed an electrostatic spray-painting system, but such is not fully utilized. Currently, both the electrostatic and conventional methods of application are used.
- Company XYZ lacks procedures for hazardous waste disposal which may result in more hazardous waste being generated than what is necessary.
- Employees may lack technical painting skills in relating to techniques of paint application and thus create surface finish quality deficiencies as well as hazardous waste.
- Company XYZ has installed a solvent recycler, but the device is not fully utilized due to being operated only a portion of the time. Utilization of the machine would

reclaim solvent that may be implemented into the production processes and therefore save on purchasing new or virgin solvent.

Recommendations

The findings of this study provide the basis for multiple engineering and administrative recommendations to be implemented into Company XYZ's hazardous waste management system that may ultimately decrease the generation of such materials. Following are recommendations for Company XYZ which are intended to reduce the extent of hazardous waste paint that is generated and thus promote overall organizational profitability:

- Increased effort to provide incentives for customers to choose the powder coating method since the leftover and waste powder materials do not require hazardous waste disposal. This method may provide the desired cost savings due to the significant decrease in hazardous waste generation and therefore disposal.
- Improve the paint ordering system to minimize the amount of material purchased and limit the excess paint that is not used after application. Increasing the effectiveness of the paint purchasing system may potentially save $100,000 per year.
- Utilize electrostatic spray-painting and track the amount of paint required for this method versus the predominantly used conventional approach to determine the most cost-effective method of paint application.
- Define the process for hazardous waste disposal and train employees to follow developed procedures. The developed process may produce less hazardous waste for materials that should not be disposed of at any given time.

- Develop a paint application training program to instruct employees on proper application methods and techniques to increase efficiency and minimize waste during painting processes.
- Utilize the solvent recycler to reuse reclaimed solvent waste thinner that would otherwise be disposed of as hazardous waste and decrease the cost of purchasing lacquer thinner related materials. Company XYZ may potentially save $25,000 per year by utilizing the solvent recycler and thus incorporating the reclaimed solvent in various production processes.

Areas of Further Research

In addition to the findings of this paper, follows are areas of further research that may identify opportunities to enhance Company XYZ's hazardous waste management system:

- Purchase or develop a paint purchasing formula which is based on the surface area of a customer-requested product.
- Develop a system which tracks the amount of paint required for electrostatic versus conventional spray painting to determine the most cost-effective method of paint application.

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