Safer Alternatives for the Chemical, Pharmaceutical and Biotechnology Industries: Paint Manufacturing Tank Cleaning

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EXECUTIVE SUMMARY

It is estimated that there are more than 1,200 chemical manufacturing facilities in California. The chemical industry is diverse and in addition to direct chemical manufacturing, it includes manufacturing of plastics, synthetic resins, soap, paint, varnishes, lacquers and enamels. Virtually all manufacturers of these types of products use a range of different solvents extensively to clean production tanks and associated equipment. Companies with batch and campaign operations particularly rely on solvent cleaning operations when they are changing products that require different input materials. Many of the solvents that are used in the cleaning operations are toxic and they pose a threat to workers and the surrounding community. Use of the solvents results in air emissions and the generation of large amounts of hazardous waste.

This project focused on identifying and analyzing options for reducing or eliminating the use of solvents used in typical cleaning operations for reactor tanks and other associated equipment. The project was sponsored by U.S. EPA Region IX and Cal/EPA's Department of Toxic Substances Control (DTSC). The project was conducted by the Institute for Research and Technical Assistance (IRTA), a small nonprofit technical environmental organization with specific expertise in solvent alternatives.

IRTA investigated the feasibility and cost of adopting alternative approaches, processes and cleaners for eliminating the use of methylene chloride for cleaning paint manufacturing tanks in a hypothetical paint manufacturing facility. The facility manufactures waterborne paint which is sold into the local California market. The hypothetical plant manufactures the paint in five production tanks; the products are produced in batches which require different input materials and they must be cleaned four times per year. Under the baseline case, the facility personnel perform the tank cleaning after the paint has cured so aggressive stripping methods must be used. Two strategies, one where a methylene chloride stripping formulation is used in one gallon containers and one where the same formulation is used in drum quantities, form the baseline for the cost comparison. Alternative options that were examined include four cases where water or water-based cleaners are used to clean the tanks before the paint is cured. Other alternative options that were investigated for stripping the coating from the tanks after it is cured are using sanding discs to physically abrade the paint from the tanks and using a safer alternative benzyl alcohol formulation in either one gallon containers or drum quantities to strip the paint from the tanks.

Table E-1 summarizes and compares the options for cleaning the tanks that were analyzed during the project. The baseline methylene chloride options are the first two listed in the table. Using a methylene chloride formulation in one gallon containers to strip the cured paint from the tanks is the highest cost option in the table. The next four options listed in the table involve changing the schedule to clean before the paint cures and using plain water or a water-based cleaner to clean the tanks. The lowest cost option of these four is to use a pressure washer with plain water for the cleaning. Flushing the tank with water and using the mixer in the bottom of the tank to circulate the water is also low cost. Using a water-based cleaner and reusing the cleaner from the first tank to clean the other four tanks is also relative low cost. Using a water-based cleaner for flushing the tank without recycling the cleaner is a fairly high cost option. The last three options in the table involve cleaning the tank after the paint has cured. Using sanding discs to physically abrade the paint from the tanks is relatively low cost. The two options that involve using a safer alternative stripping formulation based on benzyl alcohol are fairly high cost options.

Table E-1 Annual Cost Comparison of Options for Cleaning Paint Manufacturing Tanks	
Option	**Annual Cost**
Methylene Chloride Stripping—One Gallon Containers	$11,010
Methylene Chloride Stripping—Drum Quantities	$8,851
Plain Water Flushing	$2,029
Water-Based Cleaner Flushing	$10,543
Water-Based Cleaner Flushing—Tank Recycling	$3,732
Plain Water—Pressure Washer	$1,366
Sanding Discs Abrasion	$5,709
Benzyl Alcohol Stripping—One Gallon Containers	$9,439
Benzyl Alcohol Stripping—Drum Quantities	$8,524

The best options for cleaning the production tanks from an overall health and environmental standpoint are those that rely on plain water or water-based cleaning. These cleaning options must be performed before the waterborne paint is cured. Companies should schedule the tank cleaning directly after the paint is routed from the production tank.

If it is impossible to schedule the cleaning before the paint is cured, the best option is to physically abrade the coating from the tank surfaces with sanding discs. As a last resort, the benzyl alcohol stripping formulations can be used to strip the cured paint. Benzyl alcohol is safer than methylene chloride but the formulations are solvent based and all solvents can have an effect on the central nervous system if they are not used judiciously.

Companies should take into account the fact that the paint tanks are confined spaces and that procedures for working in confined spaces should always be exercised regardless of the option used to clean the tanks. Workers should be trained in these procedures carefully and should always exercise caution when cleaning the tanks.

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I. INTRODUCTION AND BACKGROUND

Californians are strongly concerned about the quality of their environment and are vitally interested in minimizing the releases and generation of toxic and other hazardous materials. In response to continuing concerns about pollution, in 1998, the Legislature augmented the State's Pollution Prevention (P2) Program at California's Environmental Protection Agency Department of Toxic Substances Control (DTSC) through legislation called Senate Bill 1916. The program involves selecting certain industries every few years for detailed focus to address P2 priorities and promote implementation of source reduction measures. For the fiscal year 07/08 cycle of SB 1916, DTSC selected the Chemical Industry. The Chemical Industry project is a voluntary program that addresses an industry primarily composed of large businesses but many members of the industry are also small and medium sized businesses. DTSC has established a partnership with the Chemical Industry Council of California (CICC) as part of the project which is designed to reduce hazardous waste generation and other multimedia releases.

According to the American Chemistry Council, the California chemical industry produces about $27 billion worth of goods and contributes nearly $17 billion to the gross state product. In 2004, the most recent year for which data are available, there were 1,206 chemical manufacturing facilities in the State with 90,970 employees. This industry includes a wide variety of manufacturing operations used to produce inorganic chemicals, organic chemicals, plastics and synthetic resins, drugs, soap, detergent and cleaning preparations, paints, varnishes, lacquers, enamels and agricultural chemicals. The chemical industry ranks first in hazardous waste generation and fifth in total hazardous releases in the federal Toxics Release Inventory (TRI) among all California industries. The highest concentrations of TRI releases are in southern California, especially in Los Angeles, Orange and Riverside counties, and around the Bay Area and the northern Central Valley. The industry's air emissions account for 95 percent of the industry's total on-site disposal and other releases and 75 percent of the industry's total on- and off-site releases.

According to DTSC manifest data, the chemical industry generated about 70,000 tons of hazardous wastes in 2005. Major waste generating processes in the chemical industry include cleaning activities like washing out reactor vessels and other production equipment, bottles, glassware, containers and tanks and flushing lines, valves and hoses. Waste streams classified as oxygenated, hydrocarbon and unspecified solvents account for 17 percent. The spent solvents and aqueous streams include materials used in cleaning activities. The California Air Resources Board (CARB) reports that the chemical industry was responsible for 4.6 million pounds of toxic air emissions in 2002. Many of the chemicals that comprise these toxic air emissions are solvents of various types and it is likely they are used for cleaning activities. Most of the solvents used for cleaning are classified as Volatile Organic Compounds (VOCs) which contribute to photochemical smog and many are considered toxic as well.

The focus of this project was to identify, evaluate and analyze alternative safer methods of cleaning reactor tanks and related equipment for the chemical industry. The aim of the project was to reduce or eliminate the use of toxic and VOC cleaning materials and minimize the generation of hazardous waste and air emissions. Use of safer cleaning alternatives protects workers and community members in California. The Institute for Research and Technical Assistance (IRTA) is a nonprofit organization established in 1989. IRTA's mission is to identify, develop, test and demonstrate safer alternatives in a variety of applications. A significant focus of IRTA's work has been on solvent alternatives. IRTA partnered with DTSC's Pollution Prevention group to conduct this project which was sponsored under EPA's Pollution Prevention Grants Program.

In the original project formulation, IRTA and DTSC wanted to focus on methods of reducing or eliminating the use of solvents in a commonly used operation that involved cleaning reactor tanks or associated equipment in the chemical industry. The best candidates for the project are the types of operations employed by companies that make many different products in batches. In a batch process, a specific substance or intermediate is manufactured in a so-called campaign for a period ranging from a few days to months until a sufficient amount of substance is produced to satisfy the contract. At the end of the campaign, another substance is made and the same equipment with different configurations is often used. Different raw materials are used as inputs, different process steps may be involved and different waste streams may be generated. Because they are producing or blending these different products in shorter runs, their cleaning needs between product runs are greater and they use a number of solvents and high volumes of solvents for cleaning.

There are several companies in California that manufacture paints and coatings of various kinds. Although a few of these companies produce solventborne paints, most of the California manufacturers produce waterborne paints. This follows from the fact that the air regulations in California are more stringent than they are in other states and air agencies have low VOC limits for most of the paints that are used here. As a consequence, paint manufacturers produce largely waterborne paints to satisfy the local market. IRTA focused on coating manufacturer production tank cleaning for evaluation in this document. In Section II of the report, IRTA presents a detailed case study analysis of paint tank cleaning for a hypothetical company. Some of the characteristics of the operation are based on an actual case of a paint manufacturer in California. The evaluation involves devising methods of using alternative approaches, processes and formulations to remove paint from paint manufacturing tanks. It focuses on estimating the requirements and costs for paint removal using the alternative options. Section III of the document summarizes the results of the analysis.

II. PAINT TANK CLEANING

In October, 2011, the Orange County Register reported that a worker died while he was using a paint stripper inside a tank at a paint manufacturing facility (OCR, 2011). A co-worker also entered the tank when he saw the first worker unconscious at the bottom of the tank. The co-worker also passed out; he was hospitalized but he did survive. The Occupational Health Branch of the California Department of Public Health issued a Worker Fatality Alert for this case (DPH, 2011). The worker was using a stripping formulation based on methylene chloride to remove the cured paint from a tank used to produce the paint. IRTA used this actual unfortunate case to construct a hypothetical tank cleaning operation for a paint manufacturing operation.

For the hypothetical case study, IRTA assumed that the stripping formulation used to remove the paint from the tank was the same one used in the actual case. A Material Safety Data Sheet (MSDS) for the stripper, called Jasco Premium Paint and Epoxy Remover, is shown in Appendix A. The major ingredient in the stripper is methylene chloride; other ingredients listed on the MSDS include methanol and Stoddard Solvent. The methylene chloride content is listed at 60 to 100 percent. The methanol content is listed at 10 to 30 percent and the Stoddard Solvent content is listed at between one and five percent. The paint stripper is made by W.M. Barr and it is sold in one gallon containers in hardware and home improvement stores.

Paint tanks in paint manufacturing facilities come in a range of sizes. Many manufacturers produce small amounts of a number of different paints on a regular or as-needed schedule. After a run of one type of paint, the tank is cleaned so the new ingredients can be introduced for the next paint batch. This section focuses on tank cleaning operations at a hypothetical paint manufacturing facility in California. The analysis that follows examines a baseline and alternative methods of cleaning the paint manufacturing tanks. It estimates the cost of conducting the cleaning using the baseline method and compares that to the cost of using the alternative tank cleaning methods.

DESCRIPTION OF PAINT TANK

The paint tank used in the analysis for the hypothetical tank cleaning operation is the actual tank from the case study. The tank is made of stainless steel and its dimensions are seven feet by seven feet with a depth of nine feet. The top of the tank is a hinged cover and the tank opening is two feet wide by seven feet long. A picture of the outside of the tank is shown in Figure 2-1 and a picture of the inside of the tank is shown in Figure 2-2. As Figure 2-2 shows, the inside of the tank includes a ladder for workers to descend to the bottom of the tank. It also has a center rod mixer for mixing the ingredients when a production run is underway.

CHARACTERISTICS OF BASELINE STRIPPER

A picture of the Jasco stripper used to remove the paint from the paint tank is shown in Figure 2-3. The active ingredient in the paint stripper, methylene chloride, is classified as a carcinogen. It is listed as a Hazardous Air Pollutant (HAP) by EPA, it is on the Toxic Air Contaminant (TAC) list in California and it is also listed on California's Proposition 65. It is a listed hazardous waste under the Resource Conservation and Recovery Act (RCRA). Methylene chloride is not considered a VOC and is exempt from VOC regulations. In 1998, the Occupational Safety and Health Administration (OSHA) reduced the Permissible Exposure Level (PEL), the level to which workers may be exposed, from 500 ppm to 25 ppm.

Figure 2-1. Tank at Paint Manufacturing Facility

Figure 2-2. Inside of Tank at Paint Manufacturing Facility

Figure 2-3. Jasco Stripping Formulation

The agency also established an action level at 12.5 ppm which would trigger medical surveillance and reporting requirements. In addition to its carcinogenicity, methylene chloride metabolizes to carbon monoxide in the body and can cause a condition called carboxyhemoglobin in which carbon monoxide builds up in the blood. Exposure to even low concentrations can lead to asphyxiation.

The second ingredient, methanol, is also toxic in its own right. It is a listed HAP and a listed RCRA hazardous waste. It is also classified as a VOC. It is often added to paint strippers containing methylene chloride because it acts in a synergistic way with the chemical. The third ingredient, Stoddard Solvent, is a petroleum solvent which is classified as a VOC.

According to the label, the paint stripping formulation is a semi-paste. This indicates it is thixotropic and can cling to vertical surfaces. This is an important characteristic for stripping the sides and top of the tank. The methylene chloride is very volatile and the paste quality will hold it on the surface longer so it can loosen the paint.

The VOC content of the stripper is fairly low, about 14.5 percent according to the regulatory sheet, because the majority of the formulation is methylene chloride which is not classified as a VOC. The California Air Resources Board (CARB) regulates the VOC and toxic air contaminant content of consumer products in California. CARB has regulated the VOC content of consumer product strippers and has set a limit of 50 percent. Although CARB has prohibited the use of methylene chloride in many other consumer products, the agency has not adopted such a prohibition for paint strippers. They are still available to consumers and businesses in hardware and home improvement stores in California.

HYPOTHETICAL CASE STUDY OPERATION

The hypothetical operation is a paint manufacturer in California. The product manufactured by the company is waterborne latex paint used in the architectural industry. The paint is produced in campaigns where small quantities are produced for a period of time. The company has five tanks that are similar to the tank describe earlier. The tank dimensions are seven feet by seven feet with a depth of nine feet. The opening on the top is nine feet by two feet and the hypothetical company has five of these tanks.

Baseline Cleaning Operation

Like the company in the actual case described above, the hypothetical company does not have a regular cleaning schedule. When waterborne paints are applied, the application equipment can be cleaned with plain water if the cleaning is done shortly after application before the paint is cured. If more time passes, however, and the paint cures, the cured coating is much more difficult to remove. The reason the actual company and the hypothetical company would use a methylene chloride stripping formulation is because the cleaning of the tank is performed after the paint has cured.

For a paint tank with about 440 cubic feet, it would require between five and 10 gallons of stripper to completely remove the cured paint. Depending on the company's practices, they may allow buildup of a few coats of paint before stripping. Two applications of stripper would likely be required. For purposes of analysis, it was assumed that each of the five tanks requires stripping four times per year. It was further assumed that 7.5 gallons of stripper is required each time one of the tanks is stripped. On this basis, the amount of stripper required for the cleanup operations is 150 gallons per year.

The company might be expected to purchase the stripper in drums or five gallon pails rather than one gallon containers because the price per gallon would be lower for the larger quantity packaging. On the other hand, because the tank is a confined space and the workers enter down a narrow ladder, the convenience of using smaller quantities that are easier to carry might outweigh the cost advantage. A five gallon container would weigh more than 50 pounds and it would be difficult to carry it down the ladder. If the company purchased the stripper in drums or five gallon containers, the workers would probably have to dispense it in smaller quantity containers to carry it into the paint manufacturing tanks.

IRTA examined two different cases, one case where the company purchases stripper in one gallon containers for convenience and another where the company purchases the stripper in drum quantities. One home improvement store prices the one gallon containers of the stripper at $24.97 (Lowe's, 2012). On this basis, the cost of purchasing 150 gallons per year would amount to about $3,746. The stripping formulation used by the company is sold only in smaller quantity containers and it is apparently not available in drums. Another methylene chloride based formulation that is similar to this formulation is sold in drum quantities. An MSDS for this stripper, called #B4, is shown in Appendix A. Like the other stripping formulation, this stripper is a paste that can be used to strip vertical surfaces. According to the supplier, the current cost of the stripper is $582 per drum (Benco Sales, 2012). The cost of using 150 gallons annually of this stripper amounts to $1,587. Note that the cost of purchasing the stripper in the larger quantity container is significantly less than the cost of purchasing the one gallon containers.

The paint stripper would not likely remove all of the cured paint and the worker would have to use an abrasive sand paper to remove all vestiges of the remaining cured paint. A DA sander with 40 grit sandpaper could be used for this purpose. Because cured paint is difficult to remove, perhaps as many as 10 pieces of sandpaper would be required for each tank to finish the job. One company who sells sanding discs indicates that a package of 50 six inch sanding discs would cost between about $27 and $31 (WMI, 2012). Assuming a cost of $30 and that 10 discs would be used per tank per cleaning, the annual cost of purchasing sanding discs for the polishing operation is $120.

It would take a worker about eight hours to strip each tank with the methylene chloride paint stripper. An additional two hours would be required for the abrasive removal to finish the tank. Assuming 10 hours are required to strip each of the five tanks, the labor requirement for stripping the five tanks four times each year would be 200 hours. The maintenance staff would be responsible for the cleaning and these workers would have a labor rate of $20 per hour. On this basis, the annual labor cost for chemically stripping the tank with an abrasive removal polish with sand paper would amount to $4,000.

The waste from the methylene chloride stripping operation is classified as hazardous waste. Methylene chloride is a listed RCRA waste so any waste material containing it, including the sandpaper used for the polishing process, would be considered hazardous waste. As the MSDS for the stripping formulation shows, the major ingredients are methylene chloride and methanol. These two solvents are very volatile and would likely evaporate during the stripping process. The residue from the stripping operations would be in the form of a sludge that would include some solvent and a significant amount of solids from the removed paint. The volume of the waste generated would depend on the buildup of the cured paint in the tank. For purposes of analysis, it was assumed that about 10 gallons of waste would be generated each time one of the tanks is stripped. On this basis, stripping the five tanks would generate about one 55 gallon drum of hazardous waste. If the stripping were conducted four times per year, the company would generate four 55 gallon drums of hazardous stripping waste each year.

The company is probably classified as a large quantity generator (LQG) and, on that basis, the waste would require disposal every 90 days. One waste hauler estimates that the cost of disposing of one drum of methylene chloride stripping waste, containing about three-fourths solids, is about $400 per drum (PSC, 2012) or $400 per quarter. Because it contains some solvent, this waste would be shipped out of state for incineration.

The sandpaper waste used to completely strip or polish the tanks after the methylene chloride stripping would also be classified as hazardous waste. According to one waste hauler, if the paint tanks are made of stainless steel, the spent discs are likely to be contaminated with a small amount of chromium (PSC, 2012). Assuming 10 discs are used for each of the five tanks, 50 waste discs would be generated each quarter. These discs would likely fit into a five gallon pail. The discs would be contaminated with some methylene chloride so they would have to be incinerated. A hauler estimates that disposal of the spent waste discs would be $87 per five gallon pail (PSC, 2012).

The cost of disposal of the methylene chloride waste drums is $400 per quarter and the cost of disposal of the discs is $87 per quarter. The other fee charged by the hauler is a stop charge fee. This fee is $185 for up to five drums and $38 per drum thereafter for a stop with a maximum fee at any one stop of $740. It was assumed that one drum of methylene chloride stripping waste and the five gallon pail of spent sanding discs would have a stop fee of $185. A third fee charged by haulers is an environmental surcharge which can range from 12 to 22 percent of the total hazardous waste charge. Assuming this fee is 17 percent, the additional charge would amount to $114. The total cost of disposal would be $786 per quarter or $3,144 per year.

There are a number of other costs associated with maintaining the paint manufacturing tanks. These include a worker safety program that trains workers on the proper methods to use in confined spaces. The tanks are confined spaces and whenever a worker enters a tank for any purpose, which may not be just related to tank cleaning, they should exercise proper procedures. These include use of proper ventilation, supplied air respiratory protection, air monitoring, communications and proper rescue and retrieval procedures (DPH, 2011). Because these procedures would apply no matter what methods are used to clean the tanks, their cost is not analyzed here or included in the comparative evaluation.

The cost of stripping the tanks in the operation currently is summarized in Table 2-1. The cost of using the methylene chloride for stripping the cured paint and using sanding discs for the polish amounts to a little more than $11,000 annually when the one gallon containers are used. The cost is lower when the stripper is purchased in drums. The figures show that the highest component of the cost is the labor cost.

Table 2-1
Annual Cost of Cleaning Tanks With Methylene Chloride Stripper

	One Gallon Containers	**Drums**
Materials Cost		
Stripping Formulation	$3,746	$1,587
Sanding Discs	$120	$120
Labor Cost	$4,000	$4,000
Hazardous Waste Disposal Cost	$3,144	$3,144
Total Cost	$11,010	$8,851

ALTERNATIVE METHODS OF TANK CLEANING

There are three alternative methods of cleaning the tank that were evaluated during this study. These include:

- Cleaning the tank with plain water or water and detergent
- Physically abrading the paint in the tank with sanding discs
- Using a non-methylene chloride stripper to strip the tank

Each of these methods is discussed in more detail below.

Water or Water and Detergent Cleaning

The hypothetical company manufactures waterborne paints. Such paints can be cleaned up and thinned with plain water. In some cases, the cleanup may require a detergent or high pressure to enhance the cleaning. In order for this option to work, however, the paint must be cleaned before it cures. In the paint manufacturing, this means that cleanup of the tank must be scheduled immediately after the paint is blended in the tank. Assuming the product is pumped out of the tank for packaging after manufacture, the cleanup could be done within a very short period of time. IRTA analyzed three separate options for cleaning the tank with water directly after production. In the first case, the company would flush the tanks with plain water. In the second case, a small amount of a water-based cleaner would be added to the water used to flush the tank. In the third case, the company would use a portable pressure washer with plain water to clean the tank.

Tank Flushing. Paint manufacturers generally pump the ingredients used to make the paint into the tank through process hoses connected to tanks or drums holding the reactant materials. A related document which was prepared as part of this project describes the alternatives that are available for process hose cleaning for chemical, pharmaceutical or biotechnology companies (Wolf, 2011). In this case, because the product is waterborne paint, water is one of the ingredients that is introduced into the tank for the mixing. When the process hoses are cleaned, it is very likely they are flushed with water. The same process hoses could be used to introduce the plain water or the water-based cleaner into the tank for cleaning.

In an earlier project IRTA conducted for the South Coast Air Quality Management District (SCAQMD), IRTA investigated and tested alternative low-VOC, low toxicity coating and adhesive application equipment cleaners (Morris and Wolf, 2003). In one case, IRTA worked with a furniture stripping company which, at times, applied waterborne paints to wood items. IRTA tested an alkaline water-based cleaner for cleaning the spray gun and it was very effective in the cleaning operation. The paint manufacturer could clean the tank with the same water-based cleaner. An MSDS for this cleaner, called Spray Clean 12, is shown in Appendix B.

As Figure 2-1 shows, there is an air powered mixer in the bottom of the tank that is used to mix the ingredients in the tank. This same mixer can be used to uniformly circulate the plain water and the water-based cleaner throughout the tank to remove the reactants and any uncured product that remains. Since all the ingredients are water soluble, this should be an effective method of cleaning the tank. The spent cleaner is than evacuated from the tank through another process hose and is routed to a wastewater treatment system.

The volume of the tank is 441 cubic feet or about 3,300 gallons. In the case where plain water is used to clean the tank, there would be no cost for purchasing materials. In the case where the water-based cleaner is added, there would be a materials cost. A formulation of one percent of the Spray Clean 12 in water could clean the tank effectively. On this basis, 33 gallons of the water-based cleaning concentrate would be required for cleaning each of the five tanks. The water-based cleaner supplier indicates that the company could purchase 55 gallon drums of the cleaner for $709.50 per drum (CTI, 2012). To clean all five tanks four times per year, the cost of purchasing the water-based cleaner would amount to $8,514. It might be possible to reuse the water-based cleaner used to flush one tank for flushing the other four tanks as well. In this event, the cost of purchasing the water-based cleaner would only amount to $1,703 per year. To ensure that the tanks were completely clean for manufacturing the next batch of paint, they would be flushed with plain water as a rinse.

The flush with water or a water-based cleaner might not completely remove all of the remaining residue in the paint tank. In this case, sanding discs could be used to polish the tank, as was the case for the methylene chloride stripping. As before for the sanding disc polish, the annual cost of purchasing sanding discs is $120.

No labor would be required to flush the tank with water since it is automated. The water-based cleaner would be mixed with water using a metering device which paint manufacturers generally already have in place. Two hours of labor would be required for the polish of each tank with sanding discs after flushing with water. The labor cost for polishing the five tanks four times a year, assuming a labor rate of $20 per hour, is $800.

It is likely that the paint manufacturer has a wastewater treatment facility where thewater used in the process would be routinely routed. This treatment facility would probably be used to treat any water used in maintenance activities throughout the tank and for flushing all kinds of equipment used in the process. It might also be used for disposal of any off-spec product that is produced. The plain water, the water-based cleaner containing one percent concentrate, and the rinse water would be routed to the system four times a year after it is used to flush the tanks. Although there would be a cost for treating this water, it would likely be a small incremental cost. For this case, the incremental wastewater treatment cost was ignored.

The sanding discs used in the abrasion process would require disposal. The discs may contain the small amount of chromium from the stainless steel tanks. In this case, however, they would not contain any solvent contamination. Instead of requiring incineration, the discs would be stabilized and landfilled at a cost of $52 per five gallon pail. Ten pieces of sandpaper would be necessary for stripping each tank. Each time the five tanks are stripped, there would be 50 spent sanding discs that would require disposal. Since the sanding discs are small, 50 spent discs would easily fit in a five gallon pail.

As discussed earlier, the cost for a one drum pickup is $185. The hauler, in this case, is required to send a truck to pick up the drum and the hauling company incurs cost for transportation and fuel. It is likely that a paint manufacturer would have other waste requiring pickup at the same time. Such manufacturers end up producing off-spec products at times and they may dispose of them as hazardous waste. If the company had additional waste drums for pickup, the cost for the first five drums would be $185 and the cost of disposing of the five gallon pail of spent discs would account for only a portion of that fee. To be conservative in the analysis, however, it was assumed that the only waste the company has accumulated is the five gallon pail of spent discs. On this basis, the one drum pickup fee of $185 and an environmental surcharge fee of 17 percent, the cost of disposing of the sanding disc waste would amount to $277 per quarter or $1,109 annually.

Table 2-2 summarizes three cases where water or water-based cleaners are used for the tank flushing. The first option is using plain water for the flushing operation and a polish with sanding discs. The second option is to use a water-based cleaner followed by the polish with sanding discs. The third option is to reuse the water-based cleaner for flushing the other four tanks followed by the polish.

The lowest cost option in Table 2-2 is to flush the tanks with plain water. Using the water-based cleaner but reusing the cleaner for all five tanks is the next highest cost option. Using the water-based cleaner on a one pass through for each tank is the highest cost option. The cost of using the water-based flushing option is lower, in all three cases, than the cost of using the methylene chloride stripper in one gallon containers.

<u>Pressure Washer Cleaning.</u> In this case, plain water would be used to clean the tank but, instead of using the flushing system, the worker would use a pressure washer. This option should be more

Table 2-2 Annual Cost of Flushing Tanks With Water and Water-Based Cleaner			
	Plain Water/ Discs	Water-Based Cleaner/ Discs	Reuse Cleaner/ Discs
Materials Cost			
Cleaner	-	$8,514	$1,703
Sanding Discs	$120	$120	$120
Labor Cost	$800	$800	$800
Hazardous Waste Disposal Cost	$1,109	$1,109	$1,109
Total Cost	$2,029	$10,543	$3,732

aggressive than flushing the system with plain water since pressure washers deliver a higher pressure spray.

Figure 2-4 shows one portable pressure washer from Northern Tool & Equipment that might be used to flush the tanks with plain water (www.northerntool.com). The system is portable and the unit could be left outside the tank and the worker could stand in the tank and clean it with the wand. The system is electrically driven and requires 230 volt power, it can achieve up to 3,000 pounds per square inch pressure and it delivers 2.5 gallons of cold water per minute. The worker would clean the tank from bottom to top and would have to stop periodically to evacuate the water from the tank. The spent water would be routed through the process hose to the wastewater treatment system.

The cost of the system is $799 and one company representative indicates it should last at least five years (Northern Tool & Equipment, 2012). Assuming the capital cost of $799, a five year life for the equipment and a four percent cost of capital, the annualized cost of purchasing the equipment is $166. Because the pressure washer could be used with high pressure if necessary to remove all the residue in the tank, no additional stripping with the sand paper would be required in this case.

The worker cleaning the tank would have to wear a water proof suit while using the pressure washer and would have to take all the confined space measures described earlier. It is estimated that the worker would require three hours to clean the tank thoroughly. Assuming a labor rate of $20 per hour and that five tanks would be cleaned four times per year, the annual labor cost would be $1,200.

The system is a five horsepower or a 3.73 kW unit. Assuming that 60 total labor hours would be required for the cleaning per year, 224 kWh of electricity would be required annually. Assuming an electricity cost of 12 cents per kWh, the annual cost of electricity would amount to $27.

The spent water used in the pressure washing system would be sent to the wastewater treatment system. As for the other water cleaning options, the incremental cost for treating this water is assumed to be negligible.

Figure 2-4. Portable Pressure Washer

Table 2-3 summarizes the cost of using the pressure washer to clean the tank and remove the uncured paint residue. The cost of using this option is lower than the cost of using the other water flushing options. This follows from the fact that no additional stripping with the sand paper is required.

Table 2-3	
Annualized Cost of Cleaning Tanks With Pressure Washer	
Annualized Capital Cost of Unit	$166
Labor Cost	$1,200
Total Cost	$1,366

Physical Abrasion

As discussed in the baseline case study cleaning, the methylene chloride stripping formulation may not completely remove all of the cured coating from the sides and bottom of the paint tank. Some hand abrasion will always be necessary as a final removal method or a polish. This option involves using sanding methods exclusively instead of using the methylene chloride stripper to completely strip the tank. This option would be necessary only if the paint tank was not cleaned with water and detergent before it cured. In effect, use of abrasive exclusively or chemical stripping is necessary only if the tank is cleaned after the paint is cured.

Stripping the entire tank with the DA sander and 40 grit sandpaper would likely require 10 hours of a worker's time and 50 pieces of sandpaper. Again, assuming a cost of sandpaper of $30 for a package of 50 pieces, the cost of purchasing sandpaper for stripping each tank would amount to $30. Cleaning five tanks would require five packages of 50 pieces or $150. Stripping the tanks four times per year would require $600 in material costs.

Each tank would require 10 labor hours to strip. Stripping the five tanks four times per year and assuming a labor cost of $20 per hour, the annual labor cost would be $4,000.

The sanding discs used in the abrasion process would require disposal. The discs would contain the small amount of chromium from the stainless steel tanks. In this case, however, they would not contain any solvent contamination. Instead of requiring incineration, the discs would be stabilized and landfilled at a cost of $52 per five gallon pail. Fifty pieces of sandpaper would be necessary for stripping each tank. Each time the five tanks are stripped, there would be 250 spent sanding discs that would require disposal. Since the sanding discs are small, it is likely that the 250 sanding discs would fit in a five gallon pail.

As discussed earlier, the cost for a one drum pickup is $185. The hauler, in this case, is required to send a truck to pick up the drum and the hauling company incurs cost for transportation and fuel. The paint manufacturer might have other waste requiring pickup at the same time. To be conservative in the analysis, it was assumed that the only waste the company has accumulated is the five gallon pail of spent discs. On this basis, the one drum pickup fee of $185 and an environmental surcharge fee of 17 percent, the cost of disposing of the sanding disc waste would amount to $277 per quarter or $1,109 annually.

In this case, like the case where methylene chloride is used, confined space practices would have to be observed. The same general procedures would have to be exercised in using the sanding discs for the tank cleaning.

Table 2-4 summarizes the annual cost of using the sanding discs in place of the methylene chloride chemical stripping formulation. Comparing Tables 2-1 and 2-4 shows that the labor cost for the stripping operation using sanding discs is the same as the labor cost of using the methylene chloride stripper to clean the tank. The total annual cost of using the sanding discs is 48 percent lower than the total annual cost of using the methylene chloride stripper in one gallon containers.

Table 2-4	
Annual Cost of Cleaning Tanks With Abrasive Sanding Discs	
Cost of Sanding Discs	$600
Labor Cost	$4,000
Hazardous Waste Disposal Cost	$1,109
Total Cost	$5,709

Alternative Stripping Formulations

The best option for cleaning the tanks, as mentioned earlier, is to have a regular cleaning schedule where water or a water-based cleaner is used to flush the tank directly after the paint has been produced. If that practice cannot be implemented, the paint will cure and the method used for cleaning the tank must be much more aggressive. Assuming the paint is cured, this option involves using a non-methylene chloride paint stripper to remove the paint from the tank.

In an earlier project conducted in 2006, IRTA worked with a stripping formulation supplier to formulate alternative strippers for testing that are safer than methylene chloride strippers (Morris and Wolf, 2006). The stripping formulations developed during that project were tested for conventional consumer product stripping applications, for on-site stripping contractor activities and with furniture stripping facilities. Such facilities generally use methylene chloride strippers. They must strip cured paint of all kinds on furniture and other items and they must be able to strip quickly so they can run a profitable business. Abrasive methods may damage some of the items they strip which can include antique furniture pieces. A chemical stripper must be used by these facilities.

Alternative chemical strippers are available on the market but they almost always contain N-methyl pyrrolidone (NMP) as one of the active ingredients. NMP is a reproductive and developmental toxin. It is listed on California's Proposition 65. In finding alternative chemical strippers for furniture stripping facilities in the earlier project, IRTA wanted to avoid the use of NMP because of its toxicity. The alternative stripping formulations that worked best in the project were based on benzyl alcohol. The Department of Health Services Hazard Evaluation System & Information Service (HESIS) evaluated the toxicity of the alternative strippers that were developed and also compared their toxicity to the methylene chloride strippers commonly used today. HESIS concluded that the alternative strippers containing benzyl alcohol are generally much safer for workers than the methylene chloride strippers.

Two of the alternative non-methylene chloride strippers performed well. One of the strippers, called #B96, stripped a range of coatings encountered at two furniture stripping facilities well. In particular, it was a better stripper than the traditional methylene chloride stripper for latex paint which is the type of paint produced at the hypothetical paint manufacturing facility. This stripper was specifically designed for use in a flow tray which is employed by furniture stripping facilities. The second stripper, which performed well for hand stripping at the furniture stripping facilities and might be suitable for consumer product applications, was called #B95. An MSDS for the B#95 hand stripper, the one that would be used for stripping the paint manufacturing tank, is shown in Appendix B.

IRTA analyzed the cost to the paint manufacturer for using the #B95 alternative stripper in place of the methylene chloride stripper. Two assumptions about the alternative stripping formulations were made for the analysis. The methylene chloride stripping formulation is very volatile since it contains methylene chloride and methanol and both chemicals have a very high vapor pressure and therefore a very fast evaporation rate. The first assumption is that only half as much of the alternative benzyl alcohol stripper would be required to complete the stripping task. Benzyl alcohol's vapor pressure is much lower than the vapor pressure of methylene chloride and it would correspondingly not evaporate as rapidly. The benzyl alcohol, which is the active ingredient in the stripper, would stay on the surface of the paint tank for a much longer period. During the stripping tests in the earlier project, the methylene chloride stripper did dry out much more quickly than the benzyl alcohol stripper and the furniture stripping workers estimated that twice as much methylene chloride stripper would be necessary to complete a comparable task (Morris and Wolf, 2006).

In this case, like the case of the methylene chloride stripper, the company could purchase the stripper in either one gallon containers or drums. The supplier who developed #B95 and #B96 indicates that the cost of either stripper in one gallon containers would amount to between $28 and $30 per gallon. The supplier estimates that either stripper would be priced at $924 for one drum quantities (Benco Sales, 2012). For each tank, 3.75 gallons of stripper would be required, half as much as the methylene chloride stripper. On this basis, stripping the five tanks would require 18.75 gallons of stripper. Assuming the tanks are stripped four times each year, 75 gallons of stripper would be used annually. Assuming the midpoint price of the one gallon container of $29, the annual cost of purchasing stripper in one gallon quantities amounts to $2,175 per year and the annual cost of purchasing it in drums would be $1,260.

Again, as was the case for the methylene chloride stripper, the benzyl alcohol stripper would not likely remove all of the cured paint and the worker would have to use an abrasive sand paper to completely remove the remaining cured paint. Again, assuming a cost of $30 for a package containing 50 discs and that 10 discs would be used per tank per cleaning, the annual cost of purchasing sanding discs for the abrasive removal operation is $120.

The labor for stripping the tanks in this case is the same as the labor required for stripping the tanks with the methylene chloride stripper. It would take a worker about eight hours to strip each tank. An additional two hours would be required for the abrasive removal to finish the tank. Assuming 10 hours are required to strip each of the five tanks, the labor requirement for stripping the five tanks four times each in a year, the annual labor requirement would be 200 hours. At a labor rate of $20 per hour, the annual labor cost for stripping the tank with the benzyl alcohol stripper and an abrasive removal polish would amount to $4,000.

Even though the labor requirement for stripping the tanks is likely to be the same, procedures that take into account the different characteristics of the benzyl alcohol stripper would have to be followed. The methylene chloride in the methylene chloride stripper is a small molecule that is able to penetrate the coating surface and lift the coating from the substrate in a fairly short period of time. The methylene chloride, with its high vapor pressure, will evaporate quickly, however, which is why more than one application may be necessary. The paint can be removed from the surface of the tank after the applications of the stripper. The benzyl alcohol stripper works differently. This stripper actually softens the paint and it takes longer to do so. Because the benzyl alcohol does not evaporate quickly, the one application is probably enough to soften the paint sufficiently for it to be removed. It may have to be left on a particular surface longer than the methylene chloride stripper. Workers may have to apply the benzyl alcohol stripper to each of the five tanks and then return to the first tank to completely remove the paint. Since the workers are applying paint to the other four tanks while awaiting the stripping action for the first tank, there is no net increase in labor required for the stripping.

The second assumption is that more waste stripper would be generated if the facility used the benzyl alcohol stripper in place of the methylene chloride stripper. This again follows from the fact that the methylene chloride stripper is much more volatile than the benzyl alcohol stripper. More waste benzyl alcohol from the used benzyl alcohol stripper will be left after stripping than from the used methylene chloride stripper. The same amount of paint solids will be generated in the waste in the stripping process with both stripping formulations since the paint residue is the same in both cases. Only half the amount of benzyl alcohol stripper is used since it remains on the surface longer.

In the baseline case, it was assumed that stripping each paint tank would generate one drum of waste containing about three-fourths paint residue and one-fourth methylene chloride. In the case of the the benzyl alcohol stripper, it was assumed that 1.25 drums of waste are generated from the stripping of the five paint tanks and that three-fourths of a drum are paint solids and half a drum is waste benzyl alcohol stripper. The benzyl alcohol stripper waste can be used in a blend for fuel because it does not contain halogens like the methylene chloride stripper waste. It is therefore less costly to dispose of than the methylene chloride stripping waste on a per drum basis. The disposal cost for each drum of benzyl alcohol stripping waste is $200 for a total cost of $400 per quarter. The disposal cost of the sanding discs in a five gallon pail will be $87 since the discs contain solvent. The two drums and the five gallon pail that are generated each quarter will require a pickup fee of $185. Assuming the surcharge fee of 17 percent, the total cost of disposal amounts to $3,144 per year.

Table 2-5 summarizes the cost of using the benzyl alcohol stripper with the abrasive polish to clean the paint manufacturing tanks. In comparing the total cost of using this stripping formulation with the total cost of using the methylene chloride stripping formulation in Table 2-1, the values indicate that it is about 14 percent less costly to use the benzyl alcohol stripper. Although the price of the benzyl alcohol stripper is much higher than the price of the methylene chloride stripper on a per gallon basis, much less of the benzyl alcohol stripper is required to accomplish the task.

Table 2-5
Annual Cost of Cleaning Tanks With Benzyl Alcohol Stripper

	One Gallon Containers	Drums
Materials Cost		
Stripping Formulation	$2,175	$1,260
Sanding Discs	$120	$120
Labor Cost	$4,000	$4,000
Hazardous Waste Disposal Cost	$3,144	$3,144
Total Cost	$9,439	$8,524

IV. RESULTS AND CONCLUSIONS

There are a number of paint manufacturers in California and many of them produce waterborne paint to satisfy the local market. Many of the plants manufacture paint in batch operations and the tanks used in the production must be cleaned between batches. Some companies currently use methylene chloride stripping formulations to clean the paint production tanks. The chemical is a carcinogen and is a dangerous chemical to use, particularly in confined spaces like paint production tanks. A worker recently died using such a formulation at a paint manufacturing tank.

This document focuses on a hypothetical paint manufacturing plant in California. This plant has five paint manufacturing tanks and workers clean them four times per year between production runs. The report establishes a baseline cleaning procedure used by the hypothetical plant. It then analyzes the feasibility and cost of using alternative practices, processes and cleaners for cleaning the paint tanks. The alternative methods that were analyzed are all safer for workers than using the methylene chloride formulations in the baseline case. In all cases, however, provisions for working in confined spaces should be exercised and workers should be trained to use them.

In the baseline case, IRTA assumed the paint manufacturer would allow the waterborne paint to cure in the five production tanks before they were cleaned. IRTA analyzed the cost of using the methylene chloride formulations for cleaning the five paint tanks four times per year for two cases. The first case involves purchasing the methylene chloride for stripping the cured paint from a hardware or home improvement store in one gallon containers. The tanks are seven feet by seven feet by nine feet deep with a narrow two foot wide opening on the top. Workers enter the tank on a ladder on one side of the tank. Using the one gallon containers offers a convenience to the worker in the restricted space. The second case involves purchasing the methylene chloride formulation in drums and metering it out into smaller quantity containers for the stripping. The methylene chloride stripping formulation may not completely remove the cured coating and sanding discs could be used to polish the tanks. The annual cost of stripping the tanks using the one gallon containers amounts to $11,010 and the annual cost of stripping the tanks using the drum quantities is lower, at $8,851.

The best alternative practice for the paint manufacturer is to schedule the tank cleaning directly after production. The product is pumped out of the tank into containers for sale and the tank could be cleaned directly afterward. If this practice is followed, the tank can be cleaned using plain water or water-based materials. IRTA analyzed the cost of using water in three different ways. First, the tank could be flushed with plain water using the tank process hoses. Second, the tank could be flushed with a water-based cleaner using the tank process hoses. Two cases of using the water-based cleaner were considered, one where the cleaner was used on a one pass through and the other where the cleaner used to clean the first tank was reused to clean the other four tanks. Third, the tank could be cleaned using a portable pressure washer. In the first two cases, the water and water-based cleaner flush may not be able to completely remove the paint so a polish with sand paper may be needed. The pressure washer is designed to use higher pressure if necessary so no sand paper polish will be needed with this option.

If the manufacturer does not clean the tank shortly after the paint is manufactured, it will cure and more aggressive stripping methods will be required. IRTA analyzed the cost of using sanding discs to strip all of the tanks in the event the paint cures. IRTA also analyzed using an alternative stripping formulation instead of the methylene chloride formulation for stripping the tank after the paint has cured. IRTA tested this formulation for stripping cured paint in an earlier project and it was demonstrated to be effective. The alternative formulation is based on benzyl alcohol and is safer for workers than using methylene chloride. Two cases were considered, one where the stripper is used in one gallon containers and another where the alternative stripper is used in drum quantities.

Table 3-1 summarizes the costs of the baseline case where methylene chloride stripper is used to clean five paint manufacturing tanks four times each year. It compares the cost of using the other options for cleaning the tank to the baseline case.

Table 3-1
Annual Cost Comparison of Options for Cleaning Paint Tanks

Option	Annual Cost
Methylene Chloride Stripping—One Gallon Containers	$11,010
Methylene Chloride Stripping—Drum Quantities	$8,851
Plain Water Flushing	$2,029
Water-Based Cleaner Flushing	$10,543
Water-Based Cleaner Flushing—Tank Recycling	$3,732
Plain Water—Pressure Washer	$1,366
Sanding Discs Abrasion	$5,709
Benzyl Alcohol Stripping—One Gallon Containers	$9,439
Benzyl Alcohol Stripping—Drum Quantities	$8,524

The baseline option of using the methylene chloride stripper in one gallon containers is the highest cost option. Using the methylene chloride stripper in drums reduces the cost. Both of these options entail the use of a solvent which is a carcinogen. Stripping the paint when it is cured with the benzyl alcohol stripper is somewhat less costly than using the methylene chloride stripper. Although using the benzyl alcohol stripper is better than using the methylene chloride stripper, it still exposes the worker to solvents in a confined space. Perhaps the best option for cleaning the tank if the paint cures is the sanding disc abrasion although it also has limitations. The worker, once again, must comply with confined space procedures and must wear protective equipment that will prevent airborne dust exposure to the paint residue. The abrasion option is less costly than using the chemical strippers.

The best options for cleaning the paint tank must be used before the paint is cured. Using plain water with the pressure washer is the lowest cost option of all. Because the pressure washer spray is aggressive, plain water can be used in this case. Using plain water for flushing the tank using the mixer in the bottom of the tank is also a low cost option. Using the water-based cleaner either with or without recycling the cleaning agent is more expensive than the plain water options, primarily because of the cost of the water-based cleaner. All of these options that rely on water are better from an overall health and environmental standpoint than any of the cured paint stripping options. Confined space procedures must still be followed, however, even when the water options are used.

Manufacturers of waterborne paint can use the analysis here for the theoretical plant to evaluate the different options for tank cleaning in their specific situation. Minimizing the cost is important but it is also important to minimize the worker and environmental impacts.

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