Blast Clean
ArcelorMittal

Team #4: Green Stream
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Dr. Ritter
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Final Report

(Prototype nozzle for soda blaster)

Containers and Residue  Soda Blast x2  Water Wash x2  Cleaned Drums (Test)  Recycle Containers

(Basic process of our solution)
Executive Summary

In order to reduce ArcelorMittal’s waste stream from the plastic drums and totes used to transport the chemicals used in the steelmaking process, we researched different ways to clean and then reuse or recycle the drums. We found that by using soda blasting (a power washer which uses sodium bicarbonate instead of water) in conjunction with traditional pressure washers combined with tests to determine the amounts of chemical residue in the drums, we could successfully recycle them in an environmentally friendly and profitable process.

Introduction and Problem Statement:

ArcelorMittal would like to reduce its impact on the Earth by reusing and/or recycling their chemical drums and totes.

Currently, ArcelorMittal disposess of all its chemical drums and totes used at their steel plants because they contain harsh chemical residue. This residual waste leads to decreased profit and increased damage to the environment. If this problem is not resolved in the near future, it will continue to have negative side effects that pose a threat to future generations.

This project will develop a way to reuse and recycle the company’s chemical drums and totes by creating a more efficient method of processing the drums, while still providing a process that is environmentally and economically sustainable. We intend to accomplish this task by studying the current disposal procedure as well as the properties of the chemicals contained in the drums and totes.

Definition of Sustainability:

We believe that sustainability is the use and maintenance of the Earth’s resources in ways that are able to support and strengthen the longevity and quality of the Earth and the lives of her inhabitants.
Background:

Chemical Research

**GE Depositrol:** EPA Standards call for a maximum concentration of 16000 mg/L before it is considered corrosive. Because the main hazardous component of the GE Depositrol is phosphonic acid, we can use a pH meter test to detect the concentration of hydrogen ions in chemical residue left in the barrels after the cleaning process, thereby giving us the concentration of the remaining chemical. Once we ensure that the concentration is below the EPA standard, we will know that the barrels are sufficiently clean [15].

**Propylene Glycol:** EPA Standards call for a maximum concentration of 5000 mg/L before it is considered corrosive. We can use an IR Spectrometer to test the concentration of the remnants of this chemical left in the containers after cleaning, as this instrument detects the Carbon-Oxygen bonds within the substance being analyzed-- since the propylene glycol is an organic compound of the formula C₃H₈O₂, this instrument will count the number of C-O bonds and thereby allow us to calculate the concentration of the remaining chemical [16].

**Ethylene Glycol:** EPA Standards call for a maximum concentration of 5000 mg/L before it is considered corrosive. We can also use an IR Spectrometer to test the concentration of the remnants of this chemical left in the containers after cleaning, as this instrument detects the Carbon-Oxygen bonds within the substance being analyzed-- since the ethylene glycol is an organic compound of the formula C₂H₆O₂, this instrument will count the number of C-O bonds and thereby allow us to calculate the concentration of the remaining chemical [17].
Cleaning Method Research

**Sand blasting:** One of our initial ideas for our cleaning process was sandblasting the barrels. This method works by blasting fine, abrasive particles at high speeds to clean a surface or, in our case, the inside of a container. While this process would work, the sand blasting method itself is abrasive and would require more work to clean up and separate the sand and chemicals from the barrel. Furthermore, it was unclear whether or not we could integrate the sand/chemical mixture into ArcelorMittal’s waste stream, which would provide another obstacle to deal with [19].

**Water washing:** Another option for our cleaning process was water washing, also known as power or pressure washing, which consists of sending a highly-pressurized line of water through a nozzle to clean a surface. While this method would be cheap and fairly effective, it was unclear how well the water would clean the chemicals from the barrels which was a risk we did not want to take, considering the necessity that the barrels must be ensured clean before anything else could be done with them [20].

**Soda blasting:** Our final big idea was to utilize a soda blasting method. This method is much like sand blasting or power washing, the main difference being that instead of sand or abrasive particles, it uses sodium bicarbonate as its cleaning substance. Since sodium bicarbonate is water soluble and biodegradable, we would be able to integrate this waste from this process directly into ArcelorMittal’s waste stream. We found this method to be highly effective, as it provides the same grade of cleaning as sandblasting without the issues of disposal or damage [21].
Recycling vs. Reusing Research

While researching how recycling the materials from the containers compared to reusing the containers to be refilled with chemicals, we found that reusing the containers posed a plethora of issues and obstacles for ArcelorMittal to face. According to the Occupational Safety and Hazard Administration, containers that once contained chemical may only be reused if: the containers are entirely cleaned of any chemical residue, the surfaces are stripped of any label once attached to them, and an MSDS (Material Safety Data Sheet) of the chemical is attached to each and every container. All of these requirements, however reasonable, would simply be too much of a hassle for ArcelorMittal to deal with. Furthermore, there would also be an obstacle with the chemical company providing them with these containers as many companies will not refill already used containers for the same liability and regulatory issues [22].

Recycling Facility Research

The US Recycling Facility is located at 1745 N. 7th Street, Harrisburg, PA 17102, which is approximately 6 miles from ArcelorMittal’s Steel Plant in Harrisburg. This short distance makes recycling the valuable materials leftover from ArcelorMittal’s steelmaking process very opportune with very little cost for transportation and minimal fuel emissions [18].

Cost Research

Initial Investment:
Industrial Power Washer = $4,738 [5].
Heavy-Duty Soda Blaster = appx. $2,000 [4].
IR Spectrometer = appx. $3,000 [10].
Total Investment = $9,738
Recurring Costs:
Sodium Bicarbonate (10 drums/$40 bag) = $528 [3].
Transportation (12 miles per round trip to recycling facility) = $6.60 [14].
Energy = minimal/negligible compared to other costs [2].
Water (264 gallons tap water) = $1.06 [11].
Total Recurring Costs (per ton of processed material) = $535

Return Profit:
Recycled Steel (1 Ton) = $360 [9].
Recycled Plastic (1 Ton) = $800 [18].
Total Profit: $1,160

Net Gain per Ton of Recycled Material = $625

Customer Needs:

The customer needs our group deemed most important were cost efficiency, waste reduction and environmental friendliness. The design goal of our project was to create a system that reduced waste and did not harm the environment-- for this reason, these needs were at the top of our priority list. ArcelorMittal would not want to adopt our system if it was going to be costly, therefore, a cost efficient system was also one our most important customer needs.

The need of a safe system for both employees and Mother Earth was also high on our list of customer needs, as ArcelorMittal would not want to adopt a dangerous system.

We wanted to create a system that only used a small amount of ArcelorMittal’s resources. With minimal capital usage, ArcelorMittal would not have to alter its current production processes to make room for our system. Ranked as importantly as minimal capital usage is sustainability. Obviously environmental sustainability is one of our goals, but sustainability for the company is also integral so that our system could continue to function for years to come.
Ranked lowest among our customer needs were a quick process and a positive company image. While these needs are important and were definitely kept in mind throughout our design process, they are greatly outweighed by the more crucial needs.

**AHP Matrix**

*Table 1: The following table is our AHP Matrix which allowed us to properly weight the criteria we needed to incorporate into our design according to our customer’s needs.*

<table>
<thead>
<tr>
<th>Needs</th>
<th>Reduce Waste</th>
<th>Cost Efficient</th>
<th>Positive Image</th>
<th>Environmentally Friendly</th>
<th>Safe</th>
<th>Sustainable</th>
<th>Quick Process</th>
<th>Minimal Capital</th>
<th>Total</th>
<th>Weight</th>
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Concept Generation:

Initially we had multiple ideas of what to do with the drums and totes-- but from the beginning, it was clear that the process of recycling would be split into 2 phases; Phase 1 would be the cleaning step and Phase 2 would be the reusing step.

For Phase 1, we initially thought of neutralizing the chemicals inside the barrels. However, this would not work due to the cost of the chemicals-- plus, there was no easy and efficient way to test whether the solution inside the barrels would be neutral. The second idea was to sandblast the barrels. The issues with sandblasting, however, is that it is abrasive, messy and would be difficult to separate from the barrel once blasted inside of it. We also considered water washing the barrels, but realized we would not be able to be absolutely certain of whether the chemicals were completely cleared or not. Other ideas included vaporizing the liquid and breaking down the barrels and then cleaning them-- unfortunately, however, both of these would be too cost intensive. Ultimately, we decided to go with soda blasting, as it would not be very cost intensive nor highly corrosive, but would ensure cleanliness in the barrel. Furthermore, the sodium bicarbonate is water soluble, so when the barrels are cleaned with water, it will be removed along with any other contaminants.

Assuming the barrels are clean from Phase 1, we would then proceed to Phase 2-- the reusing step of the project. Our first idea was to shred the clean barrels, then put them back into the steelmaking process. However, this would involve a high start up cost of purchasing expensive metal shredders; this would also be highly inefficient energy-wise. Our second idea was to reuse the barrels, but this would require a high level of safety checks which would involve more bureaucracy and would be highly time consuming. The last idea that we went with would be to send the now clean barrels to a recycling plant. This would result in a slight source of revenue as they pay to purchase these steel barrels.
Concept Selection:

After looking through our customer needs we split our system into three separate parts, cleaning methods, testing methods, and opportunities to reuse or recycle the cleaned drums. For cleaning methods we considered using a chemical reaction to neutralize the drums, pressure washing, sandblasting, and soda blasting. After researching the chemical properties of the chemicals used in ArcelorMittal’s steelmaking process, it became clear that this solution would not be viable because it would be very difficult to achieve the conditions required for the possible reactions to occur to any substantial extent, and there also were no simple means of converting the chemicals into significantly more stable products. Next we investigated traditional power washers; we were able to find many patents on different techniques for cleaning chemical barrels. Our challenge will be to use these ideas as a springboard to develop a simple, safe, and cost efficient method for ArcelorMittal to clean the drums. An alternative to power washing the drums is sand blasting, which would offer superior cleaning ability, but with the costs of being more abrasive against the plastic drums, and creating a larger mess which would require additional cleanup. The last option we considered was soda blasting, a technique used for stripping paint and cleaning large surface areas. It works much the same way as power washing or sandblasting, except it sprays particles of sodium bicarbonate. The advantages of soda blasting are that it is very effective at removing residue, does not damage the surface underneath, is biodegradable, and water soluble. For these reasons in conjunction with a fairly low initial cost, simple procedure, and predicted reliability, our team selected the method of soda blasting to be the cleaning process of our final solution.

Our next challenge was to find a reliable way to test the contents of the barrels and prove that they were clean. In order to ensure the cleanliness and safety of the chemical containers after they undergo our cleaning process, we needed to provide a method of testing that would give solid proof
that the containers would not be harmful or hazardous in any way to meet standards set by the EPA. For the GE Depositrol we determined that a simple pH test using a pH meter would be sufficient to prove that the chemical was well below EPA limits. One of the main components of GE Depositrol is phosphoric acid, and it has a known mole fraction in the chemical. Using this information and the known $K_a$ value of phosphoric acid it is easy to work backwards and determine the concentration of the chemical. Since the Diethylene Glycol and the Propylene Glycol are neither acids nor bases, we needed a different test. We decided to use an infrared spectrometer analysis to determine the concentration of the chemicals remaining in the drums. This analysis works much the same was as a breathalyzer and can determine the concentration of the carbon oxygen bonds in the solution. The spectrometer is able to determine this because each bond has a specific bond energy that will resonate with a specific frequency of infrared light. From this value it is then a simple calculation to determine the concentration of the chemicals left in solution.

Once the drums are cleaned and tested we are still left with the problem of what to do with them. One possibility is reusing the drums to carry more chemicals, but this faces the problems with the manufacturers because they are often unwilling, and in some places legally prevented from accepting used drums. Another possible solution would be to recycle the drums, but for this solution to work we would need to first need to reach out to the recycling plants and show them that the barrels are cleaned and meet all EPA standards as well as finding an economically viable way to get the drums to a recycling plant. After researching recycling facilities close to the ArcelorMittal factory in Harrisburg and finding that soda blasting was a viable solution for the cleaning step of our solution, our team concluded that recycling the containers would be a better solution than reusing them, and thus, the final step of our solution was decided.
Table 2: This table depicts our Concept Selection Matrix which helped our team decide which of our proposed solutions would work best to resolve ArcelorMittal’s problem based on how each assessed the predetermined criteria from our AHP Matrix (Table 1).

<table>
<thead>
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<th></th>
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</tr>
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</table>

This final design process of soda blasting and double washing the drums, then testing them to confirm they are clean, and sending them to be recycled meets all of the customer needs and design requirements. It completely reduces the waste of the barrels and drums, and provides a more sustainable and profitable method for ArcelorMittal to deal with their steel and plastic chemical drums.

This system could be easily implemented onto their facilities and would require minimal training, just to ensure that the workers knew how to operate the soda blaster and the pressure washer. The chemical testing would just require the purchase of a pH meter and a infrared spectrometer, and to improve the overall feasibility of the process you would not have to test each and every barrel. Instead
employees would only need to test a randomly selected drum out of every 10 or even 100 drums to prove that the process is still meeting EPA controls.

**Design Review:**

Throughout the overall review process, Team 2 generally liked our solution; they thought that the soda blasting process was a great way to clean the barrels and that our two different purity tests should be very manageable. Their biggest concerns and suggestions for improvement were to expand on our cost analysis and show that the cleaning and recycling process would be economically viable for ArcelorMittal to implement in their facilities. In order to expand on this, we would need to get a more accurate assessment of the transportation of the empty drums to the recycling facility. We would also need to come up with a more accurate cost assessment of the soda blaster, taking into account the equipment and the need for maintenance and operation. The final step to seeing the economic viability of this process would be to research how much the recycling companies would pay per ton of recycled material from the plastic totes/barrels and metal drums. The last step in moving from our current state to our final report and presentation is to update the SolidWorks model of our pressure washer head.

Based on the feedback provided by Team 2, we fortunately don’t have to change our core idea much. We will keep all of the main ideas in place, but also take into account the waste stream of the water coming out of the barrels and whether we need to treat the wastewater from the cleaned drums, or if we can just send it down the drain and incorporate it into ArcelorMittal’s already existing waste stream. We would also need to confirm that the recycling plants will be willing to accept the drums and totes by showing how our cleaning process works, and that the two tests (pH test for GE Depositrol, and an infrared test for the propylene glycol and ethylene glycol) would show that the contaminants are well below the EPA limits. Moving forward we would also like to suggest that ArcelorMittal work with the chemical companies to be able to reuse the drums since it is better for the environment than recycling
them, as it would require far less energy. This would also be a plausible option since the soda blasting
doesn’t damage the substrate (material being cleaned) and the tests would be able to provide proof that
the barrels are no longer contaminated, thus solving the two reasons that chemical companies currently
can’t reuse the drums, totes, and barrels. That being said, we believe our solution can be improved and
adjusted to resolve ArcelorMittal’s current problem and help them become a more economically and
environmentally sustainable company.

3D Model/Prototype/Images of process, etc:

Figure 1: This diagram shows a pictorial explanation of drum/tote cleaning process.

The above diagram depicts our solution process from start to finish-- in which we take the
containers with chemical residue, soda blast them twice with our prototype nozzle (see below) and
water wash them twice to ensure that they are clean. We will then test the cleanliness of the containers
using the pH and IR Spectrometer tests described in our background section. After proven clean by our
testing methods, we will transport the clean containers to a nearby recycling facility.
Our model for SolidWorks depicts our prototype nozzle that we would suggest ArcelorMittal use for both the pressure washing of water and the soda blasting process. The nozzle has a hole at the bottom to wash the bottom of the barrels but also has holes to the sides angling in all directions so that the barrels can be washed completely with one nozzle in one swift motion. This prototype nozzle was created for maximum efficiency and will ensure that our cleaning process is thorough and successful.

Systems Diagram:

Figure 3: This system diagram highlights the inputs and outputs in our system, and shows a detailed step by step explanation for how our blasting process cleans the drums/totes, and ensures that they are safe to be recycled.

For our system of cleaning the drums and totes, the required inputs are: water, sodium bicarbonate, and energy to run the pressure washer and soda blaster, as well as the chemical drums and...
totes and the chemical residue inside the barrels. The last input to consider would be the fuel required for the shipment of the soda to the plant, as well as the fuel required to ship the drums to the recycling plant. Fortunately, there are nearby recycling plants which can handle the drums and totes which will limit the consumption of fuel.

The outputs of this process are wastewater containing small amounts of GE Depositrol, Propylene Glycol, and Diethylene Glycol as well as the sodium bicarbonate. The sodium bicarbonate is biodegradable and the chemicals when below the EPA limits can be disposed of the same way as the rest of ArcelorMittal's waste water [1]. The clean drums can then be taken and recycled at the recycling plant. This system is sustainable and would benefit the plant, city, region, and state by reducing the amount of chemical waste in the plants, and providing new readily available raw materials in the recycled plastic and steel which can then be used locally. Also, the wastewater wouldn’t have any noticeable negative side effects because it wouldn’t have a significant impact on the amount of wastewater that the plant produces.

Cost and Feasibility Analysis:

Table 3: The following table summarizes the total initial costs of the investments ArcelorMittal will need to make in order to implement our solution.

<table>
<thead>
<tr>
<th>Initial Investment</th>
<th>Industrial Power Washer</th>
<th>Heavy duty Soda Blaster</th>
<th>IR Spectrometer</th>
<th>Total</th>
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<tbody>
<tr>
<td>Price</td>
<td>$4738</td>
<td>$2000</td>
<td>$3000</td>
<td>$9,738</td>
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Table 4: The following table summarizes the recurring costs ArcelorMittal will need to pay in order to maintain our solution over time.

<table>
<thead>
<tr>
<th>Recurring Costs /1 ton</th>
<th>Sodium Bicarbonate 10 drums/ $40 bag</th>
<th>Transportation (12 miles)</th>
<th>Energy</th>
<th>Water (264 gallon tap water)</th>
<th>Total</th>
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<tbody>
<tr>
<td>Price</td>
<td>$528</td>
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</table>

Table 5: The following table summarizes the total profit ArcelorMittal will make per 1 ton of recycled steel and 1 ton of recycled plastic after paying back the initial investment costs.

<table>
<thead>
<tr>
<th>Return Costs</th>
<th>Ton of Recycled Steel</th>
<th>Ton of Recycled Plastic</th>
<th>Total</th>
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<tr>
<td>Price</td>
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<td>Net Gain/Ton</td>
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By recycling .5 tons/day it would take ArcelorMittal it would take about 32 days to pay back the initial costs then they would begin to make profit. ArcelorMittal could alternatively choose to reuse the barrels directly instead of recycling them.

ArcelorMittal would not have to change anything significantly to integrate our system. There are already government regulations placed on the chemical properties of the water that can be washed down the drain but after the soda blasting and pressure washing, the chemicals will be diluted enough to enter into general waste water streams. Thus, the adoption of our solution by ArcelorMittal is readily feasible, as it abides by government regulations and will not endanger the environment.
Life Cycle Analysis:

**Figure 4:** *This diagram shows how our process would change the drums/totes current cradle to grave life cycle into a cradle to cradle life cycle by cleaning and then recycling the drums into new products.*

Our proposed solution will resolve ArcelorMittal’s current issues with excess waste by recycling the valuable materials that make up the chemical drums, barrels, and totes. Instead of these containers being disposed of due to the chemical residue left inside after use, our system will clean them thoroughly and transport them to a nearby recycling facility. This solution eliminates the disposal step from ArcelorMittal’s involvement in the containers’ life cycles. Furthermore, when the containers reach the end of their use for ArcelorMittal, they will be recycled so that their life cycle starts anew once more—thus, exhibiting the cradle-to-cradle life cycle model (following the cyclical flow of green arrows in the diagram) as opposed to the cradle-to-grave cycle that they currently undergo (linear flow of blue/grey arrows).
Conclusions:

The best aspects our system has to offer is that it is simple, straightforward, economically feasible for ArcelorMittal to implement, and both economically and environmentally sustainable. The processes used, soda blasting and pressure washing, create byproducts that can be washed down the drain and sent to a water treatment facility like any run-of-the-mill waste water. ArcelorMittal also has the option to recycle the barrels at a recycling center or send them back to the chemical plant to reuse them directly. By reusing or recycling the barrels ArcelorMittal. However the company would need to pay the initial costs and the costs of operation back before they get can make a profit.

To further develop the system for the future, some change we can make would be to find a way to more efficient use of some of the resources we use, such as sodium bicarbonate, water and energy. We can also integrate a shredder into the system to compact the area of the barrels and make trips to the recycling centers less frequent, lowering emissions.

Our group learned there is never a single, straightforward solution to a problem. We learned that the best way to approach a problem is to keep an open mind and consider every potential solution for the most successful concept generation process. We also learned more about the steelmaking process as well as the consideration that goes into the life cycle of every material used in industrial processes.
References:


Pictures on poster:
http://snowwhiteservices.com/wp-content/uploads/2012/02/Services_Soda-Blasting.jpg
http://socialinnovation.se/wp-content/uploads/2012/03/triple-bottom-line2-519x480.jpg
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http://www.cs2inc.com/environmental.html