SUSTAINABLE DEVELOPMENT: A GUIDE TO PLATING COST EFFICIENCY

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ABSTRACT

The pursuit of the UN goal on Sustainable Development is one of the commitments of Nexperia to our customers as part of its Corporate Social Responsibility. This ensures that the future generations will have the resources to continue building a bright future. This paper is an approach on how the ATCB Plating Sustaining Engineering Team performed a sustainability development project through combined approach of Waste Management Hierarchy and DMAIC.
This challenges the team to focus on 1. Optimizing the plating chemical usage by (a) isolation tank Pb ppm limit was changed from 80ppm to 120ppm, (b) change of control method monitoring from AAS to RoHS-XRF. 2. Reduction of Tin (Sn) anode waste and 3. Change of belt stripping chemical mixture, formulated inhouse that extended usage life from 1 week to 6 months.
This sustainability development project generated a total of **$1,160,689** cost savings through groundbreaking process control and optimize use of materials and chemicals. This also resulted in considerable reduction of health and safety risks to our Chemical Handlers, Technicians, Laboratory Analyst and Operators as their daily exposure to hazardous chemicals are minimized. Consequently, this project resulted in efficiency in manufacturing operations, optimized use of energy-resources, and lessen hazardous waste disposal to environment.

1. 0 INTRODUCTION

In 1987, The UN released the Brundtland Report, defined Sustainable Development as: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Referred also as Intergeneration Equity Principle, the idea is to achieve development in harmony with society and environment.

Fig1. Sustainable development pillars

The ATCB plating sustaining engineering team performed a sustainability development project as we move towards sustainable engineering, through the combined approach of Waste Management Hierarchy and DMAIC methodology.
All of these are part of our strategy towards optimized used of resources and minimizing waste generation as part of our social and environment responsibility.

1.1 Objective

The main objective is to generate a Sustainable Development centered project that is measurable. This can be achieved by optimizing the material and chemical volume usage and reduction of chemical waste. The primary metric to measure will be the total cost of chemical used. The secondary metric falls under intangible benefits which will be operational efficiency, social and environmental sustainability.

1.1.1 Sustainable Engineering

A working definition of sustainable development is: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).
On the 2030 Nexperia $10Billion company goal, sustainable development strategy is part of this. To be sustainable, a complete approach should be considered on quantity of waste, quality of waste, and cost of waste produced by the plant. In this way, sustainability is increased as these factors directly address the bottom line which is environment, social impact, and economics.

1.1.2 Sustainable Strategy

Problem solving methodologies and process/product improvement methodologies are two terms with different starting points but with same goals to achieve a better process/product.
When one is trying to solve any process problem or simply trying to improve the quality of the product, the worst trap could be that the balance of the whole system is sacrificed for a localized fix or improvement.
The continuous improvement framework intends not only to optimize one process, but to improve the whole organization. Such improvements include not only increasing product quality and efficiency or reducing defects inside the organization; they also include improving the organization’s financial, customer satisfaction and representation, as well as benefiting, workers, environment, and society.

1.2 Project Scope

Scope of the project will be limited to ATCB Central Plating activities which includes the use of various plating chemicals, and Sn Anodes.

This study will focus on the three major waste contributors which are the Tin plating chemical, Tin (Sn) Anode balls and electrolytic belt stripper mixture.

2.0 REVIEW OF RELATED LITERATURE

2.1 Waste Management

Waste is defined as any unwanted materials which are discarded after use. US Environmental Protection Agency (US EPA) provided a structured way to tackle waste management. The inverted triangle below showed the hierarchy from the most preferred to the least preferred, such as Source Reduction and Reuse, Recycling, Energy Recovery and Treatment & Disposal.

Fig2. Waste Management Hierarchy

2.2 RoHS

Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) EU rules restricting the use of hazardous substances in electrical and electronic equipment to protect the environment and public health.

Last 2003, EU laws adopted the restriction of identified hazardous substances that includes Pb. This is known as the RoHS directive (for Pb = 1000ppm).

EU RoHS COMPLIANT

2.2.1 Lead, Pb Contamination on Clipbonded products

The ATCB Clipbonded (CB) packages assembly process is illustrated on below assembly map.

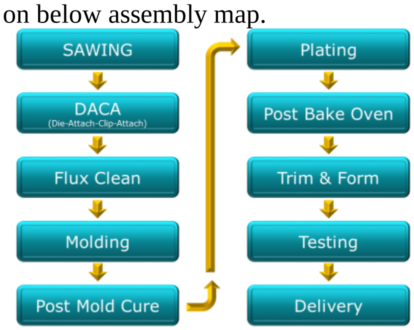


Fig3. Assembly Flow of CB Packages

During the clip bonding process (DACA), a 95%Pb solder is used to attach the clip frame to the bottom frame. An external Pb joint is exposed on the clip as shown on fig5.

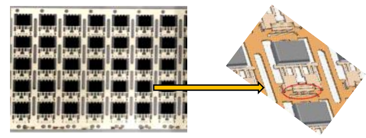


Fig4. Clipbonded package (exposed Pb)

During the plating process the exposed solder joint on the clip to frame is chemically etched. The etched Pb solder is being co-deposited as Pb contamination on the plated parts of the package.

A correlation chart between the dissolved Pb on the plating bath vs. the co-deposited Pb on the unit was established last 2011 using atomic absorption spectrometry (AAS).

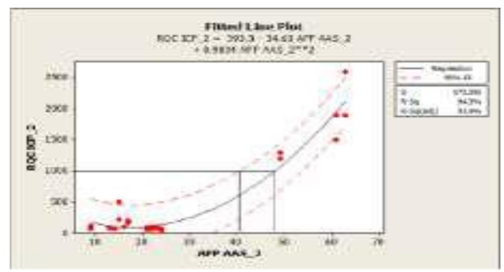


Fig5. Correlation between Co-deposited Pb and Pb in the Plating bath

From the correlation chart, Pb ppm on the package is controlled through the Pb content level of the bath solution. Chemicals with high Pb content reading are disposed and replenished with new formulations (also term as Feed and Bleed).

2.2.2 Plating Bath Life

Plating bath life determines the time in which chemicals are changed. These are based on either time of use or particle impurities content such as carbon, Sn^{4+}, Pb or other foreign heavy metals present on the plating bath.

2.2.3 Isolation Tank

One innovative idea implemented before is the use of an isolation tank.

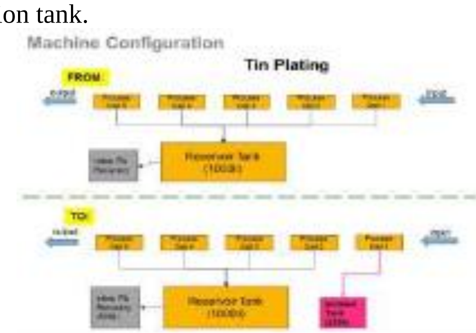


Fig6. Machine Configuration

Previous studies proved that the Pb dissolution on the clip solder joint occurs only on the first 12 seconds of exposure to chemical bath, afterwards Sn electroplating plating occurs preventing further dissolution of Pb on the plating bath. Isolating the first process cell with a separate tank dramatically restricts the Pb contamination on the first chemical sump tank.

2.2.4 Pb Analysis Method

Current ATCB capability is to control the Pb content of the Plating bath via Atomic Absorption Spectrometer (AAS).

Fig7. PG-500 AAS(Left); RoHS XRF (Right)

Pb content on the plating bath is monitored daily by our chemical laboratory analyst. Once the Pb content reaches its respective control limits, Bleed & Feed activity is performed.

2.3 Role of Anode in Electroplating

The Plating process is done on an electrolytic cell in which an electric current causes the transfer of Metal Ions from the anodes (Metal Source) to the Cathode (Leadframes) via Red-Ox reactions.

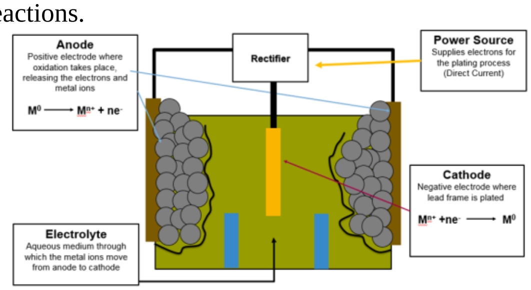


Fig8. Major components of an electroplating cell

2.3.1 Sn Anode Polarization

During the Plating Cell PM activities, used anode balls are removed, these are then clean using DI water and returned to plating cell. Small anodes are being discarded as part of process controls.

Fig9. Passivated Anode balls (Left); Fresh Anode balls (Right)

The darker appearance of the washed anodes are signs of polarization as shown in the chemical half reaction below.

$$Sn^{2+} + H_2O \rightarrow Sn(OH)_2$$
$$Sn^{4+} + H_2O \rightarrow Sn(OH)_4$$

Pure Sn anodes washed with water, hydrolyze easily forming $Sn(OH)_2$ and $Sn(OH)_4$. Stannic and Stannous hydroxides are tenacious compounds which are difficult to rinse off. These minute particles contribute to plating inefficiencies such as poor plating deposit, low plating thickness and formation of chemical bath sludges.

2.4 Importance of Belt Stripper Quality

Belt stripping is part of a high-speed strip to strip tin plating process. The purpose is to remove the tin deposits around stainless belt which holds the Leadframes that can build up overtime.

Figure10: Stripping location on the conveyor belt

Failure to remove these Sn build up during the belt cycle would eventually affect quality of product being plated such as Sn flakes and contamination.

Belt stripping evolution started from immersion using Nitric acid which is toxic and is prohibited nowadays because of its hazard level. Conversion to electrolytic belt stripping was then implemented using Methane Sulfonic Acid (MSA) as the base. The original mixture has a usage life of only one week due to turbidity and fast buildup of sludge.

Various commercially traded chemicals formulated by experts are being manufactured abroad (outside Philippines). To have a longer stripper usage life and better belt and clip life span, it would be easier to just import and qualify it. However, with the experienced issues on logistics of imported chemicals, constant supply is at risk. A challenge now arises for the team to develop a better belt stripper formula in-house that would address the issue on turbidity and sludge build-up.

2.5 ATCB Plating Chemical Cost

Total Chemical cost for Plating at ATCB Last 2021 cost at almost $2.816M.

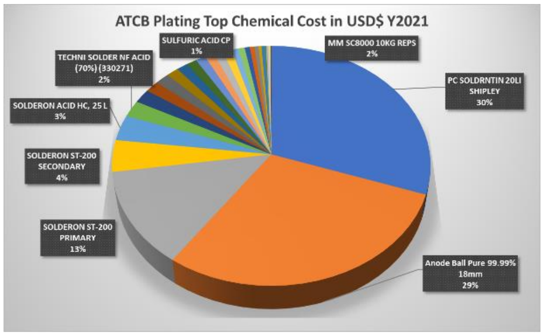


Figure 11: Y2021 ATCB Plating Chemical Cost in USD

Figure12 shows the top contributors for ATCB chemical cost last 2021. Basically, these are the components of the plating process cell, the ST-200 chemistry, Electrolytic stripper chemicals (Techni Solder Acid), and Sn Anode balls. 81% of the total costs are consumed by these three major items.

3.0 METHODOLOGY

3.1 Define

The plating process has massive amount of waste by product. The monthly average cost of waste for the top 3 contributors sums up to a total to about $108K per month.

For plating chemical Solderon ST-200, waste generated is about 70% of the fresh chemical at around $95K, disposed as acidic hazardous waste. Sn Anodes amounted to about $10K as scrap metal and electrolytic belt stripper acid at $3K as acidic hazardous waste also.

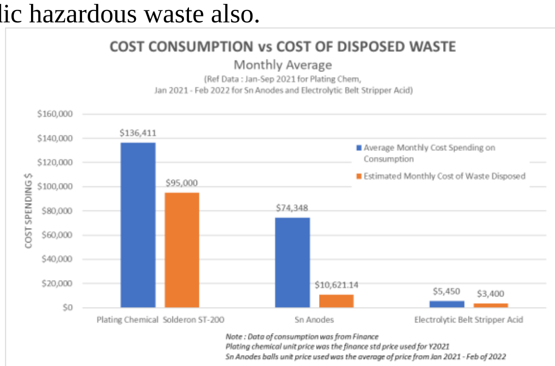


Figure 12: Q1'2022 Consumption vs Waste

The initial project goal was to create a cost saving of $500K, that is about 45% waste reduction on the overall three top contributors for a 12-month period.

The team categorize the plating waste on 3 different level.:

- Hazard level
- Volume [Usage and Disposal]
- Cost

Start

Process Name (Sub-Process)	Chemical Name	Hazard Level		Usage / Disposal Level				Cost Per Month		Priority Ranking
		Form of Waste	Waste Classification	# of Machines	Dumping Frequency	Tank Volume	Average Disposal Volume Per Month (Liters)	Average withdrawal Cost Per Month	Estimate Average Disposal Cost Per Month	
DEFLASH	SUPRACLEAN DF-11	Liquid	Corrosive	8	Annual	5430 L	556	$4.4K	$0.44K	
DEFLASH	SLOTOCLEAN DF-11	Liquid	Corrosive	3	Monthly	1250 L		$3.6K	$0.16K	
DEGREASER	SURCLEAN 201	Liquid	Corrosive	8	Monthly	1590 L	1590	$0.7K	$0.21K	
	NaOH DEGREASER			8				$0.7K	$0.05K	
Cu DESCALE	RONAETCH Cu DESCALE	Liquid	Corrosive	6	Monthly	1040 L	1040	$2.7K	$0.31K	
	SULFURIC ACID Cu DESCALE			6				$1.3K	$0.05K	
Ni DESCALE	SURNIAC DA	Liquid	Corrosive	5	Monthly	970 L	970	$2.6K	$0.31K	
PREDIP	TECHNI NF ACID PRE-DIP	Liquid	Corrosive	1	Monthly	80 L	2395	$0.003K		
	SOLDERON ACID PRED-DIP	Liquid		4	Weekly (for clip bonded)	420 L		$1.1K		
				5	Monthly (for sensors and wirebonded)	635 L				
PLATING	**SOLDERON TIN**	**Liquid**	**Corrosive Toxic**	**8**	**Yearly**	**10190 L**	**14999**	**$136K**	**$5K** for periodic dumping **$95K** for the BLEED (Take-out used chem) and FEED (Put in fresh chemical)	**1st**
	SOLDERON ACID									
	SOLDERON PRIMARY									
	SOLDERON SECONDARY									
	RD CONCENTRATE									
PLATING (isolation tank)	**SOLDERON TIN**			**4**	**Every 2-3 days for clip bonded**	**485 L**				
	SOLDERON ACID									
	SOLDERON PRIMARY									
	SOLDERON SECONDARY									
	RD CONCENTRATE									
PLATING	**99.9% Sn Anodes 18mm diam**	**Solid**	**Heavy Metal**	**8**	**Monthly**	**2500 Kg**	**~300 Kg**	**$180K** (at a price of $42.7Kg)	**~$10K** (at a price of $42.7Kg)	**2nd**
NEUTRALIZER	PT-11	Liquid	Corrosive	5	Monthly	710 L	1025	$1.7K		
	E260	Liquid		4	Monthly	315 L		$2.8K		
ANTI-TARNISH	TARNIBAN C48	Liquid	Corrosive	4	Monthly	420 L	420	$2.4K		
ELECTROLYTIC BELT STRIPPER	**NF ACID**	**Solid**	**Corrosive Heavy metal**	**6**	**Weekly**	**3250 L**	13000	**$5.3K**	**$3.4K**	**3rd**
	PRIMARY ADDITIVE	**Liquid**								

End

Table2: Plating Sub-Process Flow

Table 2 categorizes the plating sub-processes. Focus was given to the Hazard level, Volume usage/disposal level, and monthly cost. The Plating chemistry of Solderon ST-200 (a mixture of Solderon tin, Solderon acid, Primary additive, Secondary additive, and RD concentrate), Belt stripper (a mixture of Technic-NF acid and Primary additive) and Sn anode balls are the priority chemicals after ranking was done.

Profiling the financial data in terms of cost spending for withdrawal of fresh chemicals, the Plating chemical Solderon ST-200) has the highest contribution with a total 56%. This is followed by Sn Anodes balls at 27% then NF acid for electrolytic belt stripper at 2%. See fig.14

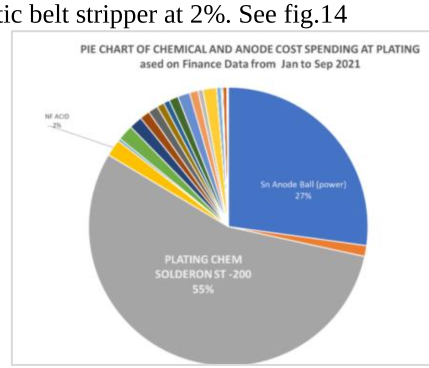


Fig 13: Plating Chemical Spending Jan-Sept Y2021

3.2 Measure

The goal of the team for the measure phase of this project was to determine what data needed to be collected to understand the current state and the impact that potential X's (chemicals) had on the Y (daily waste generation).

The primary metric which is cost saving is calculated as follows:

***Cost Save= Base line Consumption* Unit price – Actual Consumption*Unit price*

The team developed a measurement plan for secondary metrics after considering the following questions:

- What metrics need to be tracked.
- Where the metrics have already been captured.
- If not, what measurement needs to be used for data capture and who will own the information.

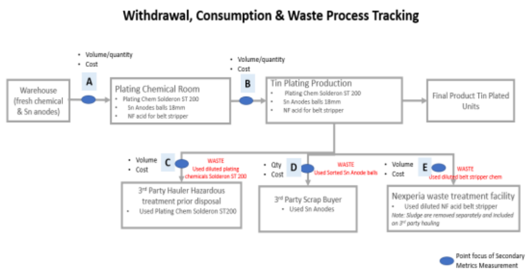


Fig14: Withdrawal, Consumption & Waste Flow Chart

Point A: There is SAP system that generates the data, members from finance cost analyst share weekly with the team data generated.

Point B: Considered as a critical point for monitoring to profile consumption per machine per chemical.

Point C, D & E: Are considered waste byproducts that are expected to be minimized or reduced.

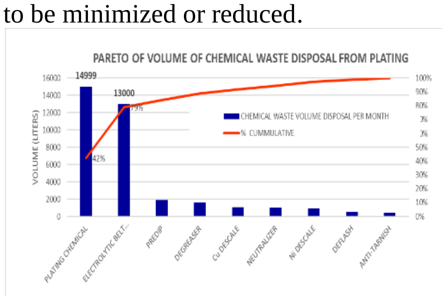


Fig 15: Pareto of Volume of Chemical Waste Disposal from Plating

3.3 Analyze Phase

The process source of chemical waste generated is analyzed. For plating chemicals, it was identified that large volume of chemical waste is coming from the bleed and feed activity. Bleed means pull-out the used chemical and feed or add with a fresh chemical.

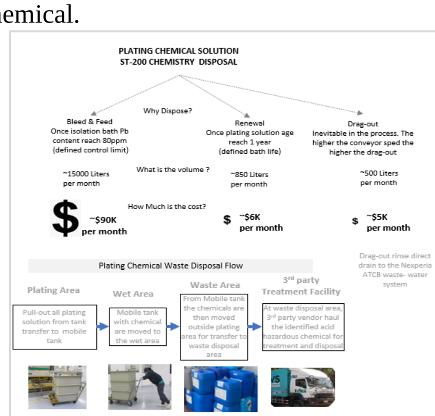


Fig 16: ST-200 Waste Analysis

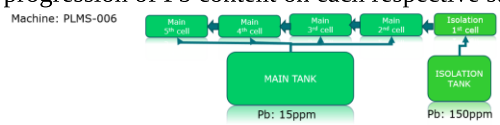
Figure.16 illustrates the plating chemical waste generation and disposal flow. It shows here the Plating process controls that requires chemical disposal, average volume of disposed, and cost of chemical being disposed.

3.3.2 AAS vs XRF-ROHS Pb ppm determination:

For a long time, the AAS method has been the standard test to measure the Pb content in the plating chemicals. The Pb co-deposited with tin has been analyzed using the non-destructive XRF fluorescence method.

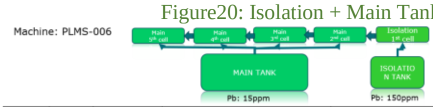
3.3.3 Segmented Pb reading per Plating Process Cell

To identify the impact of isolation tanks, two evaluation legs were performed. 1st leg is running dummy Leadframes using normal process with isolation and main tanks turned-on. 2nd leg is running dummy Leadframes using isolation tank only. Deposited Pb were measured on each process cell to check progression of Pb content on each respective stage.



ISOLATION TANK Pb in Plating Solution	MAIN TANK Pb in Plating Solution	Pb Content in Tin-Plated Leadframe (ppm)						Plating Thickness –Heatsink (um)			
		Row1	Row2	Row3	Row4	Row5	Ave	Row1	Row2	Row3	Ave
ON 150ppm	ON 15ppm	101	103	110	111	121	**109**	8.34	9.33	11.68	**9.78**
ON 150ppm	OFF	80	119	137	131	156	**124**	2.09	2.26	3.01	**2.45**
OFF	ON 15ppm	33	32	26	28	46	**33**	5.14	6.18	8.02	**6.44**

Figure20: Isolation + Main Tank On



ISOLATION TANK Pb in Plating Solution	MAIN TANK Pb in Plating Solution	# of Pass	Pb Content in Tin-Plated Leadframe						Plating Thickness -Heatsink				Visual	Solderability				Morphology
			Row1	Row2	Row3	Row4	Row5	Ave	Row1	Row2	Row3	Ave	2LF	0hr	8hrs Steam age	16hrs Dry bake	Reflow	Ok
ON 150ppm	OFF	1st Load	101	103	110	111	121	**125**	2.09	2.26	3.01	**2.45**	passed	passed	passed	passed	passed	Ok
		2nd Load (1 add-plate)	80	119	137	131	131	**284**	4.31	4.77	5.74	**4.94**	passed	passed	passed	passed	passed	Ok
		3rd Load (2 add-plate)	169	286	356	312	396	**388**	6.42	7.55	8.8	**7.59**	passed	passed	passed	passed	passed	Ok
		4th Load (3 add-plate)	329	492	471	497	527	**464**	8.86	10.33	11.55	**10.25**	passed	passed	passed	passed	passed	Ok
		5th load (4 add-plate)	471	495	540	513	544	**513**	11.35	12.72	12.92	**12.33**	passed	passed	passed	passed	passed	Ok

Figure21: Isolation Tank Only

The average Pb ppm on each run were measured and compared. Pb ppm on the 2nd run (Isolation tank only) showed significant increase on Pb ppm (average of 513ppm) compared to Isolation and Main tanks (average of 109) turned-on.

With the use of RoHS XRF, more accurate controls can be established compared to the traditional AAS which is based on Chemical bath correlation.

3.3.4 Third Party Laboratory Confirmation

With confirmatory readings on the new XRF Tester, Plated samples from different plating lines and processed on various dates and conditions were collected and analyzed for its Pb ppm content. All reading shows Pb ppm content are at below

10% of ROHS required limit.

	Machine	Date Processed	Shift	Package	Batch	REMARKS	Main	Isolation	XRF READING					AVERAGE
A	STS 8	16-Feb	B	SOT1205	MLPB060430100	Normal Production Run	13.92	110.65	49.18	46.57	44.93	78	46.2	52.98
B	STS 2	16-Feb	B	SOT1210	MLPB06006300	Normal Production Run	9.95	60.46	ND	19.16	ND	14.24	8.5	8.38
C	STS 8	25-Nov	B		dummy	Before B&F , Isolation ON , Main tank off	12.87	102.65	ND	4.37	33.77	ND	ND	7.63
D	STS 7	16-Feb	B	SOT 669	dummy		10.12	86.1	96.02	21.3	61.34	48.86	60.02	57.51
E	STS 7	23-Nov	A	SOT 669	dummy	Before B&F Isolation ON , main off	9.59	88.06	ND	ND	ND	ND	ND	0.00
F	STS 3	16-Feb	C	SOT1207	MFPB06001200	Normal Production Run	-	-	ND	ND	ND	ND	ND	0.00
G	STS 8	23-Nov	B	SOT 669	dummy	Before bleed and feed, isolation tank only	11.97	96.4	ND	ND	ND	ND		0.00
H	STS 7	23-Nov	A	SOT 669	dummy	Before bleed and feed (7-1)	9.59	88.06	78.28	23.72	ND	41	14.91	31.58
I	STS 7	23-Nov	A	SOT 669	dummy	Before bleed and feed , Miain Tank On , Isolation	9.59	-	ND	ND	ND	ND	ND	0.00
J	STS 8	25-Nov	A	SOT 669	dummy	Before B&F	12.87	102.65	71.21	74.47	62.43	78	62.47	69.72
K	STS 8	23-Nov	B	SOT 669	dummy	Before bleed and feed	9.59	88.06	ND	5.42	21.38	74.23	ND	20.21
L	STS 8	25-Nov	B	SOT 669	dummy	New bleed and feed	4.97	31.47	50.43	20.07	27.53	37.28	92.01	45.46
M	STS 8	25-Nov	B	SOT 669	dummy	Newly B&F , Isolation ON , Main tank OFF	-	31.47	ND	ND	ND	ND	ND	0.00
N	STS 8	25-Nov	B	SOT 669	dummy	Newly B&F Maintank ON, Isolation OFF	4.97	-	11.19	14.47	ND	40.09	19.06	21.20
O	STS 8	25-Nov	B	SOT 669	dummy	Before B&F Main tank ON , Isolation OFF	4.97	-	32.22	ND	14	14.33	44.05	20.92
Q	PCEM 1	16-Feb	B	SOT 404	MNPB06077300	Normal Production Run	-	-	ND	ND	ND	ND	ND	0.00
R	TECHNIC	16-Feb	C	SOT1188	MAP1306001300	Normal Production Run	-	-	30.55	22.87	70.69	45.5	20,32	42.40

Table 3: RoHS-XRF analysis results of Pb ppm in Sn Plated Leadframes

The new Pb ppm limit at the isolation tank was set from 80 to 120ppm to study if there a changed in co-deposited Pb ppm in plated product. Measurement results on plated Leadframes using the ATCB's RoHS-XRF tester showed that at within 120 Pb ppm level in isolation tank, the Pb ppm are still less than 15% of the RoHS defined limit.

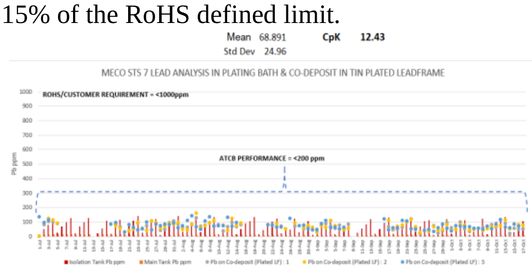


Figure 22: Pb content on Sn Plated Leadframes processed on MECO STS-7

3.3.5 Sn Anodes Waste Minimization

The source and reason for the Tin (Sn) metal for scrap was investigated. A major source was identified, which is the sorting and scrapping of anodes during preventive maintenance.

Use of DI water only in cleaning Sn anodes is not enough. The polarized surface can be minimized by soaking in acid solution at a certain concentration of about 10% to etch out the oxidized surface. Methane Sulfonic Acid (MSA) is a generally and commonly used acid. The addition of this acid soak step greatly reduces the formation of stannous and stannic hydroxides when returned to plating process cell. Cleaning with DI water and MSA is an effective way to treat anode balls for production use.

Fig 23: Tin Anode Sieve and its dimension

3.3.7 Electrolytic Belt Stripper

Belt stripper weekly renewal generates about 1.3 tons of toxic chemical waste in the form of liquid and sludge.

An experiment to determine better formulation with an objective to prevent sludge build-up to minimize hazardous waste generation was performed.

Laboratory experiment was done to determine the best formula that would give compact deposit in cathode plate, maintain solution clarity & less attack on belt.

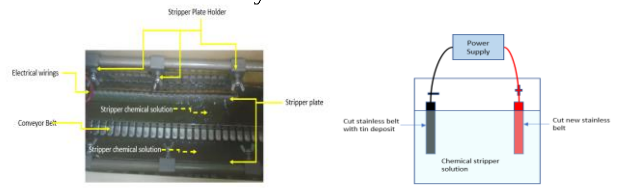


Fig24: Electrolytic Stripper configuration (Left) & Laboratory Set-up (right)

In determining the turbidity and tin deposit appearance & adhesion use new stainless belt as the cathode and used stainless belt with tin deposits as the anode. The volume of solution is 1 liter, refer to Table 1 for the concentration of various legs. Apply 3 amperes for 3 minutes.

	Concentrations	Turbidity		Tin Deposit Appearance & Adhesion
		Before	After	
Leg # 1: Original Mixture	MSA : 200ml/l Plating Additive: 10ml/l			Tin deposit is loose, easily comes off the belt
Leg # 2: Eval Mixture	MSA : 200ml/l Plating Additive: 5ml/l Plating Anti-oxidant: 5ml/l Used plating solution:5ml/l Used Stripper Solution: 60ml/l		Clear solution as compared to Leg #1 & Leg #2	Tin deposit is compact, does not come off from belt
Leg # 3: Eval Mixture	MSA : 200ml/l Used plating solution:65ml/l Used Stripper Solution: 60ml/l			Tin deposit is loose, easily comes off the belt

Fig25: Stripper Formulation vs Turbidity, Deposit, appearance, and Adhesion

	Concentrations	Weight reduction of belt	Belt appearance
Leg # 1: Original Mixture	MSA : 200ml/l Plating Additive: 10ml/l	0.29 grams	Belt etching visible, luster is lost and turns to whitish color
Leg # 2: Eval Mixture	MSA : 200ml/l Plating Additive: 5ml/l Plating Anti-oxidant: 5ml/l Used plating solution:5ml/l Used Stripper Solution: 60ml/l	0.18 grams	Less belt etching visible, some portion still retain its luster
Leg # 3: Eval Mixture	MSA : 200ml/l Used plating solution:65ml/l Used Stripper Solution: 60ml/l	0.14 grams	Visible chemical attack on belt, roughness on surface is evident

Fig26: Stripper Formulation vs Belt Appearance and Belt Weight Reduction

Based on observation Leg # 2 stripping solution mixture has less turbid and better appearance of tin deposit. It is compact and not easily detached from the belt.

In determining impact on belt chemical attack, belts with no tin deposit both on cathode and anode are used (see figure 26). The volume of solution is 1 liter, Table 1 shows the

concentration of various legs. 3 amperes current is applied for 3 minutes.
The original solution Leg#1 has more weight reduction on stainless belt compared to Leg # 2 & Leg #3. The presence of tin metal in the solution, from the used plating solution is observed to minimize the aggressive attack or chemical etching of belt. In terms of visual appearance Leg# 2 is better as it retains the luster in some portion of the belt.

Chemical Component	Concentration
Tin	1.2 g/liter
Acid	200 ml/liter
Primary Additive	11 ml/liter
Secondary Additive	0.1 ml/liter
Antioxidant	5.2 ml/liter

Table 4: Chemical Component Concentration for Leg#2

After the identified success in laboratory design of experiment, the result was validated in production run.
Better performance was observed in the improved mixture. Solution clarity was maintained after seven days of continuous operation and no sludge build up seen in cell tank. The comparison of original vs improved solution is shown below.

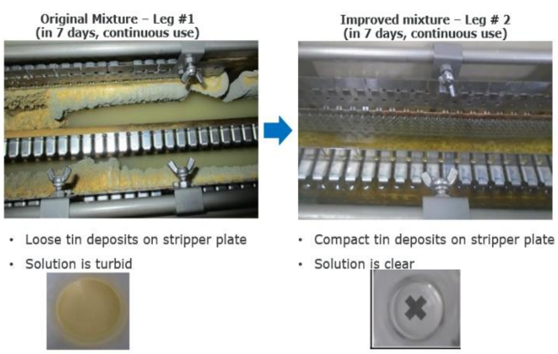


Fig27: Stripper Formulation vs Belt Appearance and Belt Weight Reduction

3.4 Improve Phase

Improvement action plans to save cost through waste minimization were summarized. Risk assessment was also considered. The estimated cost savings were identified per action plan and the investment needed.

IMPROVEMENT AREAS	IMPROVEMENT ACTION	RISK ASSESMENT	ESTIMATED COST SAVINGS PER MONTH	ESTIMATED COST OF INVESTMENT	PRIORITY #
Plating Chemicals Solderon ST-200	**Redefine Pb control limit on Isolation Tank** From: 80ppm To: 120ppm	No Risk - passing all quality test required Underwent TCN , QCM, TRB	**$30K**	None	1
	Redefine plating bath life - renewal From: Yearly To: Once metallic impurities and carbon content reach control limit	No Risk - Monthly pulled-out of chemical and bath cleaning during preventive maintenance was implemented to control and minimize contaminants	**$5K**	None	2
	Redefine control monitoring for Pb From: Pb content in plating solution analysis through AAS To: Pb content analysis on plated products using XRF (Other ROHS restricetd element like Cr,Cd & Hg will also be monitored)	No Risk - passing all quality test required Set - control limit to 500ppm vs customer/ROHS 1000ppm Will undergo TCN, TRB QCM	**$20K**	$60K	6
	Recovery and Re-use of plating chemical solution. From: Disposal through 3rd party To: Removal of Pb contaminnants through precipitation using sulfuric acid	No Risk - passing all quality test required Will undergo QCM & TRB	**$10K**	$75K	7
	Recovery of plating drag-out From: Drag-out rinse direct to drain To: Drag-out rinse replenish to plating main tank for recovery	No Risk Will undergo QCM	**$5K**	$60K	8
Sn Anode Balls	**Re-use of sorted anodes**	No Risk - passing all quality test required	**$6K**	None	3
	Stop in-line and offline Pb recovery using Sn anodes	No Risk - passing all quality test required	**$8K**	None	4
Electrolytic Belt Stripper	**Improve chemical formulation** **To address turbidity and sludge formation** From: NF acid (MSA): 200ml/L Primary Adidtive: 10ml/L To: NF acid (MSA): 200ml/L Primary Adidtive: 5ml/L Used platig Solution: 5ml/L Used Stripper Solution: 60ml/L	No -risk It improve quality by minimizing belt flakes	**$3.5K**	None	5

Table5: Improvement Plan Prioritization Table

Identified improvement plans were rank with regards to its impact in terms of cost savings and effort in terms of investment.
A simple 2x2 matrix in decision making was used as a guide in terms of prioritization.

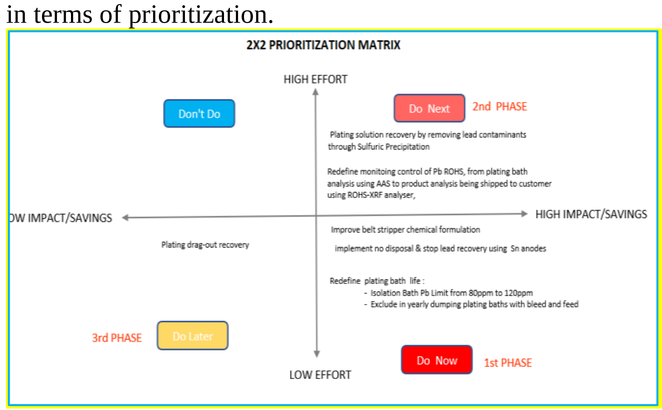


Fig28: Prioritization Matrix

In general, the combined concept of a 2x2 matrix and the waste management hierarchy (see figure 2) was applied in generating the implementation timeline shown below.

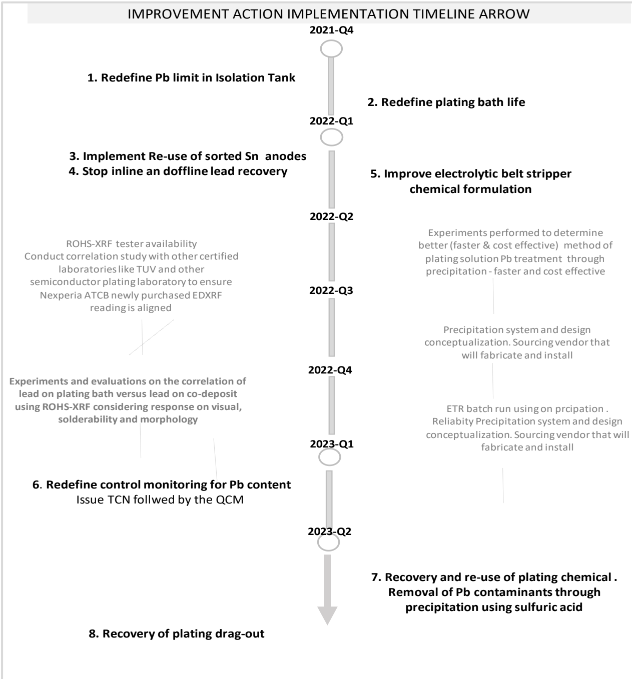


Fig29: Timeline Arrow for improvement actions

3.5 Control Phase

3.5.1 Database monitoring system

The system that is being developed will monitor usage and inventory on real time usage per machine. Later this can also be tracked to prevent wrong chemical replenishment that will risk quality of product and increase chemical wastage.

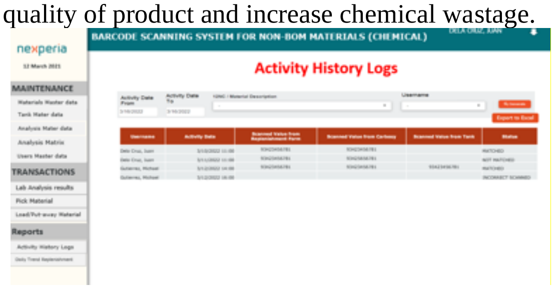


Fig 30: Sample screen of the data base system for chemicals

3.5.1 SPC charting for Pb content on the product

An SPC system was established to monitor our Pb content on product, this would also provide automatic alerts for all of the stakeholders.

Fig31: Sample Illustration SPC charting showing specs limit.

3.5.3 Documentation Updates

Documentation update of Working Instructions, PFMEA (Process Failure Mode and Effect Analysis) and update of the control plan were done. Critical changes were enrolled under Quality Change Management (QCM).

4. RESULTS AND DISCUSSION

Plating chemical cost savings initiative through waste minimization started Q4 of last year 2021. With the implemented improvement actions on the 1st phase of the over-all project, the volume consumption reduction of top contributing chemical (ST-200 Solderon) resulted to a quarterly average of 42.5%.

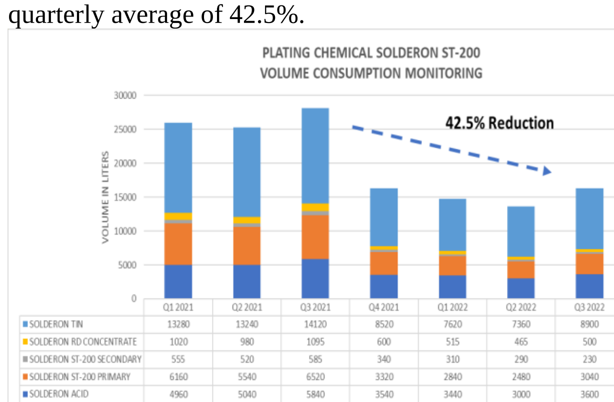


Fig 32: ST-200 Chemistry Cost Reduction Chart

For plating chemicals, hard cost savings were computed in reference to agreed normalize baseline of consumption and price of Y2021, Total of Hard cost savings of **$866,649.**

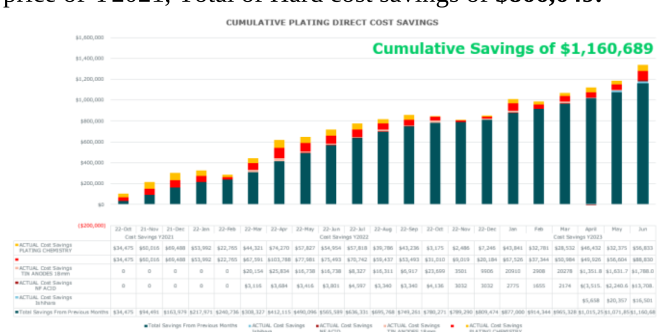


Fig 33: Cumulative Hard Cost Savings from Plating

The improvement action on Tin anodes started March year 2022. For eight months the team able to reduce consumption from a monthly average of 2,464kgs to 2,113kgs that is equivalent to 14%.

For NF acid, chemical used for electrolytic belt stripping, a hard cost savings was computed in reference to agreed normalize baseline with finance. A cummulative hard cost savings of $134,719 was achieved.

Total cumulative **hard cost savings** accounted for in the 1st phase of the project combining savings on plating chemical, Sn Anodes, NF acid was **$,1160,689**

Apart from the hard cost savings, the improvement actions also impacted the whole organization. Table 7 shows the summary of the overall tangible and intangible benefits as defined primary and secondary metrics.

AREA OF WASTE REDUCED	PRIMARY METRICS ACHIEVED	SECONDARY METRICS ACHIEVED
Plating Chemicals Solderon ST-200	Cost Savings : $ 616, 213 (Oct 2021 to Oct 2022)	• Reduce safety hazard for chemical handlers • Greener environment, reduced hazard waste disposal • Ease logistics with the 42.% reduction of volume • Reduce schedule downtime alloted for bleed and feed activity from 6hrs per week to 2 hours per week per machine • Improve 5S, with the reduction of bulk chemicals stock inside and outside plating area
Sn Anode Balls	Cost Savings : $ 143,719 (March 2022 to Oct 2022)	• Reduce safety hazard, eliminate use of nitric acid to clean corrogated plate use for inline and offline recovery • Reduce manpower - there was operator alloted for offline recovery • Ease logistics with in consumption • 5S improvement
Electrolytic Belt Stripper	Cost Savings : $ 29,429 (March 2022 to Oct 2022)	• Reduce safety hazard for cehmical handlers and operators • Greener Environment • Ease logistics • Eliminate sludge effluent to waste water system • Eliminate schedule downtime alloted for belt stripper solution replacement from 4 hrs per week per machine to zero as replacement can be parallel with the preventive maintenance schedule • Filter usage reduction alloted for stripper solution reduce by 75% • Conveyor belt life span improved • Flakes defect occurence reduction. flaking happens after renewal of belt stripper solution. Renewal is from every week to every 6 months • 5S improvement

Table 6: Summary of Project Impact

5. CONCLUSION

The team was able to internalize the need for a balance environment, workers safety, product quality and financial gain.The success in reducing plating waste is a sustainability development with the combined approach of Waste Management Hierarchy and DMAIC methodology.

Plating chemical waste is minimize through optimizing the plating chemical usage by; (a) isolation tank Pb ppm limit change from 80ppm to 120ppm – implemented; (b) change of control method monitoring from AAS to RoHS-XRF – in progress (c) Reduction of Tin (Sn) anode waste – implemented. (d) change of belt stripping chemical mixture, formulated in–house that extended usage life from 1 week to 6 months – implemented.

The massive reduction in waste generated from plating process, reduced the over-all plating chemical and tin anode consumption gaining an over-all hard cost savings of **$,1160,689** from the start of its implementation.

6. RECOMMENDATIONS

Continuation of phase 2 in reference to Improvement Action Implementation Timeline Arrow – Recover & Re-use in the waste hierarchy management.

7. ACKNOWLEDGEMENT

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