Best Practices and Hazards associated in Gold Refining

MMTC-PAMP

IGPC Delhi 15 Feb. 2024

An MKS PAMP GROUP Company

Overview of Presentation

1. MMTC-PAMP India Pvt Ltd
2. Best Practices in Refinery
3. Fine Gold and its effect
4. Effect of Base metal and Deleterious elements in Refinery process
5. Hazards associated in Gold refining

MMTC-PAMP- most trusted precious metal ecosystem

MMTC-PAMP

REFINER

Only LBMA Accredited Gold and Silver Refinery in India

Products covering entire value chain for customers

For B2B Customers

- ✓ Bullion
- ✓ Master Alloys
- ✓ Minted Products
- ✓ Old Gold Recycling
- ✓ Industrial products
- ✓ Standard Reference Material

For Retail Customers

- ✓ Gold and Silver Coins
- ✓ Digital Gold
- ✓ Buyback of Old Gold

Presence Across Digital and Physical Channels

- ✓ Counters across 145 cities
- ✓ More than 700 jewellers
- ✓ Across Amazon, Flipkart, AJIO and own platforms

Government and Industry Stakeholders

- Indian Government Mint
- BIS Hallmarking
- World Gold Council
- Swiss India Chamber of Commerce

MMTC-PAMP has put India on the global map of precious metals

1 WORLD'S HIGHEST STANDARD OF QUALITY

- The **only LBMA accredited Good Delivery** Gold and Silver refinery in India.
- The only mint outside UK to be **licensed by Royal Mint for minting Sovereigns**.
- **BIS accreditation** for 999 and 995 Gold 100 g and 1 Kg bullion bar

2 BRINGING RESPONSIBLE GOLD TO INDIA

- India's first and only LBMA independently audited and certified **Responsible Gold & Silver compliant refinery.**
- Certified (audited) member of **Responsible Jewellery Council** and member of its global board.
- **CII Sustainability Plus gold certificate 2016**
- Certified by **Responsible Jewellery Council (RJC)** for COP (Code of Practice) and CoC (Chain of custody) standards

3 IMPECCABLE MANUFACTURING STANDARD

- **SA 8000 certified**, a first for any precious metals refinery in Asia and one of only two such in the world
- ISO 9001:2015, ISO 14001:2015, ISO 45001:2018, ISO 50001:2018 certified facility.
- **Accreditation for ISO 17025:2017**

4 LEADING LOCAL INNOVATION & POLICY

Best Refinery award from:

- Bullion Federation & ASSOCHAM –4 since 2016
- IIGC & IBJA – 5 times since 2013
- GJTCI – 1 times since 2018

MMTC-PAMP is India's first precious metal company to have science based emission reduction targets approved by SBTi

MMTC-PAMP has set science-based targets consistent with limiting climate warming to 1.5°C

Commitment to reduce absolute scope 1 and 2 GHG emissions - 47% by FY 2029/2030 from a FY 2018/2019 base year and scope 3 emissions by 27.5% within the same timeframe

MMTC-PAMP has already implemented 705 KWp of solar energy panels, actively contributing to decarbonization and minimizing its carbon footprint

Reinforces our commitment to sustainability as the first precious metals company[1] in India to have science-based carbon emissions reduction targets approved by the Science Based Targets initiative (SBTi)

1 Best Practice in Refinery

Processes in Refinery

1. Pyrometallurgical process
2. Inquartation and Parting
3. Chemical refining - Aqua Regia digestion and precipitation
4. Electrochemical Refining
5. Acid less separation (ALS)

Introduction

- Primary Recovery and refining of gold from dore , jewelry scrap and other waste involves use of Pyrometallurgical processes.

- Chemical & electrochemical techniques such as Inquartation & Parting, Aqua regia, Electrolysis etc. are mostly used to achieve a purity of 99.9% and more.

- The impurities which are usually associated with gold are varied namely Ag, Cu, Zn, Sn, Fe, Ni, Co, Bi, Al, Te, Se Cd, Pb , PGM (Ir, Ru, Os) which needs to be removed to arrive at required fineness. This can be estimated by proper analysis before we start the process

- The selection of the refining technique depends on various factors such as:

  - end product requirement
  - gold content and impurity content including Silver
  - physical and chemical characteristics of the material
  - inventory holding capability
  - economic feasibility based on factors such as quantity , availability , location etc.
  - available expertise and skills
  - safety & environmental regulations .

Major Pyrometallurgical Techniques

The main processes used for Gold Recovery and Refining are as follows:

Incineration Burning of waste material having precious metal with an aim to remove moisture and organics

Volatilization Removing all metal including silver by applying vacuum and heat

Oxidation
(a) Roasting - Eliminates oxidizable metals such as Se, Zn, As etc., as fumes and also enables selective leaching of impurities such as Sn, Sb etc.,
(b) Cupellation - using lead to remove all base metal and leave gold and silver as alloy

Chlorination Purging of pure chlorine in molten metal and base metal as insoluble chloride (Miller process)

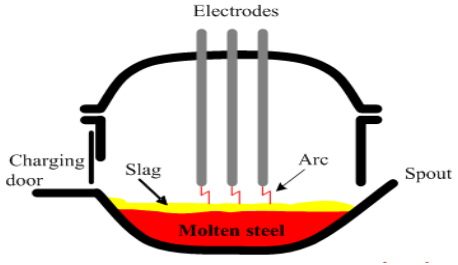
Equipment used in Pyrometallurgical process

Incineration

Induction furnace
(Induction heating)

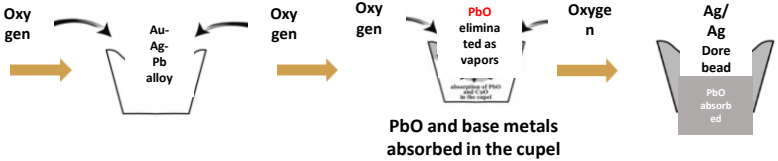
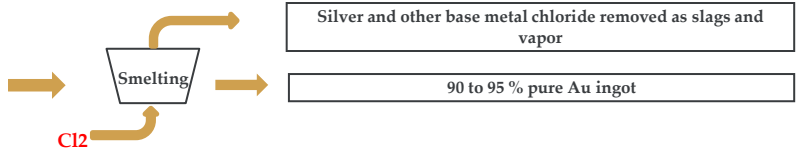
Mini Resistance
Furnace

Top Blown Rotary
Furnace (fuel fired)

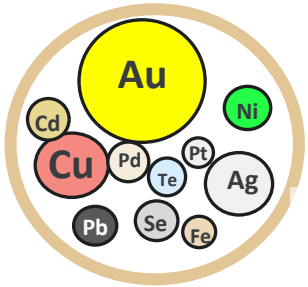


Electric Arc Furnace
(high voltage heating)

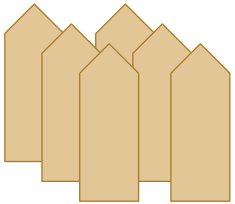
Major techniques in gold refining

TECHNIQUE		PROCESS FLOW DIAGRAM	SCOPE OF THE PROCESS
Cupellation	**Crude gold with lead as major impurity**		• Now restricted to being used only as an assaying technique and in few cases of refining due to potential lead hazard. • The process is usually followed by nitric acid digestion which yields 95 to 99.0% Fine gold
Miller Chlorination	**Crude gold with Silver as major impurity**		• Here, chlorine gas is bubbled into the molten raw gold to remove silver as its chloride slag for later recovery. • This process yields gold with fineness ranging from 90 to 99.5% based on the other impurities present.
Inquartation	**Crude gold/jewelry scraps having all kinds of impurities**		• A popular technique used predominantly by the jewelry industry. • Raw gold alloy is made up such that the gold concentration of the resulting alloy goes below 1/4th or <25% of the original alloy. • Here, the feed granules digested in nitric acid removes all the base metal impurities and Ag leaving behind >95 to 98% fine Au
Digestion & Cementation/ Chemical refining		**" THESES ARE MORE POPULARLY USED TECHNOLOGIES WHICH WILL BE DISCUSSED BRIEFLY IN THE PRECEEDING SECTIONS "**	• These are widely used technologies for refining gold to purities >99.9%.
Electro-refining/ Wholwill's Process			• While both process can be used to obtain fine gold of almost similar quality, electrorefining technique has an upper hand in terms of resource efficiency, environmental compliance and product quality

ELECTRO REFINING

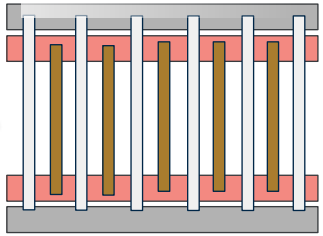


DORE



ANODES

ELECTROLYSIS

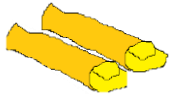


RECYCLING

GRAINS

Melting

SPONGE

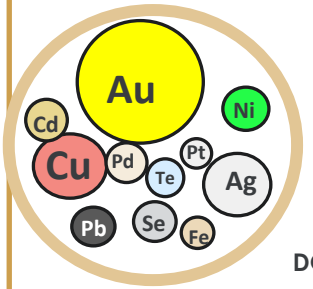


Melting in Tunnel Furnace

24K Bullion Product

CONSUMED ANODES

CHEMICAL REFINING



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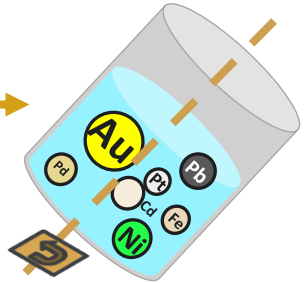


DISSOLVED IN AQUA REGIA

24K GOLD

CEMENTED GOLD

SMBS

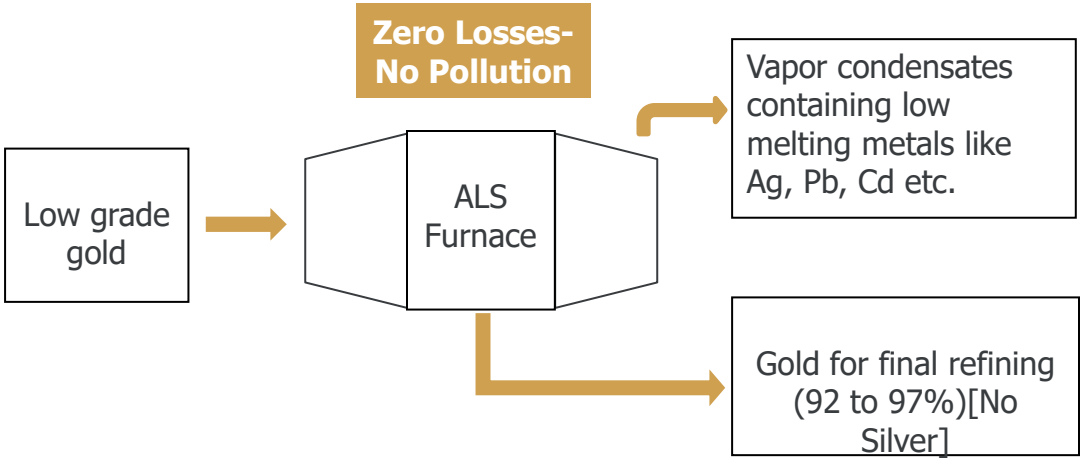
PRECIPITATION

What are the advantages & disadvantages

Parameters	Electro Refining	Chemical Refining
Scale of Operation	Suitable for large scale	Suitable for small scale
Fineness of Refined Silver	99.99% & above	99.95% maximum (99.99 by selective PPT)
Impurities in Refined Silver	Adhering to limits as specified in ASTM B 413 on individual as well as cumulative basis	Presence of deleterious elements is common
Operating cost	Low labour and chemical cost per unit of production; electricity cost is higher	Higher operating unit ; electricity cost is lower
Inventory in Process	Big inventory carrying cost	Cost of inventory in WIP is much lower
Effluent Generation	Controlled generation	Consumption of chemicals is more; generates more effluent during washing and final effluent per unit of production is higher
Quality of Jewellery produced	Higher productivity and lower rejection rate due to absence of deleterious element	Manual intervention leads to presence of impurities like Fe, Pb, Cu which lead to hard spots , oxidation , brittleness in final product

Acid less Separation (ALS) - the latest technology

This patented technology is gaining popularity with large scale refiners lately. Under application of high vacuum on molten gold, all impurities including Ag having melting temperature lower than gold becomes volatile and are removed in their metallic form. Elements like Cu, Fe, Ni, Co having melting temperature close to that of gold or more cannot be removed by this process. It is claimed that gold purity upto 97% has been achieved by a refinery who is using this technology



New Technology – Acid less Separation (ALS)

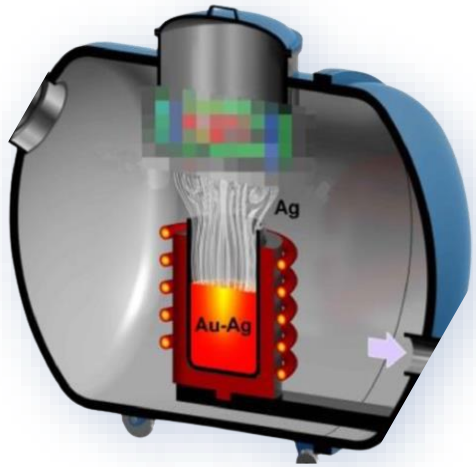
GREEN TECHNOLOGY – No use of Chemicals

LOW OPERATING COST – Very Limited manual operation

SAFE & USER FRIENDLY – Batch Process takes place in an enclosed volume & fully automated

FAST – Compared to other processes residence time of metal is low

SUSTAINABLE – No hazardous material is generated & pollution free



Acidless Separation Machine (ALS)

Testing of Gold/ Silver Metal and Other Elements

1. Potentiometric Titrator

Used to analysis Silver content in any metal/Sol Sample

2. ICP Analysis

Used to analysis in Metal Traces up to ppb Level in any metal /Sol. Sample

3. Fire Assay

Used to analysis in Gold from Dore/Alloy or fine Gold Sample

4. Chemical Lab

Used to Analysis Acid Content in Electrolyte and Sample preparation in ICP & Potentiometric Titrator

5. EDXRF Analysis

Used to Analysis Approx. Composition of Gold, Silver and Alloy Sample

6. Spark Spectrometer

Used to analysis Gold ,Silver & impurities Content in gold and Silver Fine Samples

2 Fine Gold and its effect

A one-stop solution for Precious Metals

Return metal's Purity & Weight are always doubtful

Impurities leading to poor finish and higher rejection

Chemical method if not controlled will add impurities to the Metal

Element	Electrolytic refining/ Precise controlled chemical refining			Chemically refined (uncontrolled)			
	999.9 (Sponge)	999 (Conversion)	995 (Conversion)	995 Gold	995 Gold	995 Gold	995 Gold
Gold(Au)‰	999.96	999.08	995.08	994.92	995.05	995.05	995.00
Silver(Ag) (ppm)	29	900	4903	4747.6	4791	4584	4872
Palladium (Pd)					5	38	35.5
Platinum (Pt)						11	
Aluminium (Al)					2		
Antimony (Sb)				5.5			
Arsenic (As)				6			
Copper (Cu)	11.6	14.9	13.2	161.4	98	40	14
Iron (Fe)				42	15		27
Lead (Pd)						11.5	42
Manganese (Mn)						2	
Silicon (Si)					3	4	
Tin (Sn)				89.5	15		5.8
Tellurium (te)					5	14	3.7
Zinc (Zn)				20.8			

PRODUCT COMPARISON
WE STAND OUT

MMTC PAMP GOLD

18 Y Cast tree with MMTC -PAMP gold free from impurities

Smooth, oxidation free 18 K pink gold strip casted with MMTC-PAMP gold having no impurity

Poor 18 Y tree casted using refined gold with high impurity

18 K Strip with gold having oxidized surface finish due to high impurity content

LOCAL GOLD

PRODUCT COMPARISON
WE STAND OUT

MMTC PAMP GOLD

22 K Finished ring from MMTC-PAMP gold having high lustre and finish

Bullion bar with MMTC-PAMP gold

22 K ring from gold having broken shank due to impurities

Slags on bullion bar with gold having impurities

LOCAL GOLD

3. Effect of Base Metal and Deleterious Elements in Refining Process

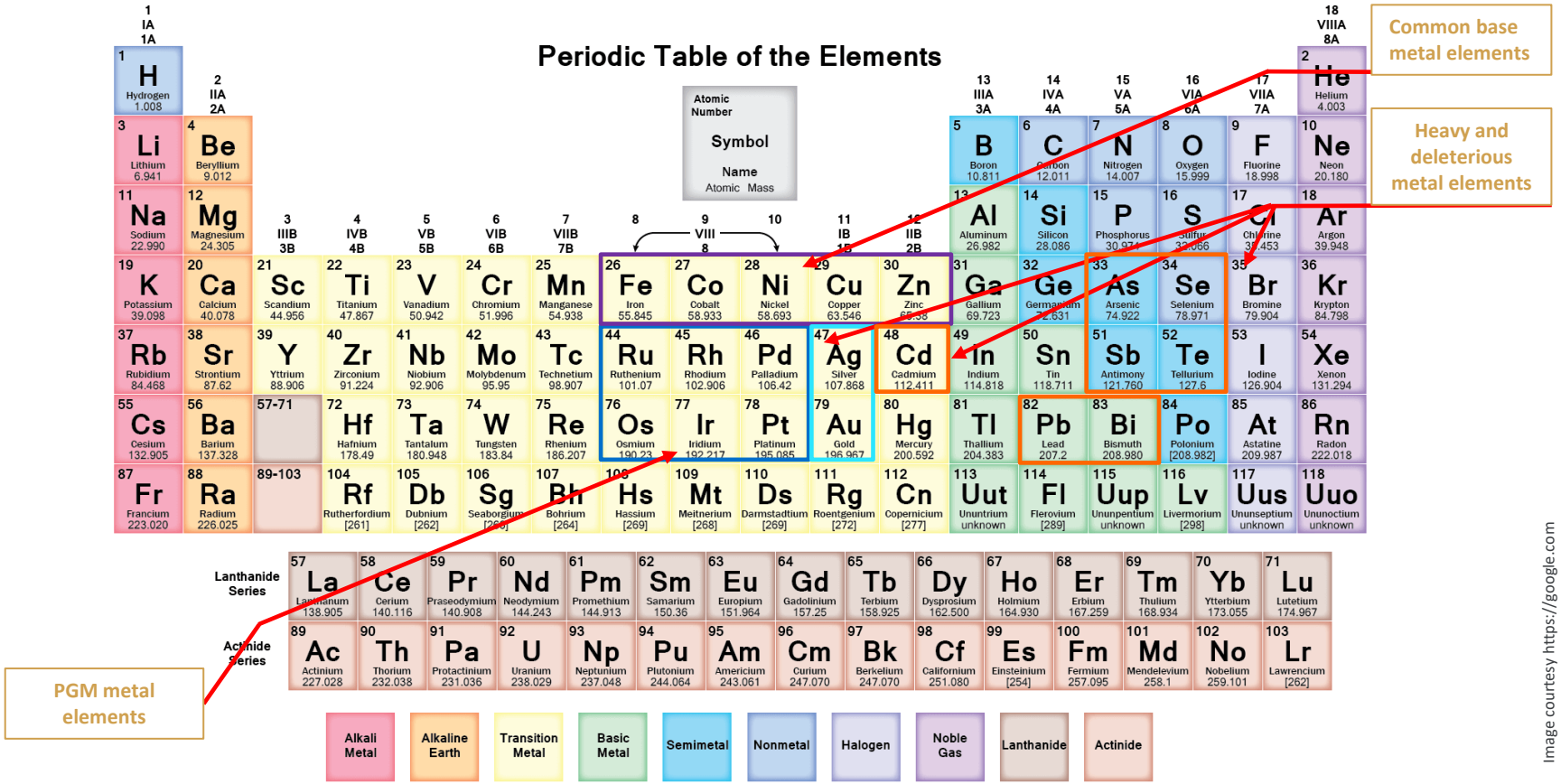
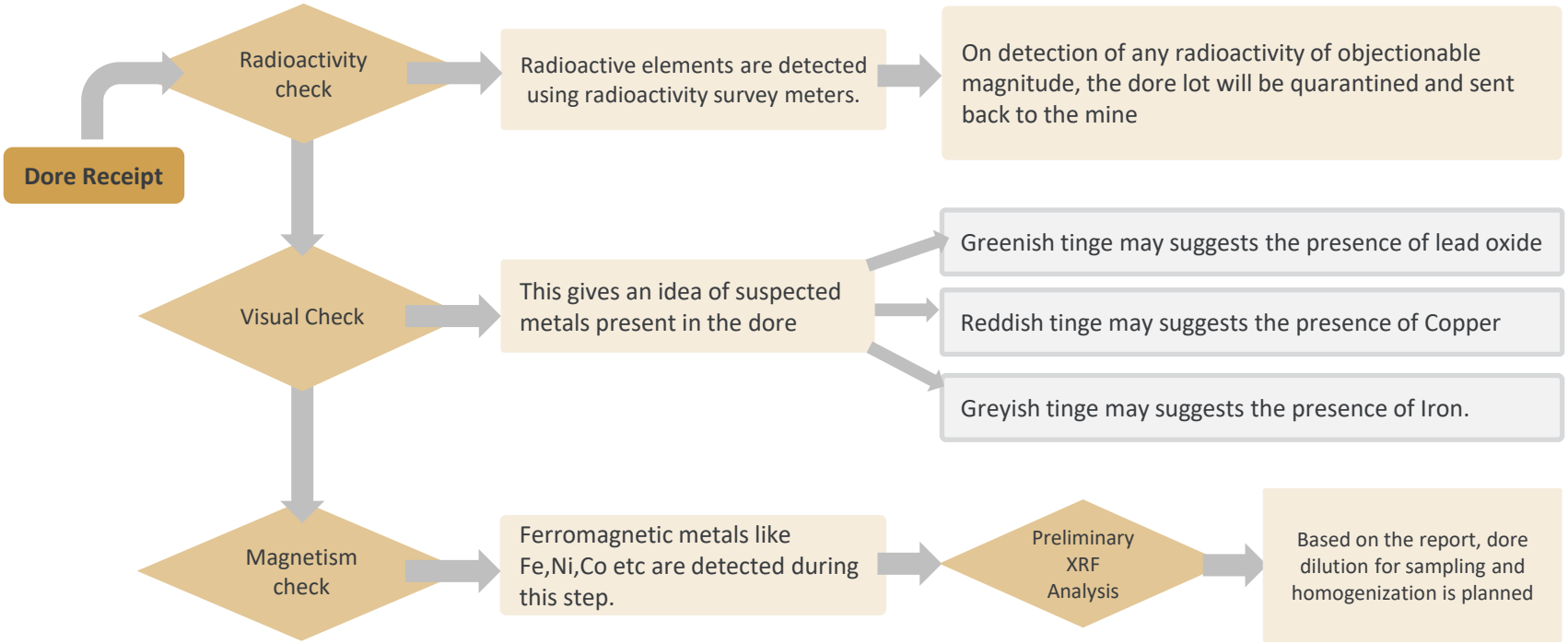


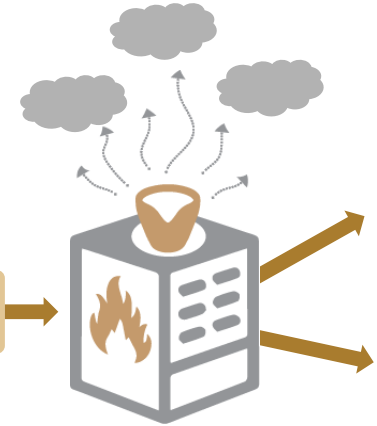
Image courtesy https://google.com

Base metal – Status at Receipt

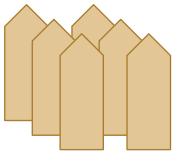


Base metal – Status in Melting operation

Volatile metals like Pb, Bi, Se, Te, As, Cd etc oxidize & escape as toxic fumes along with traces of Au and Ag are captured by Jet Bag Filters for later treatment, recovery and disposal

Analyzed Metal lot → Dilution with calculated amounts of Ag/Au → 

Melting of the blend

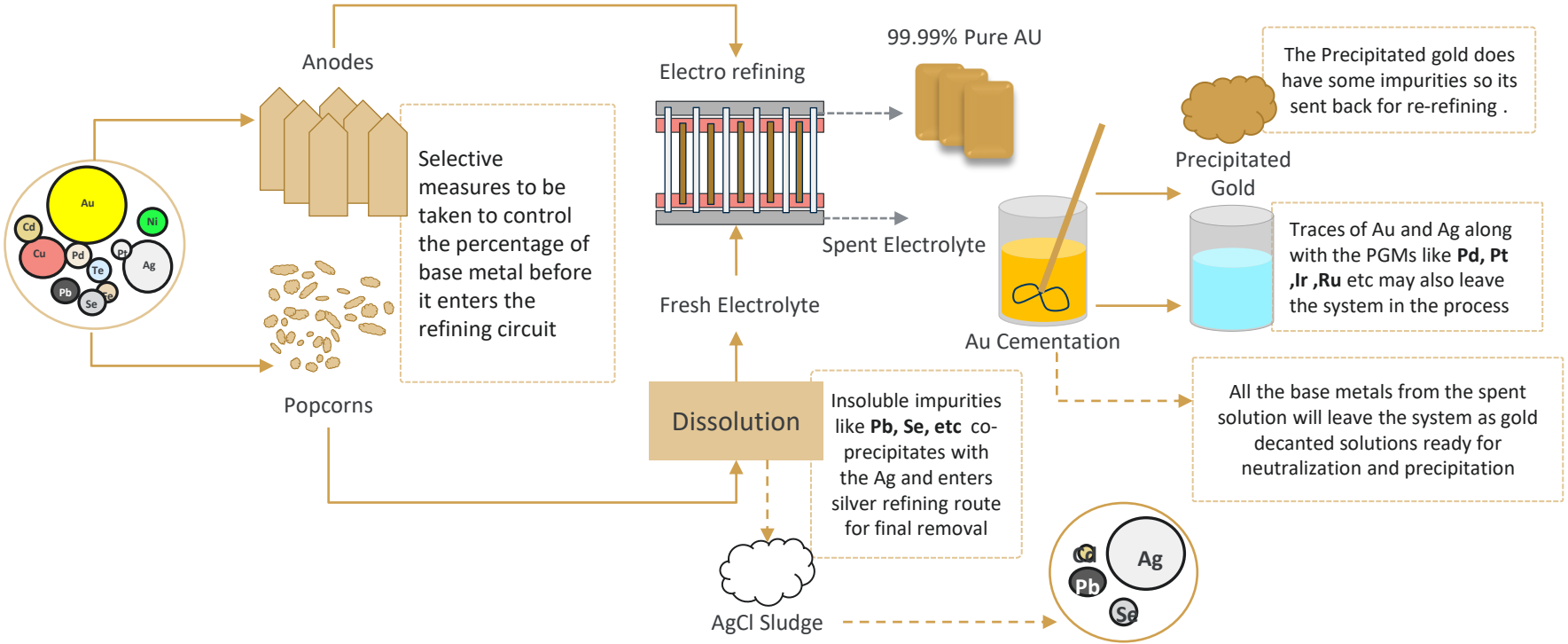


Anodes and Popcorns are rid of major deleterious and heavy metal impurities as the major volatile elements get removed during melting.

Concentration of base metals like Cu, Ni, Zn whose melting points are similar to Gold slightly increases

In case when iron is observed as the prominent impurity in the lot, care is taken to remove iron in the slag during melting

Base metal – Status in Chemical and Electrochemical Refining



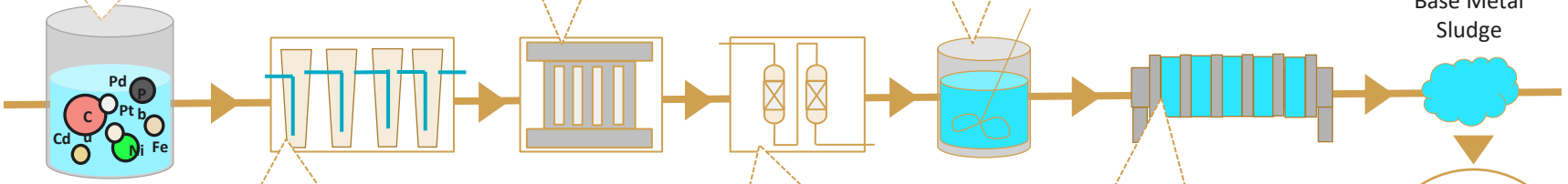
Base metal – Status in Ecology operation

The waste solutions from refinery consists majorly Copper with traces of Au , Ag , PGMs and other impurities

The media filter will produce solution free of physical gold/silver particles ready to go through **Ion Exchange** process

The base and deleterious metal rich solution is precipitated by neutralization process

Base Metal Sludge



The suspended particles of Au and Ag (in trace levels) are settled through media based filters

The Ion Exchange process selectively absorbs the precious and PGM metals

The precipitated sludge from the neutralization process is collected as filter cakes of base metal hydroxides

The base metal rich sludge so generated consists of copper as major component while all other categories of metals that had escaped the exhaustive refining process including precious and PGMs at almost undetectable traces

4. Hazards associated in Gold Refining

Identifying the various hazards

Fumes: Pyrometallurgical process

- Untreated carbon compounds
- Metal oxides
- Heavy metal particles - their treatment

Fumes by chemical Process

- Untreated acids
- Nox, Sulphur dioxide, Chlorine

Molten Metal

- Hot surfaces
- Unintended metal spurts
- Accidental fires

Effluents: - Chemical process

- High acidic
- Chemical salts of dissolved base metals

Molten Metal hazards

Molten metal work is any process in which metals are melted, poured and molded.

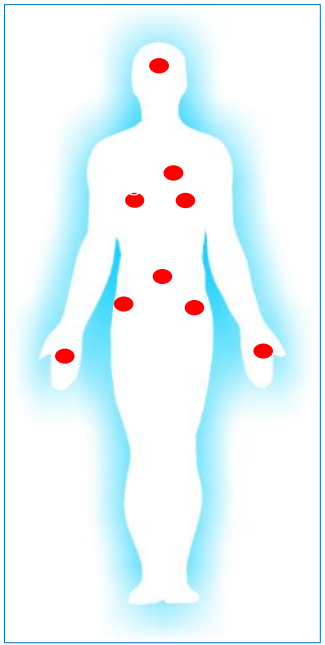
Hazards associated with molten metal include:

- **Heat stress** from exposure of persons to heat and infrared and ultra-violet radiation generated by molten metal work.
- Exposure to **airborne hazardous substances** – dusts, fumes, gases and vapour
- **Noise** and vibration generated by mold making machines, grinding and impact tools used to release and dress the work.
- Mechanical/manual handling of **heavy equipment** such as molds, ladles, scrap and products
- Physical injury and severe first, second and third-degree burns from molten metal splash, grinding equipment.
- Trips and falls.
- Vibration induced injury from use of pneumatic tools.

Effects of heavy metals on human health

When the gold containing impurities is melted, metals may get carried off as particulate matter and volatile oxides along with the fumes and add to the particulate matter (PM) of the environment.

Element	Behavior in molten condition	Effect on human health
Cadmium	Forms volatile oxide	**Possible Carcinogens** Affects the respiratory and cardiovascular system. Lead has severe effect on renal functions over long exposure; impair body's ability to produce haemoglobin; affect the nervous system too High exposure may lead to collection of fluid in the lungs and bronchitis. Arsenic trioxide may induce, vomiting, diarrhea, gastrointestinal hemorrhage, cerebral edema and hypovolemic shock.
Lead		
Selenium & Tellurium		
Arsenic		
Iron, Nickel, Cobalt and Copper	Are removed as slags; may also be carried as metallic particles in fume.	Metallic fumes if inhaled, may lead to asthma, rhino-conjunctivitis, and dermatitis.
Mercury	Vaporizes as metal at a temperature of 357 ºC	Vapors can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may turn fatal.
Zinc	Produces bright flashes of light and dust cloud .	Over-exposure to zinc oxide fume may cause metal fume fever.



(Table 3) Behavior of elements during melting and casting and their effects on Human being

Control measures to mitigate hazards from Pyro process fumes

Measures for mitigating risks due to hazards from Fumes from incineration , smelting and melting

- The **suction hoods** should be adequately cover the furnace mouth and ensure that all fumes are trapped.
- The cooled emissions then pass through **series of filters** which trap the air -borne particulates before going to **scrubber**
- The scrubber units spray alkaline solution and neutralize acidity if any in the fumes. The air gets washed as it flows through a column of strainers, becomes almost free from dust particles and exit through its stack.
- Monitoring the quality of the scrub solution as well as avoiding accumulation of sludge in the scrubber tanks is a necessity to ensure efficient functioning of the scrubbing operation.
- Stack emission sampling at frequency defined by CPCB (by authorized lab only) is a mandatory exercise ; it will ensure that processes are well controlled and avoid non-compliances during online monitoring by CPCB (CEMS).

Control measures to mitigate hazard from Chemical Fumes

- The **suction hoods** placed close to the furnace mouth and adequately covering the mouth to ensure that all fumes are trapped.
- The cooled emissions are then passed through series of filters to trap the air -borne particulates before they are processed in the **scrubber.**
- The scrubber units spray alkaline solution and neutralize acidity if any in the fumes. The air gets washed as it flows through a column of strainers, becomes free from dust particles and exit through the stack.
- Monitoring the quality of the scrub solution as well as avoiding accumulation of sludge in the scrubber tanks to ensure efficient functioning of the scrubbing operation.
- **Use expert vendor who understands suction calculation and are savvy with pollution norms to design the scrubber for you .**

Liquid Effluents from refining process

The chemical refining processes generates liquid effluents which contain impurities removed while processing the gold. The details of the solid and liquid residues/effluents generated from the chemical and electrochemical processes are summarized in the table 6 below:

Process	Liquid effluents
Parting	Acidic solutions containing bulk of metal nitrates only
Aqua Regia	Acidic solutions containing bulk of base metal nitrates, chlorides and sulphates.
Electrolytic process	

(Table 6) Details of liquid effluent generated from various process

- The effluent generated from above processes are highly acidic (ph. 1 or less) and also contain large quantity of deleterious metals in form of their soluble salts e.g. chlorides, nitrates, sulphates etc.
- All effluent generated need to be treated before they can be finally discharged as per CPCB norms.
- Any solid sludge generated from the treatment of the above effluents is categorized under hazardous waste and requires proper authorizations before attempting its recovery and refining.

Government regulations for Effluents (CPCP norms)Vs MMTC-PAMP

Process steps at ETP comprises of equalization, treatment with bases, bacterial treatment, sand and carbon filtration which ensure that the effluent discharge meets norms set by CPCB as mentioned below :

Sr No	Parameter	Unit	Permissible limits for disposal into surface water	MMTC-PAMP disposal into surface water
1	pH	-	5.5 to 9.0	7.65
2	Total suspended solids (TSS)	ppm	<100 ppm	38.1
3	Oil & Grease	ppm	<10 ppm	0.59
4	Biological/biochemical oxygen demand (BOD)	ppm	<30 ppm	22.3
5	Chemical oxygen demand (COD)	ppm	<250 ppm	79.6

(Table 7) CPCB requirements for effluents disposal

Live monitoring of data and its transmission to CPCB server under OEQMS has been made mandatory and needs to be complied in order to ensure zero non-compliance.

Control measures for mitigating hazard from Effluent

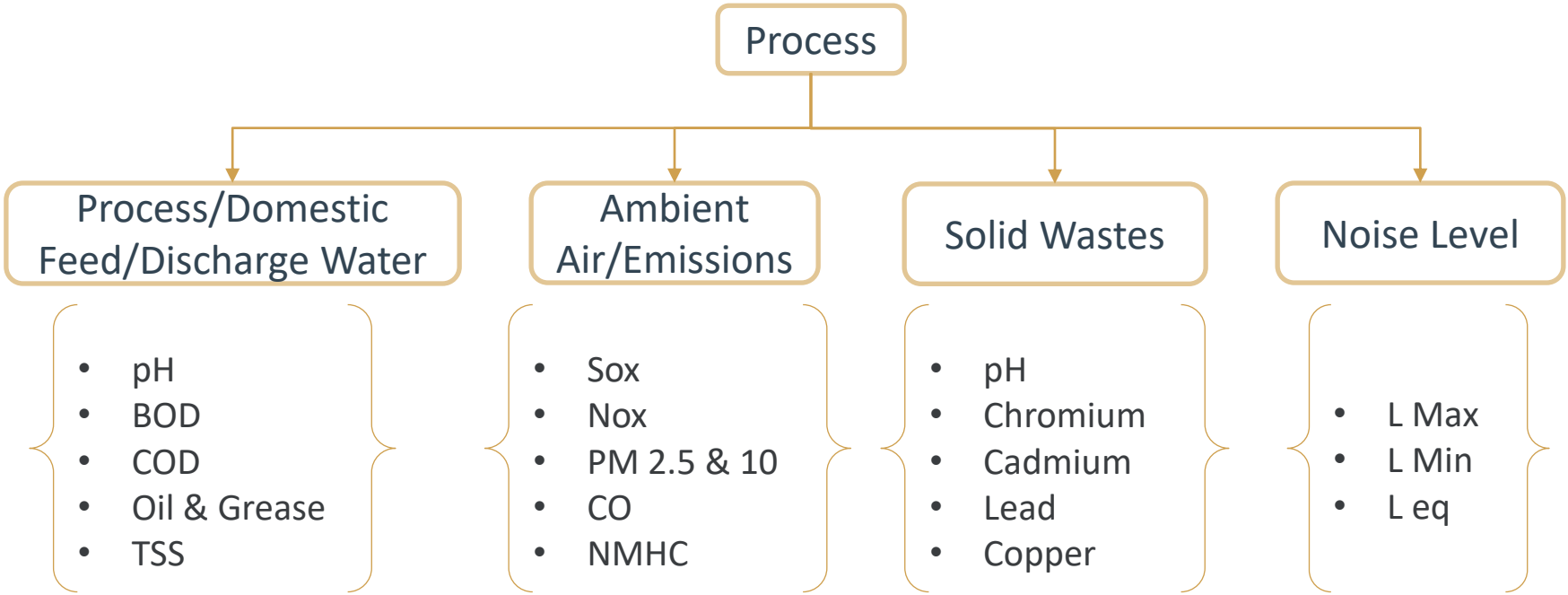
Measures for mitigating risk due to hazards from Effluent (Chemical processes)

- The quantity of effluent to be treated should be reduced in planned manner with stoichiometric use of chemicals.
- Recycling of process water with proper study of the water parameters at all stages.
- All effluent generated from the above processes are highly acidic and laden with impurity elements in form of their nitrates, chlorides, sulphates etc.
- A series of processes involving **resin treatment, neutralization, flocculation, settling and filtration** are adopted prior to sending to **ETP** which ensures that the impurities and their salt are completely removed, and compliances are duly complied.

Treating all effluent with due diligence is a necessity as the refining process is a hazardous activity .

5. MMTC PAMP Environmental Performance in Past Two Years

Government regulations for Industrial Processes (CPCB norms)



Government regulations (CPCP norms)

Group	Description	Frequency as per HSPCB	Parameters	Limits	Units	Average FY 2021-22	Average FY 2022-23
1	Analysis of Inlet Effluent Water of STP	Quarterly	PH	_	_	6.77	6.96
			Chemical Oxygen Demand (COD)	_	mg/l	480.00	278.25
			Biochemical Oxygen Demand (BOD)	_	mg/l	134.75	115.0
			Total Suspended Solids (TSS)	_	mg/l	186.05	157.5
			Oil & Grease (O & G)	_	mg/l	4.88	4.7
2	Analysis of Inlet Effluent water of ETP	Quarterly	PH	_	_	7.10	7.14
			Chemical Oxygen Demand (COD)	_	mg/l	476.20	486.9
			Biochemical Oxygen Demand (BOD)	_	mg/l	136.50	144.5
			Total Suspended Solids (TSS)	_	mg/l	65.83	202.38
			Oil & Grease (O & G)	_	mg/l	6.41	8.82
3	Analysis of Outlet Effluent water of ETP	Monthly	PH	5.5 - 9.0	_	7.30	7.65
			Chemical Oxygen Demand (COD)	250	mg/l	101.32	79.6
			Biochemical Oxygen Demand (BOD)	30	mg/l	22.90	22.3
			Total Suspended Solids (TSS)	100	mg/l	16.76	38.1
			Oil & Grease (O & G)	10	mg/l	0.33	0.59
4	Analysis of Outlet Effluent water of STP	Monthly	PH	5.5-9.0	_	7.12	7.56
			Chemical Oxygen Demand (COD)	250	mg/l	94.17	62.2
			Biochemical Oxygen Demand (BOD)	30	mg/l	21.92	20.3
			Total Suspended Solids (TSS)	100	mg/l	15.09	26.4
			Oil & Grease (O & G)	10	mg/l	0.22	0.17
5	Analysis of STP Sludge	Quarterly	PH (at 25 C)	5.5-8.5	_	6.88	7.56
			Chromium as Cr	50	mg/ kg	38.85	26.46
			Copper as Cu	300	mg/ kg	182.64	138.65
			Cadmium as Cd	5	mg/ kg	2.91	9.1
			Lead as Pb	100	mg/ kg	57.46	31.09
6	Analysis of ETP Sludge	Quarterly	PH (at 25 C)	5.5-8.5	_	7.84	7.46
			Chromium as Cr	50	mg/ kg	38.87	35.79
			Copper as Cu	300	mg/ kg	246.81	192.95
			Cadmium as Cd	5	mg/ kg	3.2	10.44
			Lead as Pb	100	mg/ kg	65.81	107.38
7	Analysis of Drinking Water (As per ISO:10500) Plant	Half Yearly	PH	6.5-8.5	_	7.02	6.94
			Chloride	250	mg/l	30.34	20.32
			Total Hardness as CaCO3	200	mg/l	13.08	54.0
			Sulphates as SO4	200	mg/l	3.17	4.0
			Total Dissolved Solids (TDS)	500	mg/l	108.5	104.0
8	Analysis of Drinking Water (As per ISO:10500) Kitchen	Half Yearly	PH	6.5-8.5	_	7.17	7.39
			Chloride	250	mg/l	19.25	32.4
			Total Hardness as CaCO3	200	mg/l	10.86	40.1
			Sulphates as SO4	200	mg/l	4.16	3.4
			Total Dissolved Solids (TDS)	500	mg/l	59.0	91.0

Government regulations (CPCP norms)

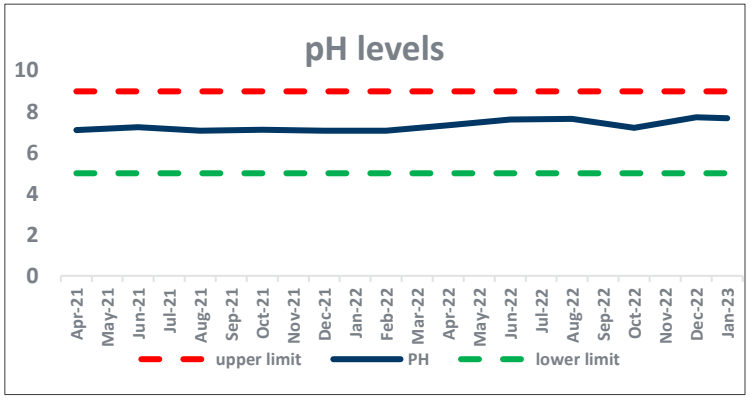
Group	Description	Frequency as per HSPCB	Parameters	Limits	Units	Average FY 2021-22	Average FY 2022-23
9	Borewell-1 Water Analysis (As per ISO-10500)	Half Yearly	PH	6.5-8.5	_	7.28	7.19
			Chloride	1000	mg/l	176.46	192.3
			Total Hardness as CaCO3	600	mg/l	537.41	370.5
			Sulphates as SO4	400	mg/l	68.8	36.26
			Total Dissolved Solids (TDS)	2000	mg/l	762.5	615.0
10	Ambient Air Monitoring (Utilty_VCB Room/ 24 Hours)	Half Yearly	Particulate Matter (PM 2.5)	60	Microgram / m3	47.89	45.65
			Particulate Matter (PM 10)	100	Microgram / m3	82.9	78.72
			Nitrogen Di Oxide (NO2)	80	Microgram / m3	25.56	23.81
			Sulphur Di Oxide (SO2)	80	Microgram / m3	11.56	11.76
			Carbon Monoxide (CO)	4	mg/m3	0.81	0.76
11	Stack Emission Monitoring (Silver & Gold Scrubber)	Half Yearly	Particulate Matter (PM)	_	mg /Nm3	24.56	22.14
			Oxides of Nitrogen (NOx)	_	mg /Nm3	27.91	26.03
			Sulphur Di Oxide (SO2)	_	mg /Nm3	11.4	11.4
			Carbon Monoxide (CO)	_	mg /Nm3	BDL	BDL
12	Stack Emission Monitoring (DG Set-1_1500 KVA)	Half Yearly	Particulate Matter (PM)	75	mg /Nm3	43.07	40.36
			Oxides of Nitrogen (NOx)	710	PPMV	199.2	194.1
			Sulphur Di Oxide (SO2)	_	mg /Nm3	46.23	46.38
			Carbon Monoxide (CO)	150	mg /Nm3	31.23	28.88
			Non-Methane Hydrocarbons (NMHC)	100	mg /Nm3	8.81	7.25
13	Work Zone Noise Monitoring (DG Set-1 for 30 Minutes)	Half Yearly	Leq (Open Acoustic Enclosure)	_	dB (A)	100.75	100.45
			Leq (Closed Acoustic Enclosure)	75	dB (A)	73.65	73.25
			Insertion Loss	_	_	27.1	27.2
14	Ambient Noise level Monitoring (Kitchen Corner/ 24 Hours)	Half Yearly	Leq (Lequivalent)		dB (A)	62.90 , 48.65	64.15 , 49.85
			Limits (Day Time) (6 :00 AM to 10:00 PM)	75	dB (A)	62.9	64.15
			Limits (Nighttime) (10 : 00 PM to 6:00 AM)	70	dB (A)	48.65	, 49.85
15	Environmental Status Report	Yearly	Detail report on water consumption, power consumption overall production, waste generated				
16	Annual Audit Report(by external agency)	Yearly	Annual audit				

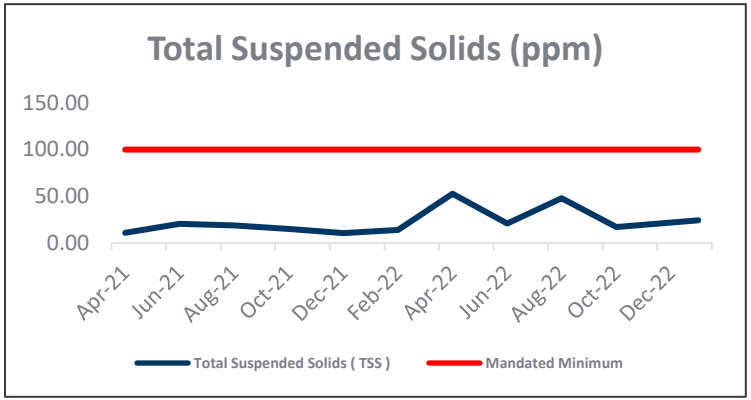
Government regulations for discharged air quality(CPCP norms)

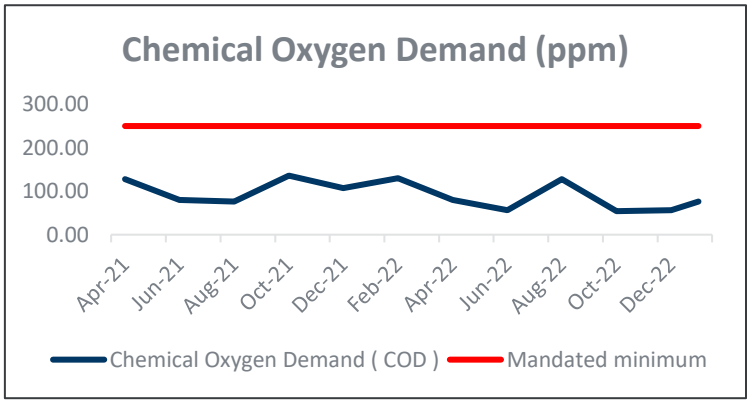
Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Sulphur Dioxide (SO2), µg/m3	Annual* 24 hours**	50 - 80	20 - 80
Nitrogen Dioxide (NO2), µg/m3	Annual* 24 hours**	40 -80	30 - 80
Particulate Matter (size less than 10 µm) or PM10 µg/m3	Annual* 24 hours**	60- 100	60 - 100
Particulate Matter (size less than 2.5 µm) or PM2.5 µg/m3	Annual* 24 hours**	40- 60	40 - 60
Lead (Pb) µg/m3	Annual* 24 hours**	0.50 - 1.0	0.50 - 1.0
Arsenic (As), ng/m3	Annual*	6	60
Nickel (Ni), ng/m3	Annual*	20	20

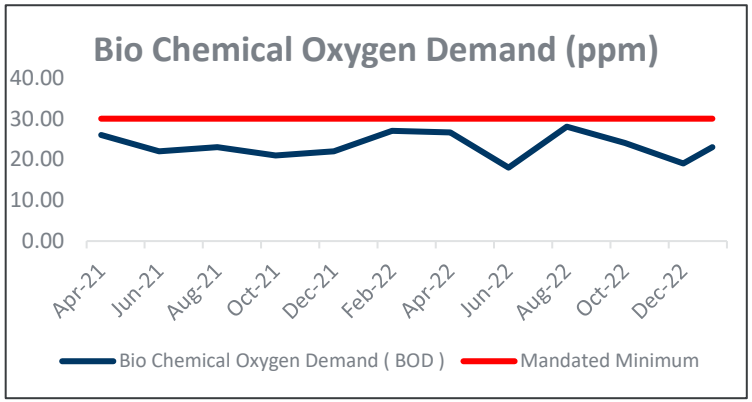
*** Annual arithmetic means of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.**
**** 24 hourly or 8 hourly or 1 hourly monitored value, as applicable, shall be complied with 98% of the time, they may exceed the limits but not on two consecutive days of monitoring.**
Source: National Ambient Air Quality Standards, Central Pollution Control Board Notification in the Gazette of India, Extraordinary, New Delhi, 18th November, 2009

1. Discharge Water

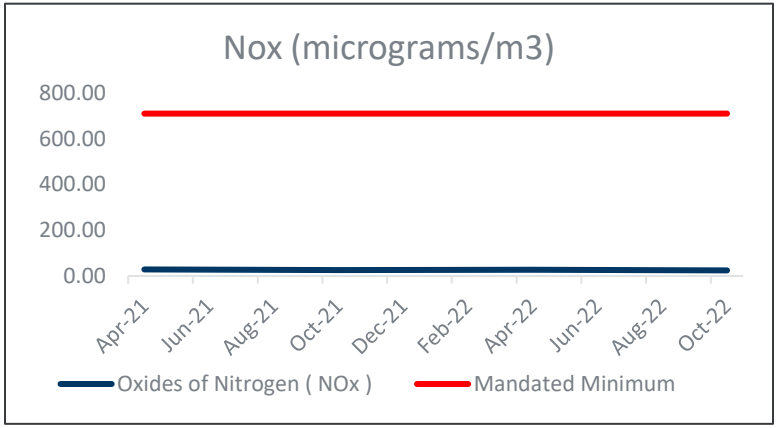


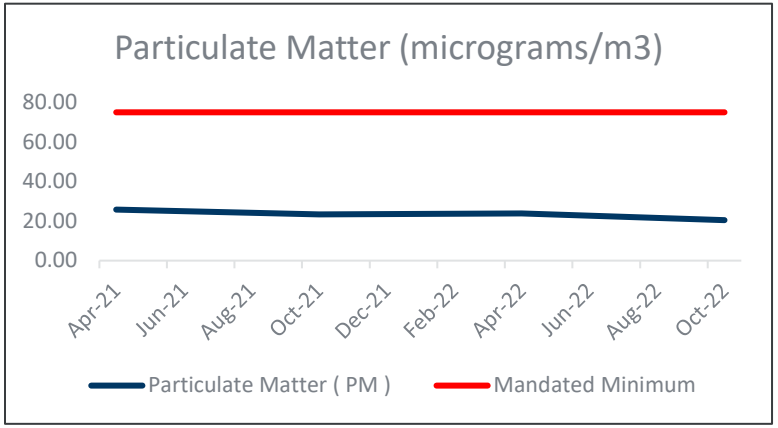


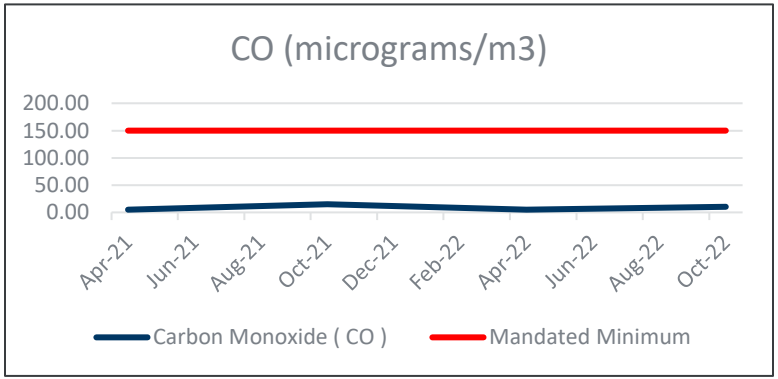


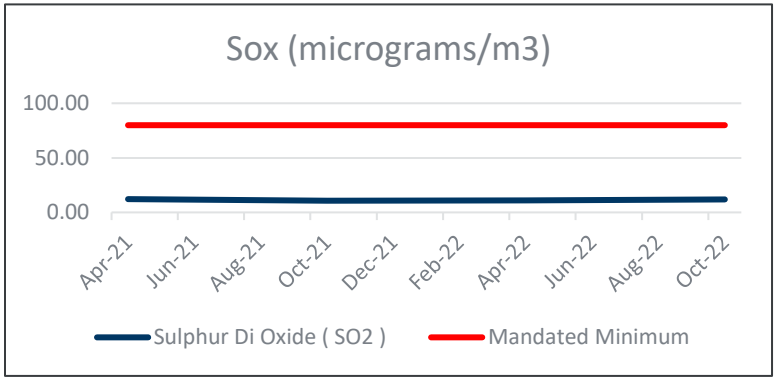


2. Emissions

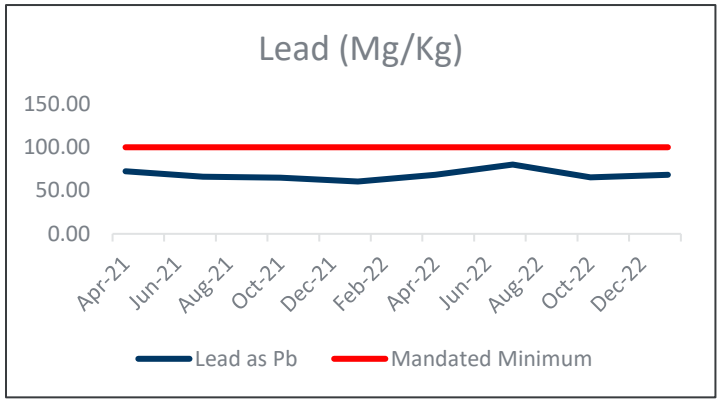

Nox (micrograms/m3)
800.00
600.00
400.00
200.00
0.00
Apr-21
Jun-21
Aug-21
Oct-21
Dec-21
Feb-22
Apr-22
Jun-22
Aug-22
Oct-22
Oxides of Nitrogen (NOx)
Mandated Minimum

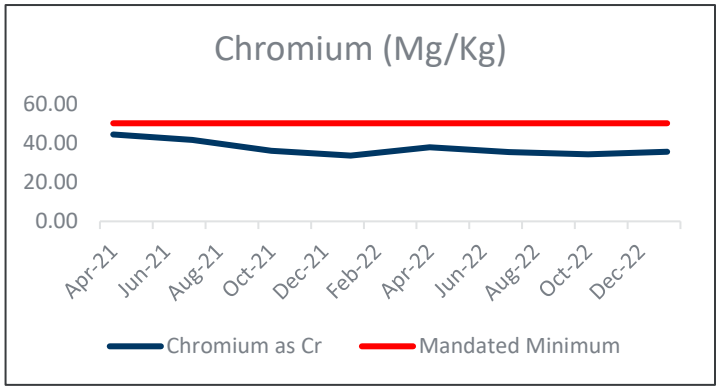

Particulate Matter (micrograms/m3)
80.00
60.00
40.00
20.00
0.00
Apr-21
Jun-21
Aug-21
Oct-21
Dec-21
Feb-22
Apr-22
Jun-22
Aug-22
Oct-22
Particulate Matter (PM)
Mandated Minimum

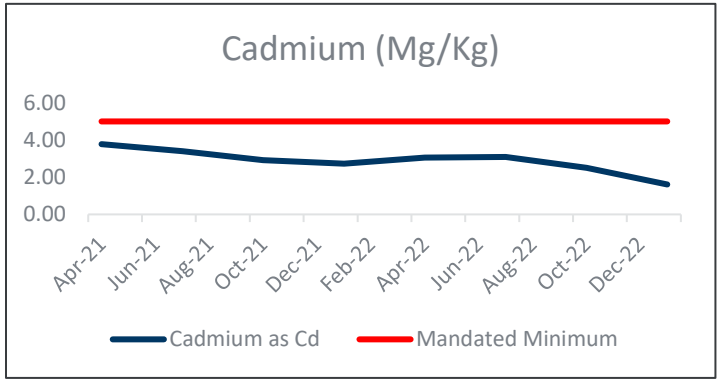

CO (micrograms/m3)
200.00
150.00
100.00
50.00
0.00
Apr-21
Jun-21
Aug-21
Oct-21
Dec-21
Feb-22
Apr-22
Jun-22
Aug-22
Oct-22
Carbon Monoxide (CO)
Mandated Minimum

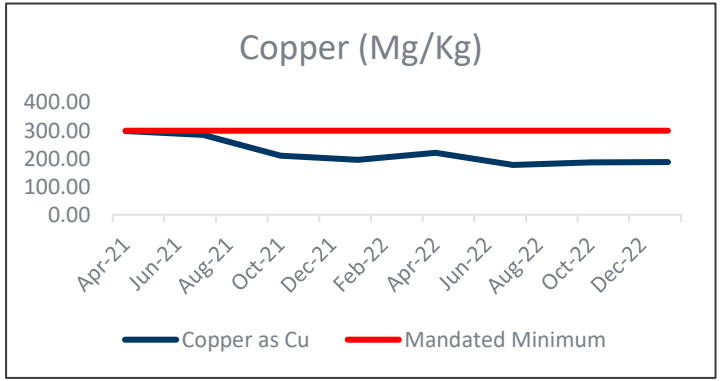

Sox (micrograms/m3)
100.00
50.00
0.00
Apr-21
Jun-21
Aug-21
Oct-21
Dec-21
Feb-22
Apr-22
Jun-22
Aug-22
Oct-22
Sulphur Di Oxide (SO2)
Mandated Minimum

3. Solid Wastes/Sludges

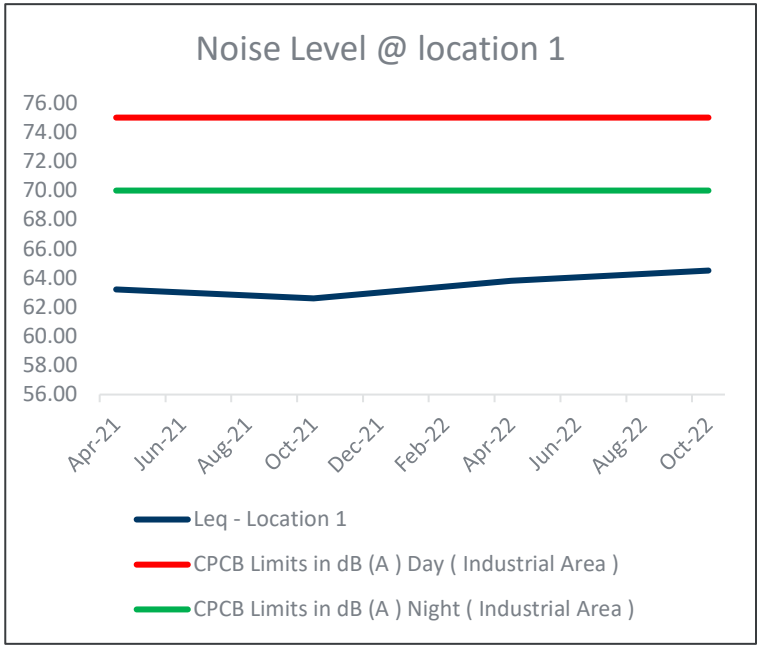


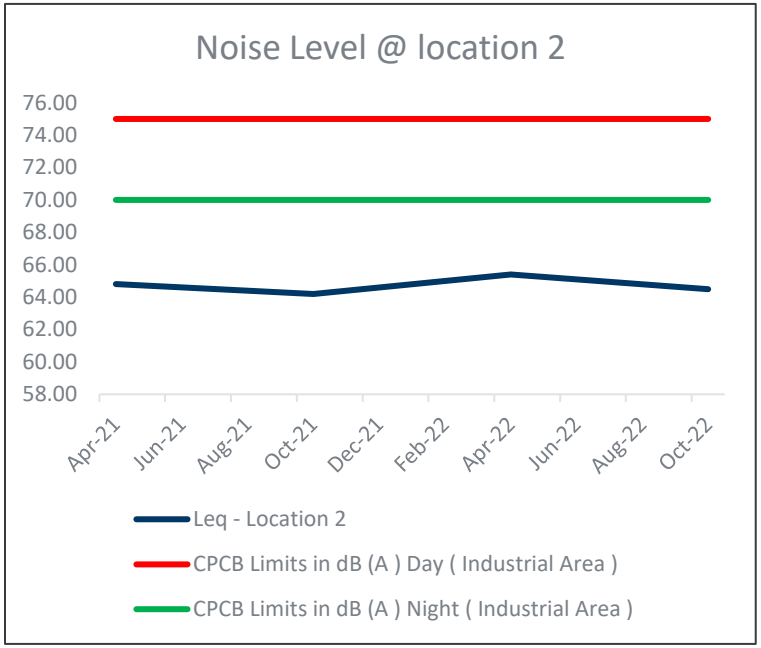






4. Ambient Noise Levels





Refinery Hazards

Sl. No.	Hazards	Cause	Risk	Level	Existing Controls	Additional Controls	Final Risk Score	Final Level
1	Fumes	NOx fumes	Skin irritants, Asphyxiation & Corrosives	Extreme Risk	Air ventilation, Scrubber (with UPS backup), Nox dector, PPE's	Periodic cleaning of scrubber, pH monitoring, Additional scrubber connected	10	Low Risk
		Sox fumes	Respiratory system, particularly lung function, and can irritate the eyes	High Risk	Air ventilation, Scrubber (with UPS backup), PPE's	Perodic cleaning of scrubber, pH monitoring, Additional scrubber connected	8	Low Risk
		Toxic smoke	Respiratory irritation and shortness of breath and can worsen medical conditions.	High Risk	Air ventilation, Scrubber (with UPS back up) & Jet bag filter, PPE's & Medical checkup	pH monitoring before charging material for melting, Furnace covering during melting.	10	Low Risk
2	Molten metal	Accidental spurts	3rd degree burns	High Risk	Usage of moisture free accessories	Fire resistant aprons, thermal gloves and other appropriate PPE's	10	Low Risk
3	Effluent	Acid burn	Redness, irritation or burning at the site of contact.	Low Risk	Shower available at workplace, Medicine available in first aid box, PPE's	Perodic checking of first aid box & Shower.	6	Low Risk
4	Physical injuries	Handling of sharp/heavy loads	Cuts/Hits caused during harvesting/casting/metal transfer	High Risk	Usage of material moving trolleys/container trays	Operator training, usage of appropriate PPEs	6	Low Risk
5	Slips and trips	Spillage of solid lubricants (graphite) on the floor	Nasty falls that may lead to severe injuries	High Risk	Frequent cleaning of the floor	Usage of anti skid tapes to make the possible area safe to operate.	10	Low Risk

Score	Action
20 to 25	Extreme Risk: Immediate action required to mitigate the risk.
16 to 19	High Risk: Action should be taken to compensate for the risk.
11 to 15	Moderate Risk: Action should be taken to monitor the risk.
5 to 10	Low Risk: Routine acceptance of the risk.

Refinery Hazards

Sl. No.	Hazards	Cause	Risk	Level	Existing Controls	Additional Controls	Final Risk Score	Final Level
1	Fire hazards	Electrical fire & Flames	Burn, Risk of life & loss of property	Moderate Risk	Fire extinguisher, Periodic checking of LPG leakage, BA Set	Preventive maintenance	10	Low Risk
2	Physical hazards	Unsafe conditions (Slips, trips, falls, noise, heat & cold) & Safety ignorance.	physical discomfort, pain, injury, illness.	Low Risk	Using anti-skid tape at high-risk area, frequent floor cleaning, Air Ventilation, PPE's	Monthly Safety training & Awareness	8	Low Risk
3	Ergonomic hazards	Unsafe Act (repetition, awkward posture, forceful motion, stationary position, direct pressure & work stress)	Workplace situations that cause wear and tear on the body and can cause of injury.	Low Risk	Using battery operated truck & trolley.	Awareness trainings	8	Low Risk
4	Workplace hazards	workload, lack of control & overworking	Stress, fatigue, error & loss of buisness.	High Risk	Working hours monitoring, Leave planning, SA-8000 certified	Week off planning before 10 days of continous working.	6	Low Risk
5	Biological hazards	Bacteria & viruses	Health effects ranging from skin irritation, allergies, tetanus, respiratory infections.	Moderate Risk	Follow up of health advisory, Medical checkup.	Awareness trainings	12	Low Risk

Score	Action
20 to 25	Extreme Risk: Immediate action required to mitigate the risk.
16 to 19	High Risk: Action should be taken to compensate for the risk.
11 to 15	Moderate Risk: Action should be taken to monitor the risk.
5 to 10	Low Risk: Routine acceptance of the risk.

Conclusion

Gold recovery and refining consists of set of complex steps involving application of high heat and hazardous chemicals

Each technique described in slides above deals with hazardous chemical and by-products during the entire cycle . The risks posed by those hazards have severe impact on human being and ecosystem if not mitigated with due diligence.

OSHAS guidelines of HIRA (hazard identification and risk assessment) are becoming increasingly stringent to ensure safety to our ecosystem. Hence, all refinery needs to adopt a strategy which aims to mitigate the risks fully and provide convincing evidence in a transparent manner during any audit.

Regular safety audits , proactive monitoring of specified parameters , use of correct PPE, health examination of working personnel are some of the key points to be monitored regularly.

For the sake of business continuity, refineries who have their inhouse facility may thus require a re-evaluation of their existing capabilities and upgrade them in order to comply with set norms.

THANK YOU