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Pollution and its control in copper industry

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ABSTRACT

Pollution is a result of development or civilization. "Nature" does not pollute but "Industry" does. The earth being the main source of most minerals, its protection from misuse is of major significance. The wide spread industrialisation in absence of a predefined direction contributes significantly to pollution, depletion of useful natural resources and ecological imbalance. The matter has been getting serious attention now to combat risk to life and to ensure conservation of resources.

The paper presents the extent, nature and effects of pollution by copper industry. It also highlights various measures to control environmental degradation and to reduce the effects of waste and intermediate products on environment. Possible safety measures and tolerable limits of discharges of effluents into air and water are also indicated. Recent technologies to control pollution in copper industry have been discussed.

Keywords : Materials efficiency, Non-ferrous metals processing technology, Conservation of resources, Pollution control in copper industy.

INTRODUCTION

Rapid industrialisation has brought about a great deterioration in the quality of our environment. The metallurgical industries are amongst the worse offenders in terms of environmental degradation. Industries confer human prosperity, but the pollution caused by them threaten the very survival of mankind. Excessive expansion of big industries and mushrooming of ancillary industries around big industries without attention to the control of the waste products give rise to imbalance in the ecosystem and pollution of the surrounding environment [1,2].

Indian non-ferrous industry has been registering considerable growth during the past decades and also witnessing upturn in its fortunes. The present economic scenario in the country is also highly conductive to all-around growth

Table 1 : Domestic production and estimated demand of non-ferrous metals

Metal	Domestic production (Tonnes in lakhs)	Future demand (Tonnes in lakhs)
Aluminium	4.28	5.76
Copper	0.50	2.50
Lead	0.64	1.54
Zinc	1.50	2.60

*Source MMR Annual '95

and development of non-ferrous industry. Among the major non-ferrous metals mined, processed and produced for industrial applications are Aluminium, Copper, Zinc and Lead. Table 1 shows current domestic production and estimated demand by the turn of this century. From this it is evident that a huge gap of about 2.0 lakh tonnes a year between domestic availability and demand for copper has triggered a surge of investment in metal production capacity by the private sector during the past couple of years in the wake of economic liberalisation. Till 1995-96, the sole primary producer in the country was the public sector enterprise, Hindustan Copper Ltd., with a total smelting capacity of about 50,000 tonnes per year, divided between Khetri (Rajasthan) and Ghatsila (Bihar). The fresh capacity coming on line is presented in Table 2 [3,4]. From this it is clear that if all the projects are completed as per schedule, then by 2002, the primary

Table 2 : Fresh capactiy of copper production in India coming on line

Name of the Plant	Location of plant	Production Capacity (tpa)	Cost involved (in crores)	Expansion capacity (tpa)	Year of commission/ expansion
Sterlite Ltd.	Tuticorin (Tamilnadu)	60,000	800.00	1.0 lakh	1997/2002
Birla Copper	Dahej (Gujarat)	1,00,000	1850.00	1.5 lakh	1997/2002
SWIL Ltd.	Jhagadia (Gujarat)	50,000	600.00	–	1997
Metdist Industries Ltd.	Pipavab (Gujarat)	1,50,000	1900.00	–	1998/99
Hindustan Copper Ltd.	Khetri (Rajasthan)	31,000	500.00	1.0 lakh	1998

Note : 1 lakh tpa = 100,000 tpa

copper production capacity in the country will have risen to 5.5 lakh tpa, a respectable figure by world standards. The domestic demand, as per current projections, will climb from 2.5 lakh tpa in 1996-97 to 4.5 lakh tpa by 2004-05. This is based on the following annual demand growth rates for the metal from the end use sectors [5].

Electrical power	7%
Electronics and Telecommunication	10%
Transport	10%
Process	6%
General Engineering	6%
Consumer Durables	12%
Construction	10%
Others	10%

Such tremendous growth of non-ferrous metal industry has resulted in substantial environmental degradation in India. The copper industry is no exception to this and is also a significant contributor to environmental problems. Therefore, copper industry is going to be very strictly scrutinized on account of dust and gases it discharges.

SOURCES OF POLLUTION IN COPPER INDUSTRY

Copper industry is a mineral based industry. Copper bearing materials in the form of oxides or sulphides occur below the earth surface. The copper mineral is extracted by various methods of mining. During mining large quantity of waste materials are generated. After the ore is taken out, it is crushed and milled. In crushing and grinding enormous amounts of dusts are generated. The ground ore is subjected to flotation for separation of copper rich mineral known as concentrate. This concentrate is roasted to remove excess sulphur. The roasted concentrate is then smelted in smelter to produce blister copper. The copper so produced is impure and is called anode copper. Anode copper in refined in electrolytic refinery. The electro-refined copper is melted and cast into wire bars. The copper wire bar is then rolled into wire rods and are pickled to remove the copper oxide dust. Therefore, it is evident that starting from mining operations to final finishing operation of copper production, all of them contribute as sources of pollution in the copper industry. Thus, the main sources of pollution in copper industry are [6,7] (i) mining, (ii) comminution operation, (iii) flotation, (iv) roasting and smelting, (v) fire refining and electro refining stages, (vi) sulphuric acid plant and (vii) water treatment plants, etc.

NATURE OF POLLUTION

Solid, liquid and gaseous environmental pollutants are generated in the copper industry. The major solid wastes and liquid/gaseous effluents from selected non-ferrous metal industries are shown in Table 3. It is clear from the table that copper industry is guilty of aggrevating both the depletion problem and the pollution problems.

Table 3 : Major solid wastes and liquid/gaseous effluents from selected non-ferrous metal industries

Metal	Solid Wastes	Liquid Effluents	Gaseous Emissions
Aluminium	Red mud sludge & spent pot lining	Process spills & waste water	Gaseous & particulate fluorides, CO, CO_2, PAHs
Copper	Smelter & converter slag, leach residues	Waste water & ER/EW sludge	SO_2, NO_X, toxic metal fumes & SPM
Zinc	Smelter slags, leach residue	Waste water, Effluent sludge &	SO_2, NO_X, Toxic metal fumes
	Drosses & β-cake	SPM	
Lead	Smelter slags,	Waste water	SO_2, NO_X & Toxic
	Drosses & scrap		metal fumes & SPM
Gold	Barren rocks, leach residues & miller drosses	Waste water (cyanide solution)	–
Uranium	Mill tailings, leach residues & sulphide wastes (byproducts)	Wate acid/alkali solutions & SX/IE reffinates	Mildly radioactive environment

During ore production considerable amount of waste rock is also produced. In case of underground mines for production of 1 ton of ore, about 8-10 tonnes of waste rock has to be mined depending upon the nature of prebody. In case of open cast mines the waste rock is called overburden and its generation may vary between 3 to 8 tonnes, as large volumes of waste has to be dumped away to reach the ore body. The communication operation generates lot of dust, suspended particulate matters (SPM) and effluents. Concentration by flotation generates waste waters which carry dissolved chemicals and particulates, xanthates and other chemical agents used for flotation. The mineral after concentration is roasted. The major polluting products in roasting operation include SO_2 and SO_3

alongwith volatile oxides of arsenic, antimony, zinc etc. During smelting and converting SO_2, CO/CO_2, NO_X, fluorides and hydrocarbons are generated. The exit gases contain entrained flux, combustible materials, metallic charge, etc. A huge quantity of slag is generated in extraction of copper which is another serious pollutant and its disposal is a severe problem. In fire refining, emissions of compounds of sulphur and fumes of metals such as Cd, Zn etc., are generated. During the electro-refining operations impurities such as nickel, iron, arsenic, antimony, etc., from anodes dissolve into the electrolyte. During melting of electro-refined copper to produce wirebars, some amount of fumes are generated which also cause pollution. The pickling of copper wire rods to remove copper oxide dust generates a huge quantity of copper sulphate which is another source of pollution. Various activities of copper industry and important environmental pollutants are presented in Table 4. [8,9]

Table 4 : Various activities of copper industry and important environmental pollutants

Operation	Environmental pollutants
Mining	Waste rock and overburden
Crushing and Grinding	Dust, suspended particulate matters (SPM) and effluents
Concentration	Waste waters, dissolved chemicals, particulates xanthates and other chemical agents
Roasting, smelting and converting	SO_2, SO_3, volatile oxides of As, Sb, Zn etc., CO/CO_2, NO_X, fluorides, hydrocarbons, smelter and converter slag.
Refining	Compounds of sulphur, fumes of Cd, Zn etc., nickel, iron, arsenic, antimony etc.
Processing	Toxic fumes, copper sulphate etc.

EFFECTS OF ENVIRONMENTAL POLLUTANTS AND THEIR STANDARD LIMITS

Environmental pollutants from copper industry have many adverse effects on earth. The ultimate effect is felt in the health and well being of men, women, children and the total ecology comprising the animal, aquatic life, insects and plants. The effect of dust and gases generated in copper industry on general health concerns is shown in Table 5. Table 6 shows the effects of toxic elements in liquid effluents and gaseous emission on human health. The noise and vibration created in smelters, electric arc furnace for copper production also create

Table 5 : Effect of dust, gases etc., from copper industry on general health concerns

Item	Diseases (Illustrative)
Dust	Fibrotic pneumoconioses, loss of hair, lung cancer, cataract, gastrointestinal (GIT) disorder
Gases	Fine dust + SO_2 combination is deadly
CO_2	Laborious breathing
CO	Asphyxia and blocks oxygen to red blood cells
H_2S	At high concentration paralysis of respiratory centre and central nervous system
NO_x	Irritation in lower respiratory tract and on long exposure pulmonary oedema
SO_2	Diseases of lungs, skin, GIT and eyes; combined with 'SPM' very fatal and causes acid rains

Table 6 : Effects of toxic elements in liquid effluents and gaseous emissions on health concerns

Toxic Element		Diseases
Copper	i)	Nausea and vomiting
	ii)	Epigastric burning and diarrhoea due to toxicity
Arsenic	i)	'Black foot' disease
	ii)	High mortality due to respiratory cancer
Zinc	i)	Nausea and vomiting, severe anemia
	ii)	Pulmonary manifestations
	iii)	Increased syrum lipase and analyse
	iv)	"Metal fume fever"
	v)	At very high dosages reduced growth, poor reproduction, decreased liver activity etc.
Lead	i)	Female infertility, loss of reproduction in men, spontaneous abortions, still births, early infant deaths.
	ii)	Persistant cough and chest pain
	iii)	Eye diseases
	iv)	Neuro-psychological disorders
	v)	Digestion problems
	vi)	Miscu loskeletal disorders
	vii)	Malfunctioning of kidneys, liver and brain cells
	viii)	Massive abruption of learning ability

Table 7 : Health problems caused by noise and vibration in copper industry

Cause		Diseases (Illustrative)
High noise levels	i)	Temporary loss of hearing or permanent/progressive hearings loss depending on level and duration of noise
	ii)	Vascoconstriction and hypertension
	iii)	Elevated blood cholesterol
	iv)	Excessive gastric secretion and peptic ulcer
	v)	Anxiety, nervousness, fear, fatigue, sleeplessness and irritation
	vi)	Reduced work efficiency and slow response resulting in lesser productivity (Task' disorders)
Vibration	i)	Several of the above and vibration syndrome including "White fingers"
	ii)	Motor and sensory disorders

severe health problems. Health problems caused by noise and vibration in copper industries are presented in Table 7.

The pollutions created in copper industries in India is becoming alarming day by day. If we can compare this level with other countries, we will see that the situation in our country is fairly bed. The ambient air quality standards (AAQ) in some countries are shown in Table 8. The emission standards for various non-ferrous metal smelting units are presented in Table 9. Table 10 presents the Ambient Air Quality Standards in respect of noise. Here day time is reckoned in between 6.00 am and 9.00 pm whereas night time is reckoned in between 9.00 pm and 6.00 am. Generally the silence zone is defined as area upto 100 meters around such premises as hospitals, educational institutions and courts. The silence zone

Table 8 : AQS specifications in some countries (median values) ($\mu g/m^3$)*

Country	Selected Pollutants				
	SPM	SO_2	NO_x	Pb	CO
INDIA					
Industrial	500	120	120	NA	5000
Residential	200	80	80	NA	2000
Sensitive	100	30	30	NA	1000
USA	150	80	200	2	NA
EU	75	80	100	1.5	NA

* Seasonal and daily : Specified location wise

Table 9 : Copper, lead and zinc smelting units : emission standards

Parameters	Source	Emission Limit
Particulate Matters	Concentrator	150 mg/Nm^3
Emission	Smelter	4 kg/tonne of concenrate
Oxides of sulhur	Converter	(100 pet) acid produced

Table 10 : Ambient air quality standards in respect of noise

Area Code	Category of Area	Limit in dB(A) Leg	
		Day Time	Night Time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

Table 11 : Inorganic chemical industry waste water discharge standards

Parameters	Concentration not exceed mg/l except pH
pH	6.0 to 9.0
Chromium as Cr Hexavalent	0.10
Total	2.00
Manganese as Mn	2.00
Nickel as Ni	2.00
Copper as Cu	2.00
Zinc as Zn	5.00
Suspended solids	0.20
Cadmium as Cd	30.00
Lead as Pb	0.10
Mercury as Hg	0.01
Cyanide as CN	0.20
Oil and Grease	10.00

area declared by the competent authority. Mixed category of area should be declared as "one of the four above mentioned categories by the competent authority and the corresponding standard shall apply". The inorganic chemical industry waste water discharge standard is given in Table 11. Table 12 indicates

Table 12 : National ambient air quality standards

Polutants	Time weighed Average	Concentration in ambient air Industrial areas	Residential, rural and other areas	Sensitive areas	Method of measurement
Sulphur dioxide (SO_2)	Annual average*	80µg/m³	60 µg/m³	15µg/m³	Improved west & greek method
	24 hours**	120µg/m³	30µg/m³	30 µg/m³	Ultra violet fluorescence
Oxides of Nitrogen as NO_2	Annual average*	80 µg/m³	60µg/m³	15µg/m³	Jacob & Hocheiser modified (Na-Arsemts method) gas
	24 hours**	120µg/m³	80µg/m³	30µg/m³	Gas phase chemilu-minescence
Suspended particulate matters (SPM)	Annual average* 24 hours**	360 µg/m³ 500µg/m³	140µg/m³ 200µg/m³	70µg/m³ 100µg/m³	High volume sampling (Average flow rate not less than 1.1m³/min)
Respirable particulate matter (size less than 10µm) (RPM)	Annual average* 24 hours**	120 µg/m³ 150µg/m³	60µg/m³ 100µg/m³	50µg/m³ 75µg/m³	Respirable particualte matter sampler
Lead (Pb)	Annual average* 24 hours**	1.0 µg/m³ 1.5µg/m³	0.75µg/m³ 1.00µg/m³	0.50µg/m³ 0.75µg/m³	Ass method after sampling using EPM 2000 or equiva-lent filter paper
Carbon monoxide (CO)	8 hours 1 hour	5.0mg/m³ 10.0mg/m³	2.0mg/m³ 4.0mg/m³	1.0mg/m³ 2.0mg/m³	Non-despersive infra red spectro-scopy

* Annual arithmatic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform intervals.

** 24 hourly/8hourly values should be met 98% of the time in year. However, 2% of the time it may exceed but not on 2 consequitive days.

the National Ambient Air Quality Standards.

POLLUTION PREVENTION AND CONTROL

Pollution prevention is defined as any practice which reduces or eliminates wastes generated or released from a facility. Until recently, environmental authorities have focussed on end of pipe pollution control. The approach is costly

Table 13 : Pollution prevention measures applied in copper industry to save environment

Operations	Pollutants	Control Measures/methods
Mining	Dust, waste rock and over burden	Dust catcher and proper disposal of these wastes
Communition	Dust, suspended particulate matters (SPM), effluents	Dust catchers, filters, precipitators and thick green plantation
Concentration	Waste waters with dissolved chemicals, particulates, xanthates and other chemical agents used for floatation and tailings	Recovery processes, use of tailing dam, use of cyclones or dozing, use of tailing pond, backfiling of under ground mines
Roasting	Dust, sulphur dioxide, sulphur trioxide, volatile oxides of Arsenic, Antomony, Zinc etc.	Use of oxygen in reverberatory furnaces, fume collecting devices, electrostatic precipitator, use of new control equipment for sulphur recovery
Smelting	Dust, NO_x, flurides, hydrocarbons, SO_2 and CO/CO_2, toxic metal fumes,	Electrostatic precipitator, modern fume collecting devices, manufacture of H_2SO_4, smelter and converter slag use of oxygen in smelters, use of flash and pneumatic smelting techniques, the use of a counter current shaft furnace, various desulphurisation schemes, etc., wet cyclone and wet scrubber having alkali water spray to absorb harmful gases.
Refining	Compounds of sulphur, fumes of metal like Cd, Zn etc., & impurities like Ni, Fe, As, Sb etc.	Modern fume collecting devices, recovery techniques of metals, H_2SO_4 manufacture, wet scrubber having alkali water spray to absorb harmful gases and acid plant effluents
Processing	Toxic fumes, copper sulphate, sludge etc.	Fume collecting decives, use of fractional crystallisation in two or more stages

and merely transfers pollutant from one media to another. Further more, as we are nearing twenty first century, we may encounter another level of environmental threats which are more complex and widespread than can be addressed by end of pipe controls. A novel approach is to implement a comprehensive pollution prevention programme at a plant or facility. Pollution prevention programme not only helps to reduce the impact of industrial activity on the environment but also makes commercial sense. Pollution prevention programme involves four major techniques: (i) source reduction, (ii) recycle/reuse, (iii) treatment and (iv) adoption of recent technologies.[10,11]

Source reduction reduces wastes before it is generated. Recycle/reuse helps in recovering usable materials from a waste. The final treatment is to reduce the volume and toxicity of a waste before it is disposed off. Of all the three cited above, source reduction is the best waste management technique because no adverse environmental impact could be realised from wastes not produced. The control measures must be applied at every stage of copper production i.e., starting from mining of ore to the production of finished copper product. Basic metal extraction process designs should pay adequate attention to the discharge of pollutants in the surroundings. Conventional smelting furnaces are to be properly maintained or be completely replaced by flash smelters. Most recent technologies such as use of oxygen in smelting, the use of flash and pneumatic smelting techniques, the use of a counter current shaft furnace, modification of ESPs, installation of converter double hoods, use of various desulphurisation schemes, making the fullest possible use of waste heat, etc., have to be adopted to eliminate or atleast reduce pollution. Adequate plantation cover has to be provided in and around the copper plant to minimize environmental effects [12]. Some of the pollution prevention measures already applied in the copper industry are mentioned in Table 13.

CONCLUSIONS

Preservation of environment and ecological balance have become the topics of serious concern today. Measures are to be taken to prevent or minimize pollution even before providing license to a copper industry. The effective control of environmental pollution in the production of copper and processing industry is becoming more important in the context of the anticipated accelerated growth in industrial activity and to become competitive in the market in this era of globalisation. A more integrated approach to pollution control through waste reduction, treatment and recovery would go a long way in not only making the environment clean or safe, but also help in conserving the much needed metal resources and also contribute to improve the quality, enhance productivity and

better economics of production.

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