ICSG

International Copper Study Group

1st International Seminar on Mining and Sustainable Development

Impurities: Regulatory Trends, Markets and Technologies

Regulatory Trends Affecting the Processing, Transport and Disposal of Copper Industry Impurities

Don Smale, Secretary-General, ICSG

Thursday 6 April, 2017 CESCO Week, Santiago, Chile

ICSG Membership

- Membership open to **any country involved in copper production, use or trade**.
- **24 member** governments plus the European Union
- Countries joining recently: **Zambia, Iran and Brazil.** Possible new members: **Mongolia and DR Congo**
- Headquarters in Lisbon, Portugal.
- With International Lead and Zinc Study Group
- and International Nickel Study Group


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Brazil

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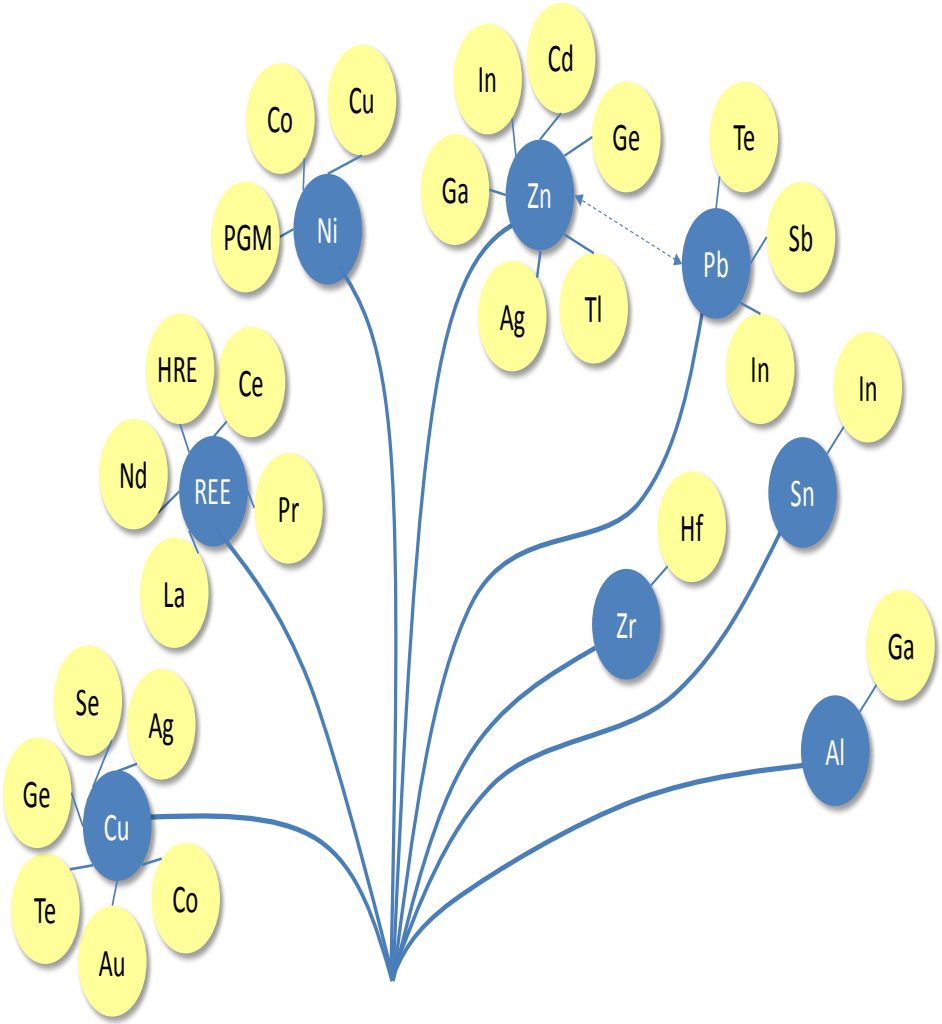
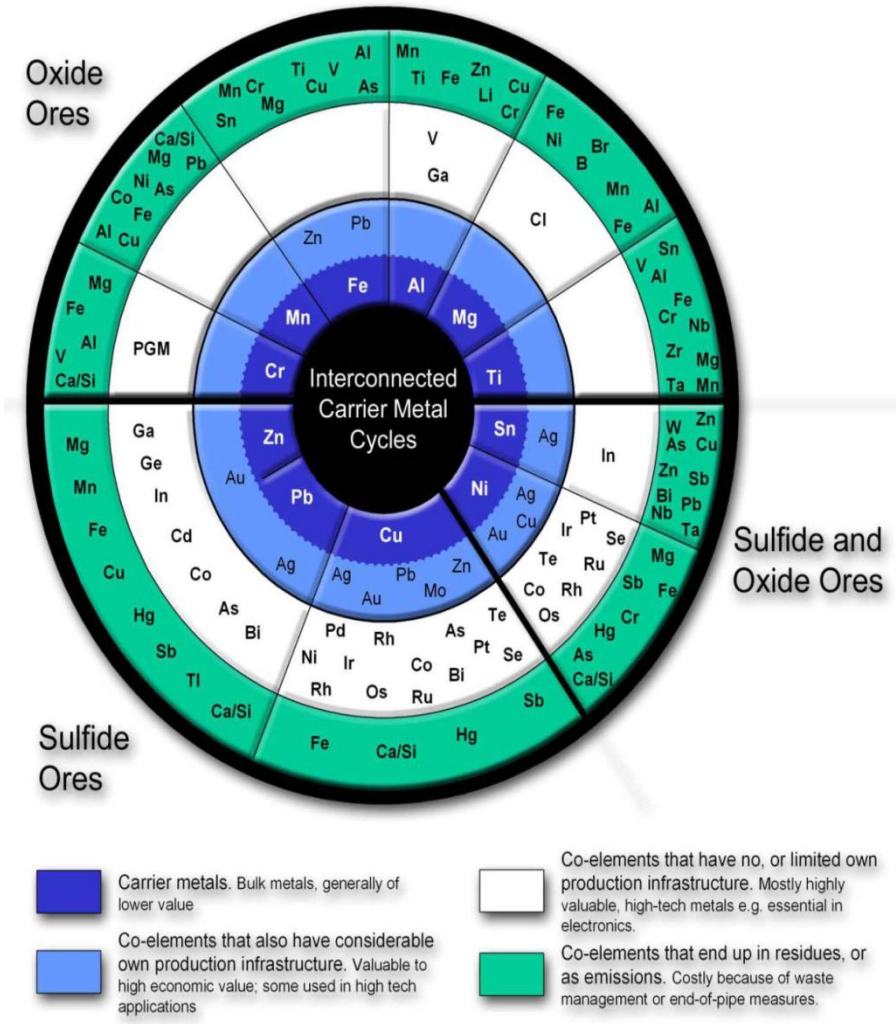
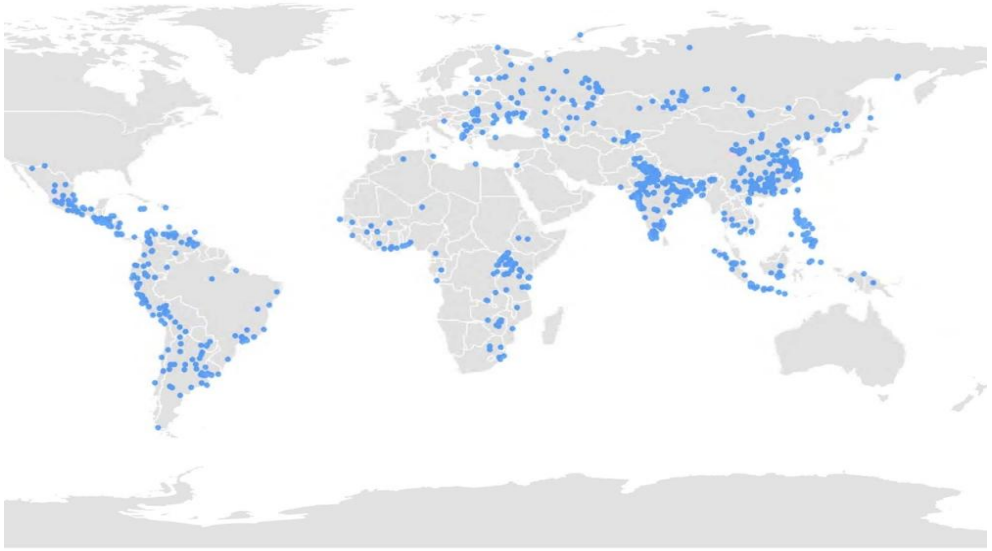
1. Drivers of Regulations on Copper Impurities: Recent Data

Regulations on impurities are tightening because metals not recovered ends as industry emissions or as hazardous waste.

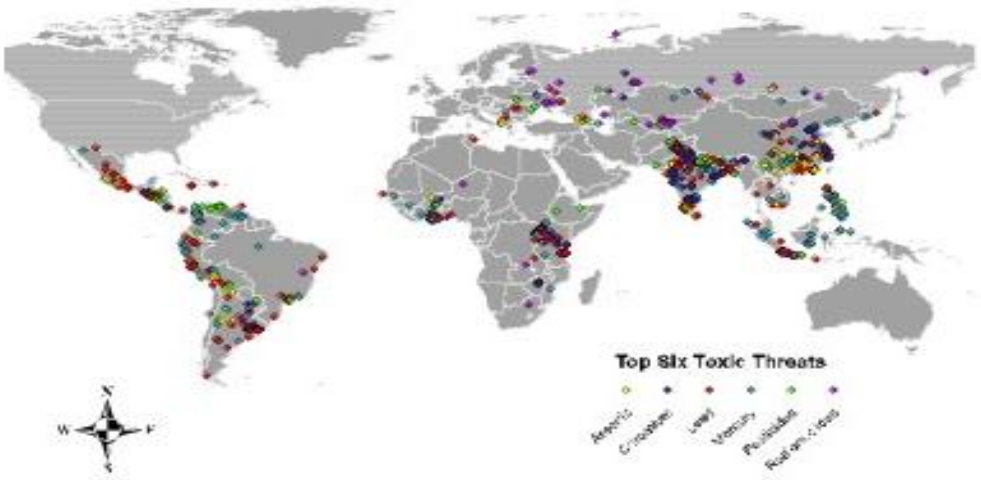




Reference: ICSG Study on By-Products – Updated 2015, Yale University (2009). www.icsg.org



Sites by Key Pollutant



"There are >3,000 industrial sites with populations at risk of industrial pollution from lead, mercury, chromium, arsenic, radio-nuclides and pesticides."

"Health impacts from pollution vary according to toxicant: lead, mercury and arsenic affect brain development in children causing disability."

Source: Blacksmith Institute, London. Presentation at the Metal Study Groups in Lisbon, 2013.

THE WORLD BANK

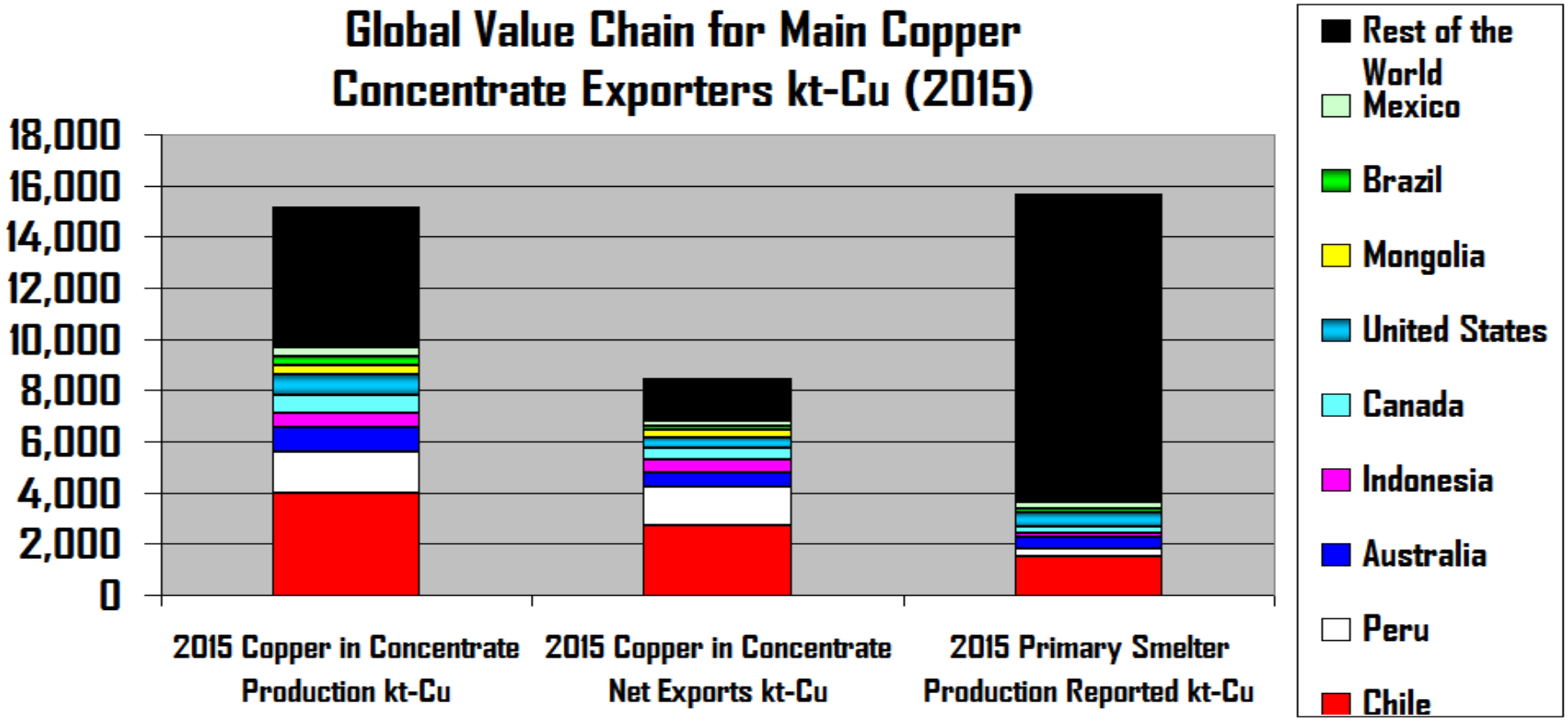
ADB

UNIDO
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

EUROPEAN COMMISSION

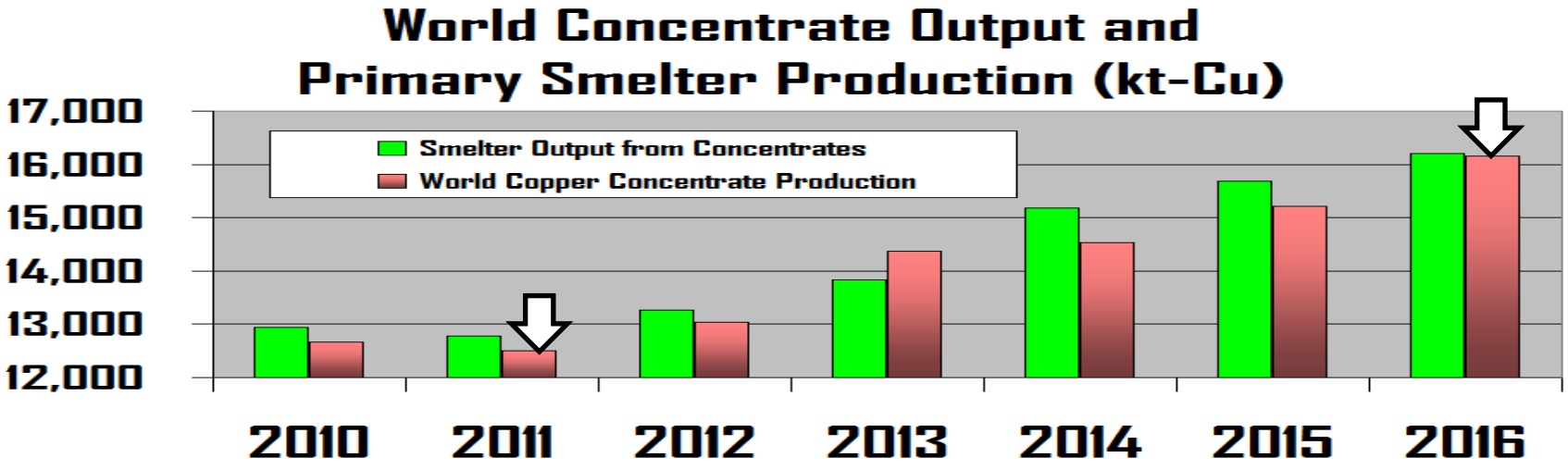
BLACKSMITH INSTITUTE

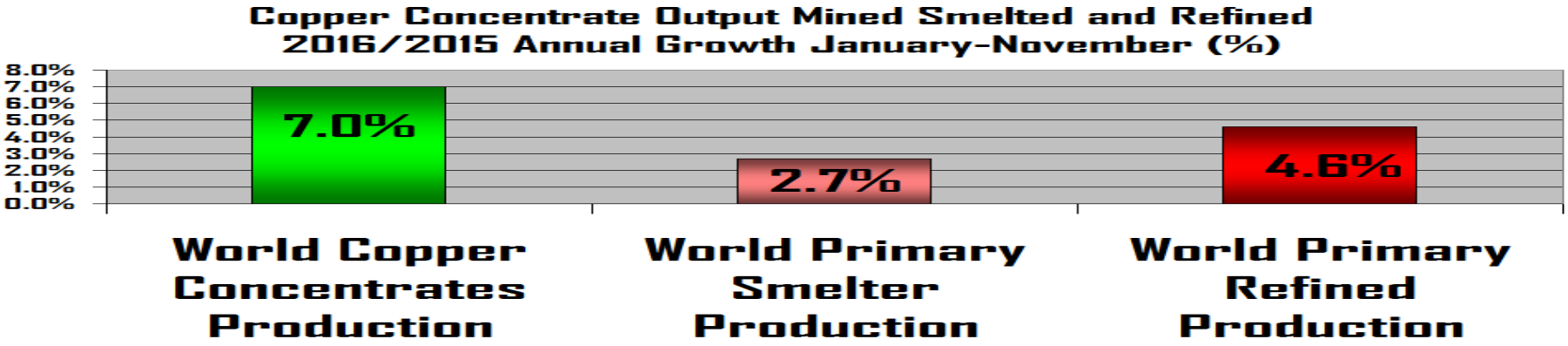
ICSG data: 55% of the copper concentrate produced is exported. 9 countries produce over 65% of global copper concentrate output



But only a share of the copper concentrate output is smelted into anodes in these 9 countries.

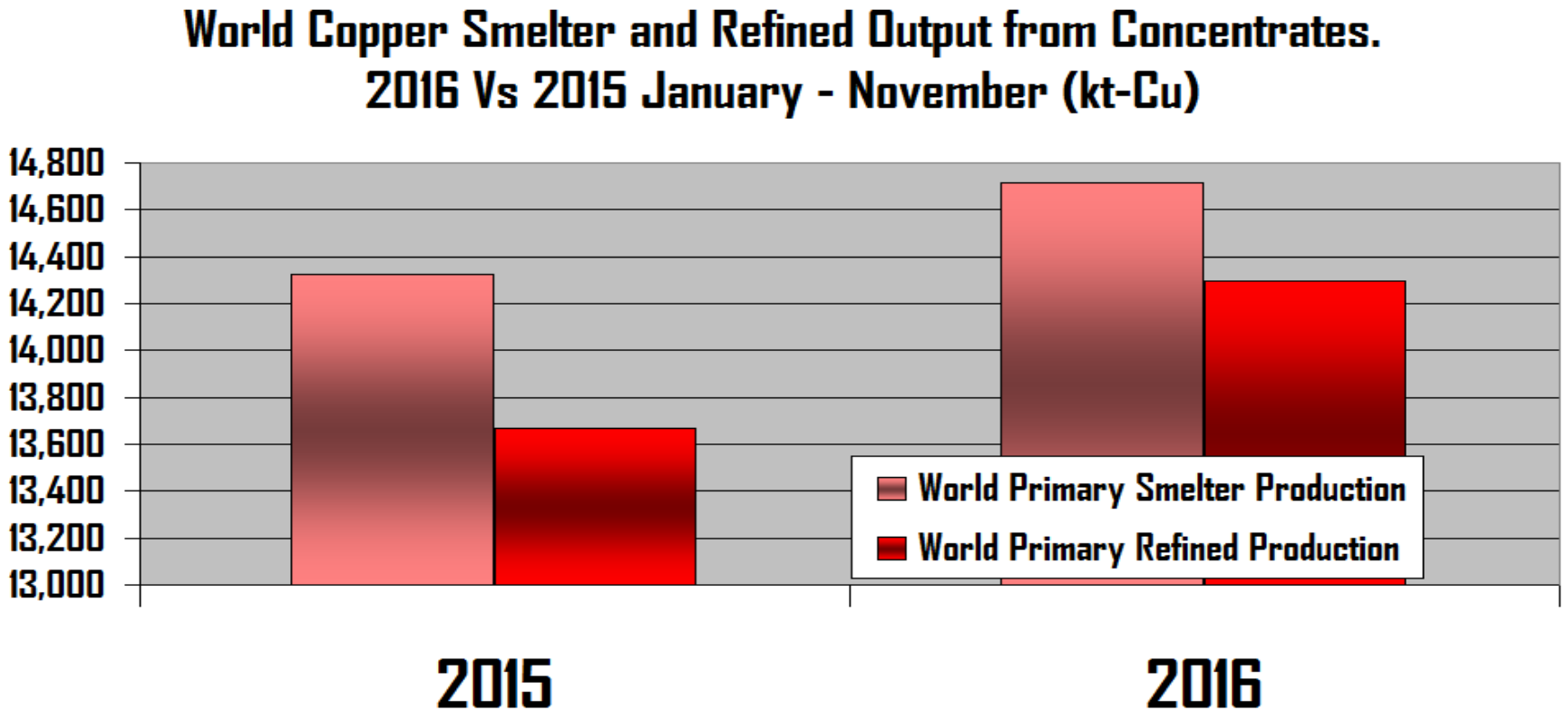
Increased global copper concentrate supply: up ~30% in 2011-2016.
With more concentrate produced, more impurities have been mined





Record global copper concentrate output growth: ~7% in 2016!

Copper content in smelter output higher than global refined copper output again in 2016

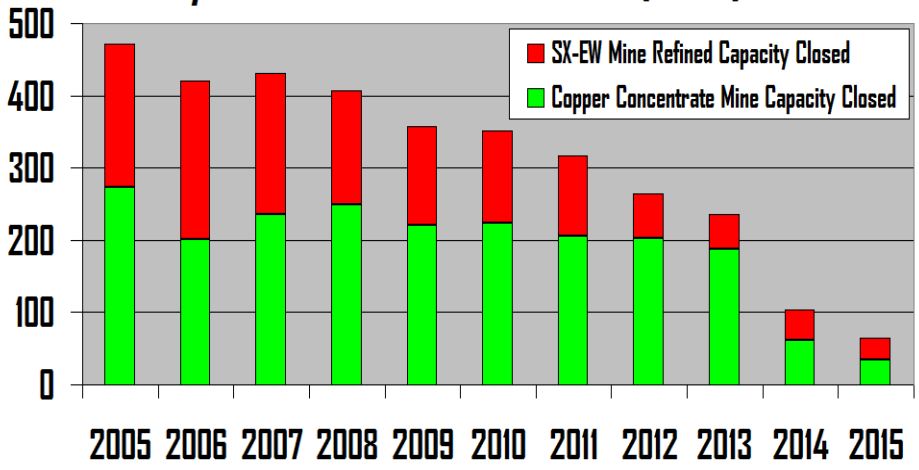


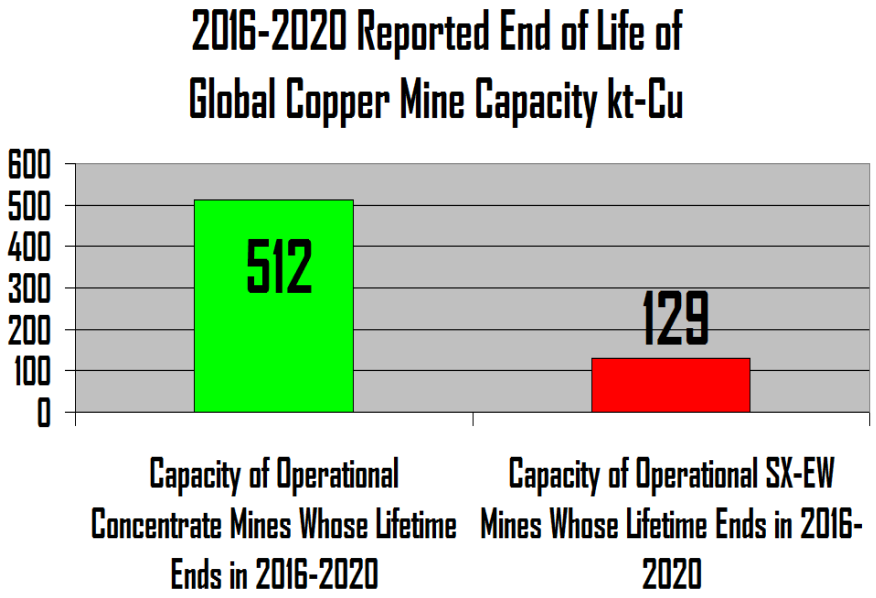
More blister/anodes from concentrates = more impurities to be recovered/disposed by copper refineries in 2017.

Depletion of surface layers is affecting copper ore quality. End of life copper mines to replace >600 kt in 2016-2020.

Porphyry Copper Deposits

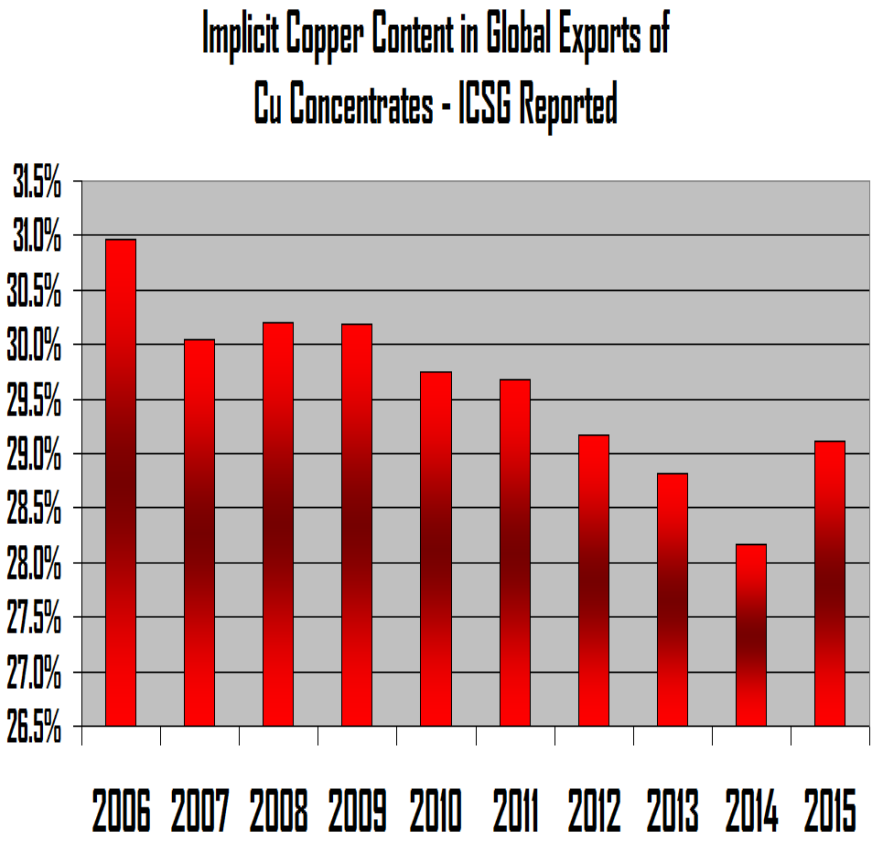
- Surface Layers: Cu2O, $CuCo_3(OH_2)$...peak output except in Congo.
- Secondary Copper Sulphide Ore Layers (Cu2S, CuS)... we are there...
- Primary Sulphide Ores Layers ($CuFeS_2$, Cu_2FeS_4)

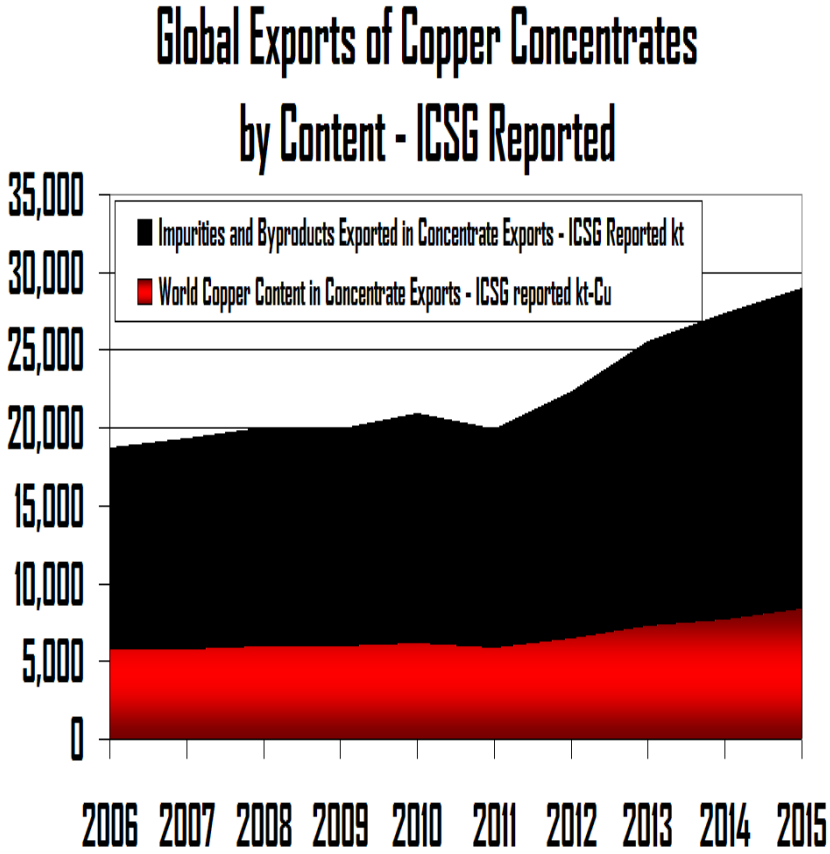




As copper content falls, copper miners export more concentrates.

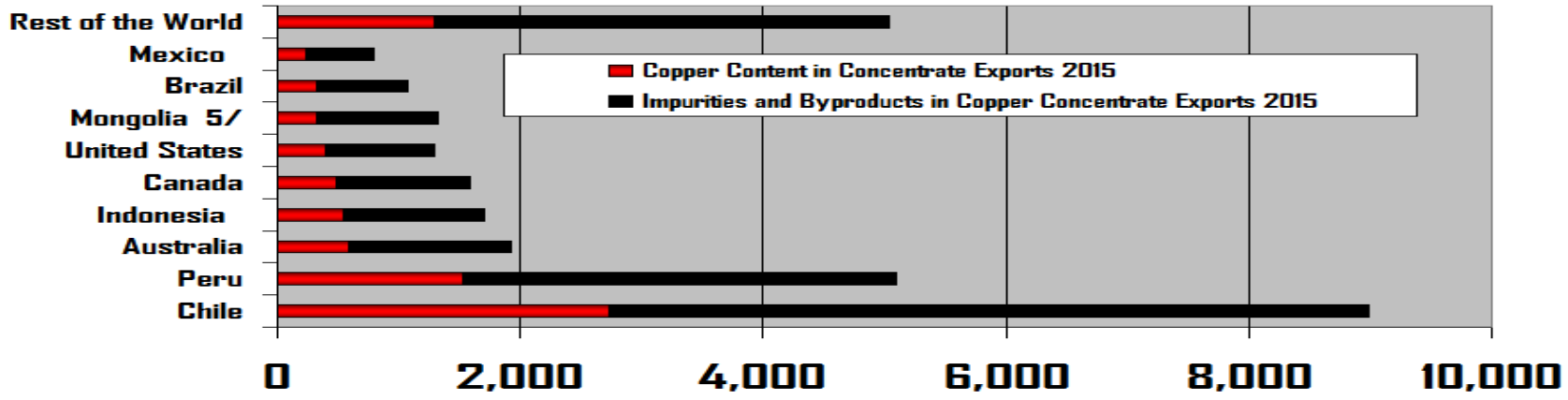
So international trade of impurities and byproducts is growing fast.



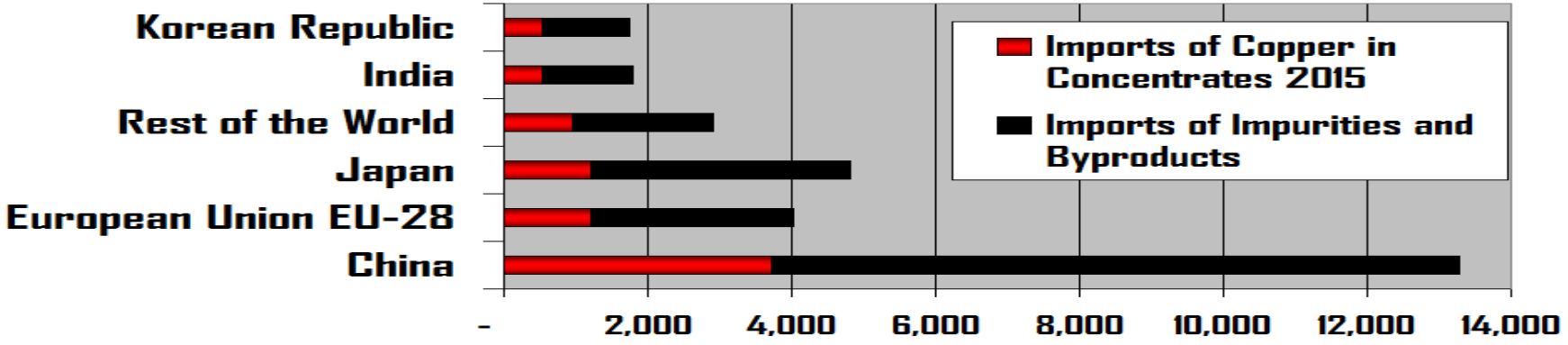


In 2015 concentrate trade achieved 8.2 Mt in copper content. More in 2016. Global trade of impurities growing faster than copper content in concentrates.

2015 Global Exports of Copper Concentrates by Exporter Country and Content kt

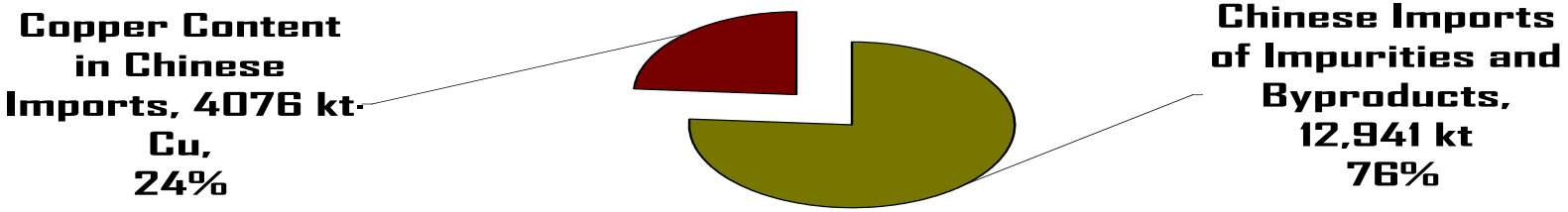


2015 Imports of Copper Concentrates by Main Importers and by Content kt

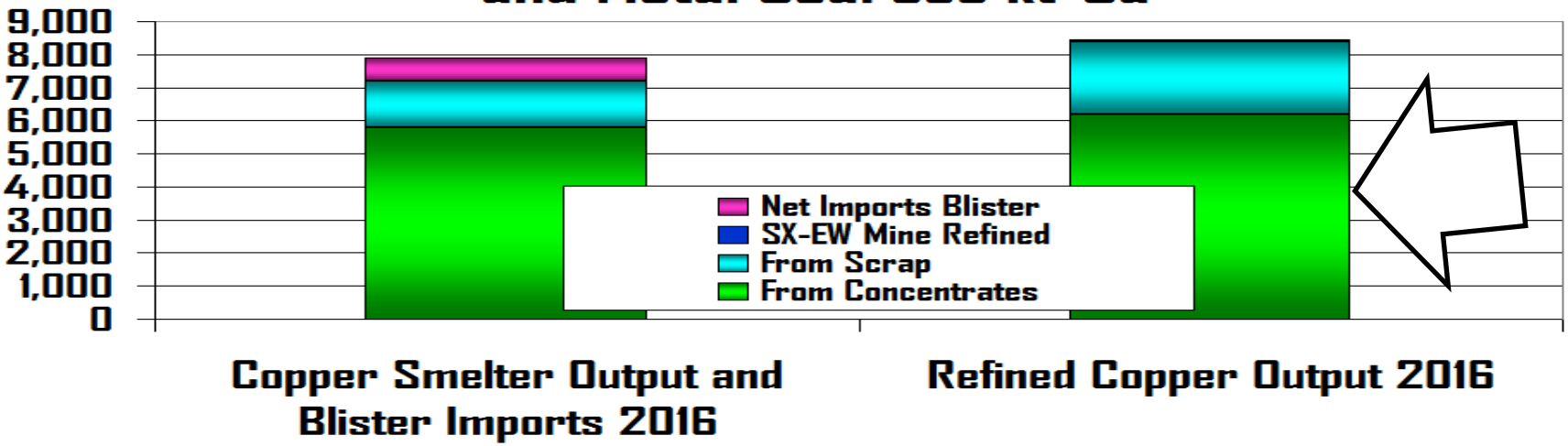


Chinese imports of copper concentrates: up ~28% YoY in 2016. But ICSG reported copper content in imported concentrate: 25.2%.

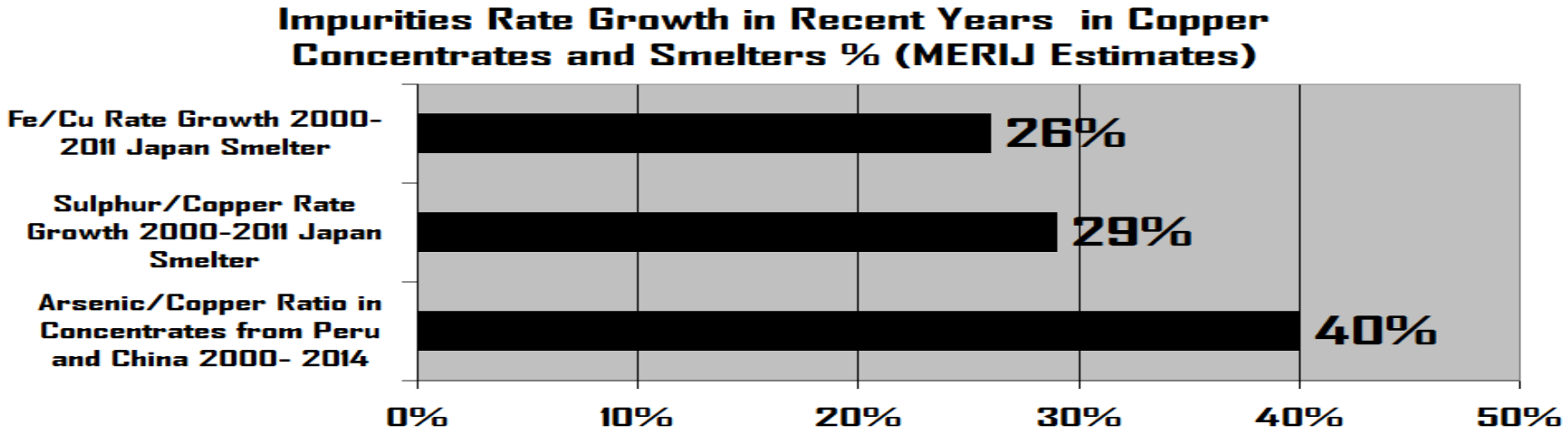
China 2016 Copper Concentrate Imports and Contents kt-Cu



China 2016 Refined Copper Output and Metal Sources kt-Cu



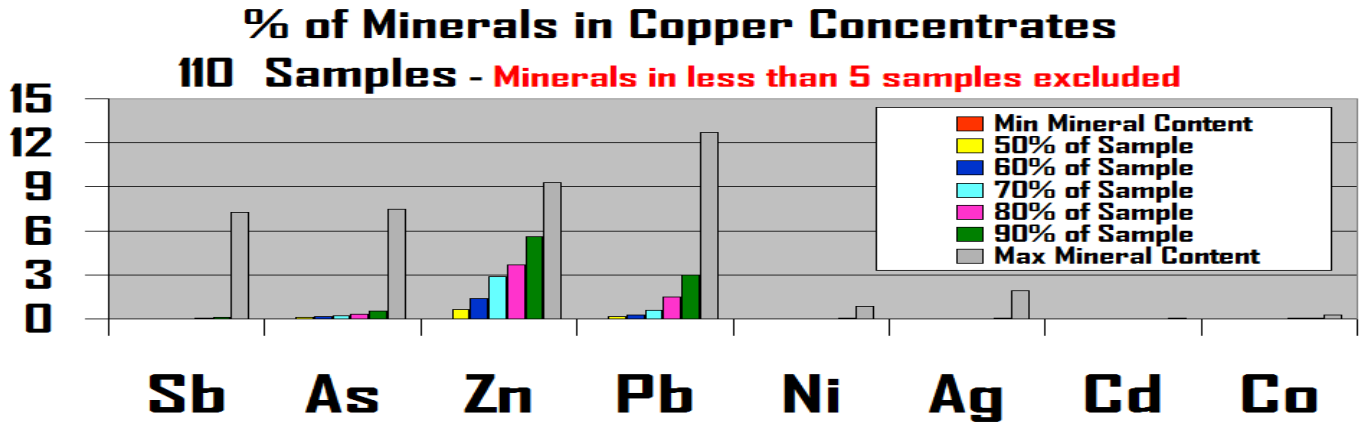
Increasing rates of arsenic, sulphur and iron in copper concentrates: reported before the current expansion in concentrate production.



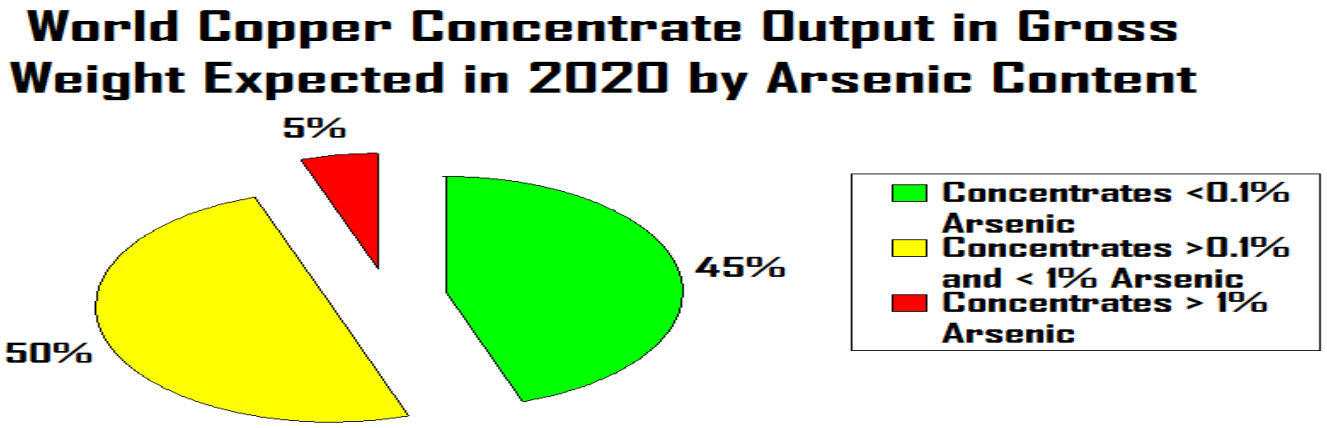
Global sample of copper concentrates of the copper industry:

4 years ago 10% of copper concentrates reported arsenic levels between 0.42% and 7.5%.

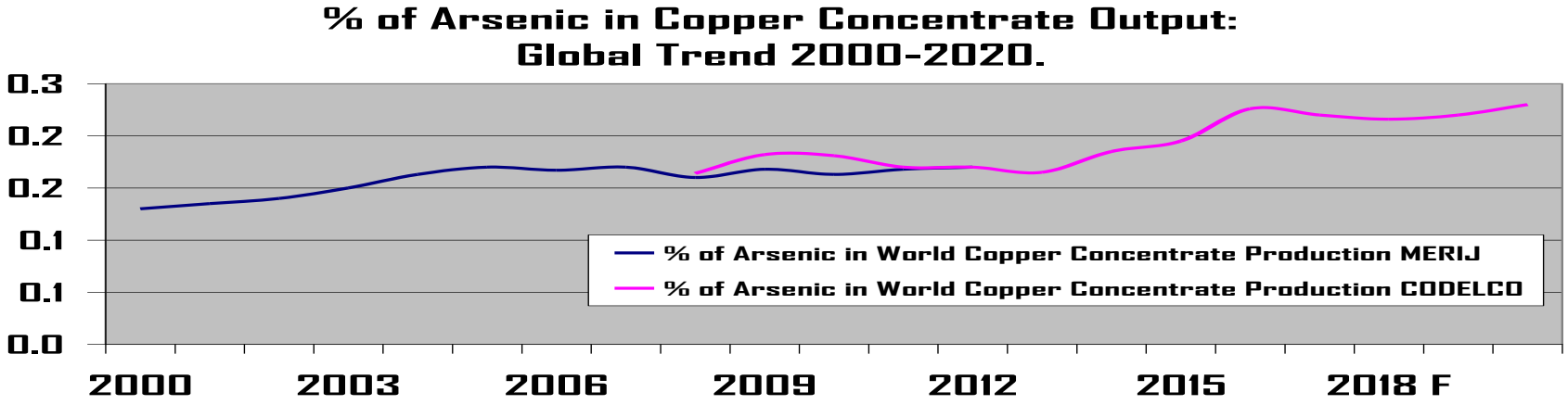
Cu Copper Alliance



Arsenic content in world concentrate output is growing fast: 0.13% in 2000 ...>0.20% in 2016*...0.30% in 2020?



10% of the global copper concentrate supply already has arsenic levels over the 0.2% penaly level **

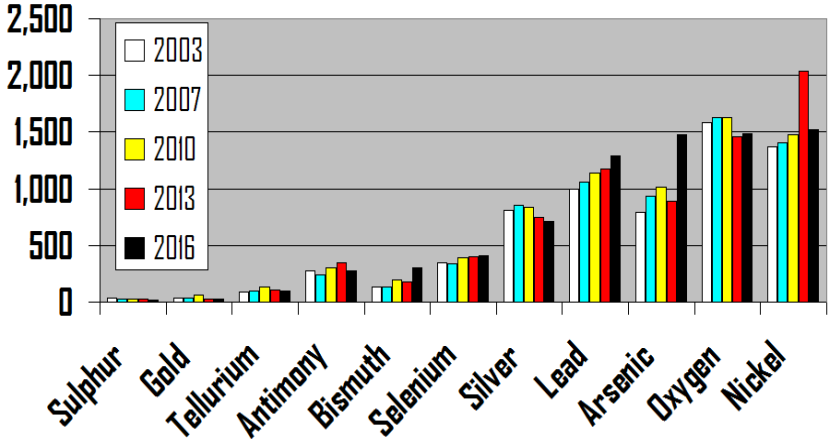


* Metal Economics Research Institute, Japan – November 2016, CODELCO Website 2016. ** Bruce (2014) ** Document PY13-3, Copper 2016, Kobe, Japan.

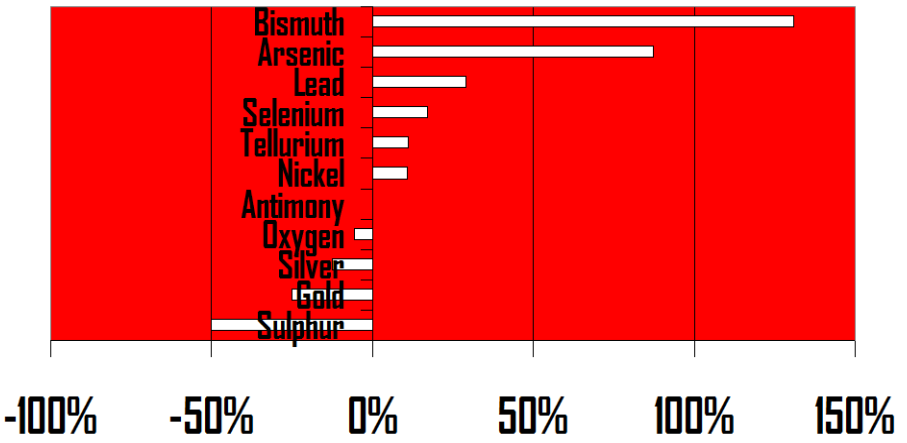
Impact of more complex copper concentrates:

more impurities in anodes, more smelter flue dust, more refinery slimes, more by-products.

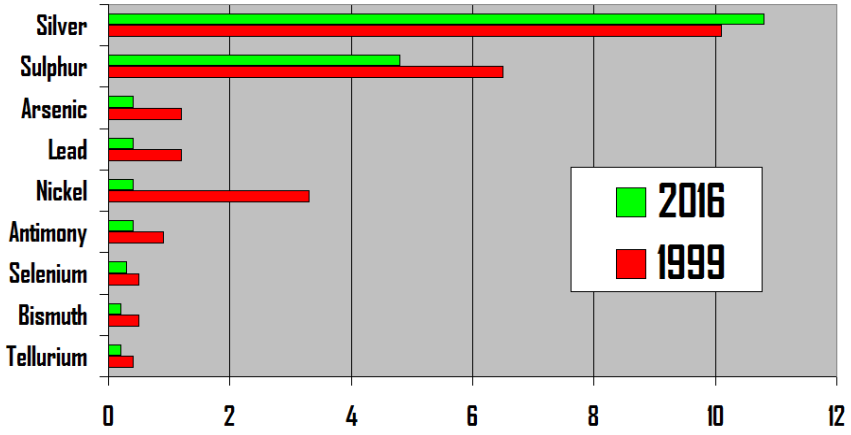
Impurities Content in Copper Anodes 2003-2016
by Metal Received in 30 Refineries (ppm)



Impurities Content in Copper Anodes of 30 Electrolytic
Refineries- % Growth 2003-2016

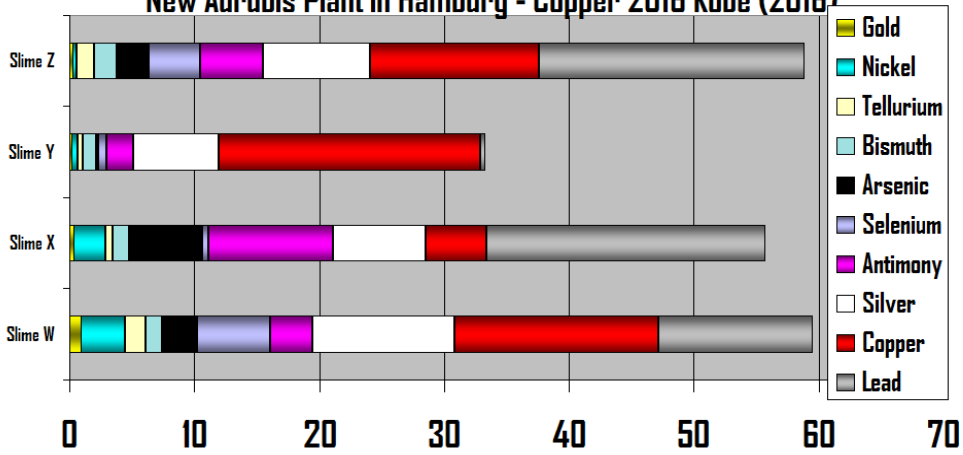


Impurities in Copper Cathode Output
in 30 Electrorefineries Processing Anodes (ppm)



Anode Slimes Metal Composition (%)

New Aurubis Plant in Hamburg - Copper 2016 Kobe (2016)



Over 58% of all copper tailings 1910-2010 generated after 1990.

Report commissioned by the Canadian Government defines tight standards to prevent more copper mines tailings failures after Mount Polley mine incident.

For **new mines**, a shift to "Best Available Technologies (BATs)" in tailings storage, including the following:

a) **Eliminate surface water from the impoundment.**
b) Unsaturated conditions with **drainage provisions.**
c) Achieve dilatant conditions by **compaction.**

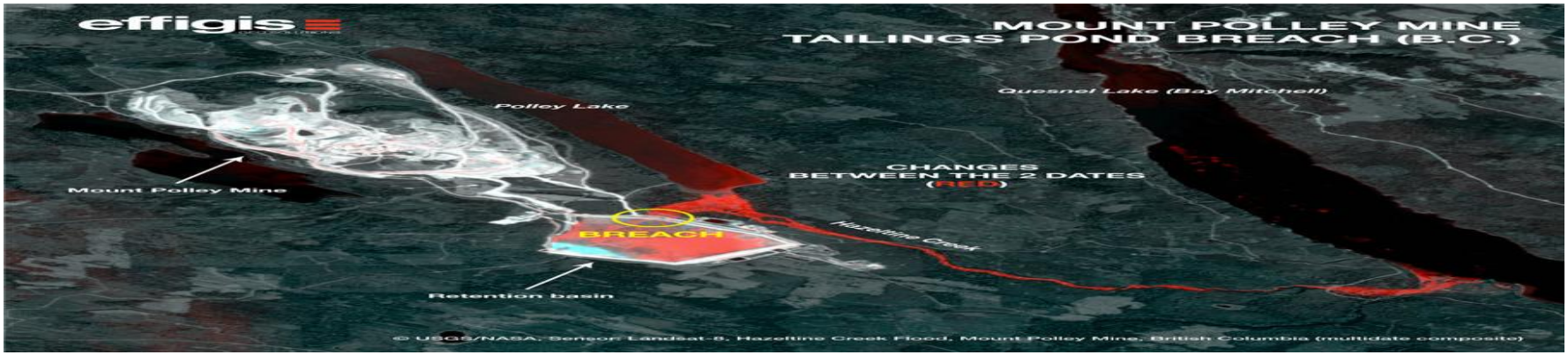
For **existing mines**, applying BATs to conduct

- **dry closure of tailings impoundments.**
- **Mines should dewater tailings**
- and pursue all alternatives to perpetual water covers.

Appointment of Independent Tailings Review Boards

to provide **third-party advice**

- on design,
- construction,
- Operation,
- closure.



https://www.mountpolleyreviewpanel.ca/final-report

ICMM members position on preventing catastrophic failure of tailings storage facilities: December 2016

- Physical and chemical characteristics of tailings vary with nature of the ore, geological setting and climate.

- The position statement will not apply retroactively.

ICMM members recognise that:

1. Tailings production will remain so for the foreseeable future.
2. Catastrophic TSF failures are unacceptable.
3. Systems, standards and resources to prevent failures required.
4. Potential for TSF failures must be taken account of.
5. Technical guidance to prevent catastrophic failures of TSFs.
6. Each mine TSF site: unique tailings technology and storage solutions.

- ICMM Members to implement their commitments by November 2018.

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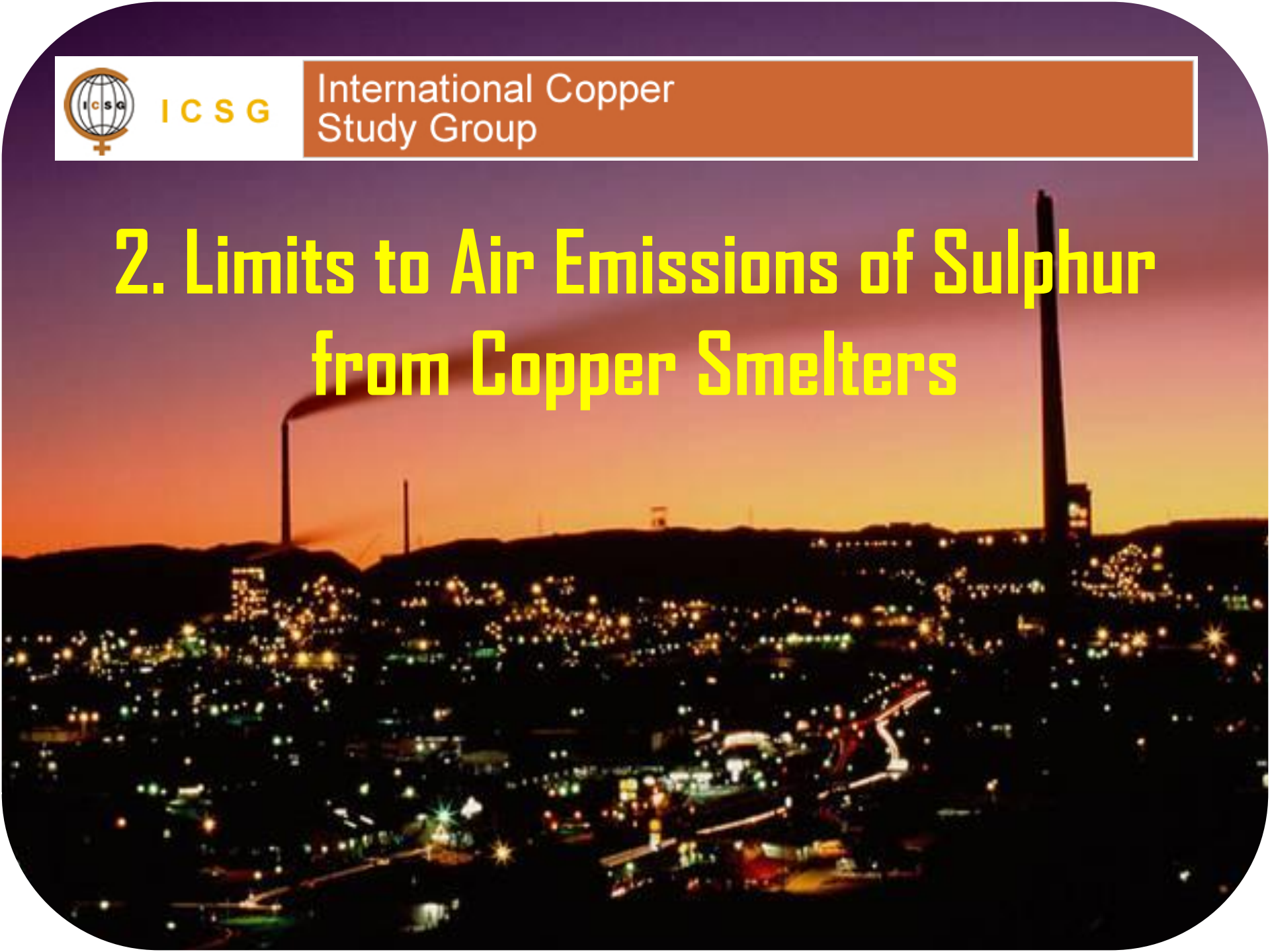
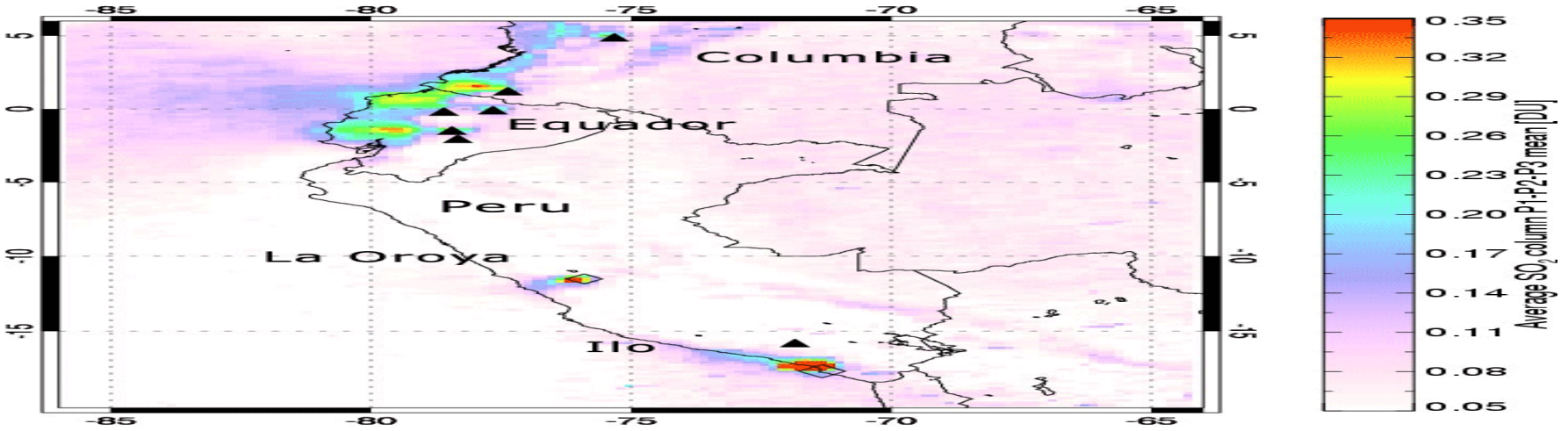
2. Limits to Air Emissions of Sulphur from Copper Smelters

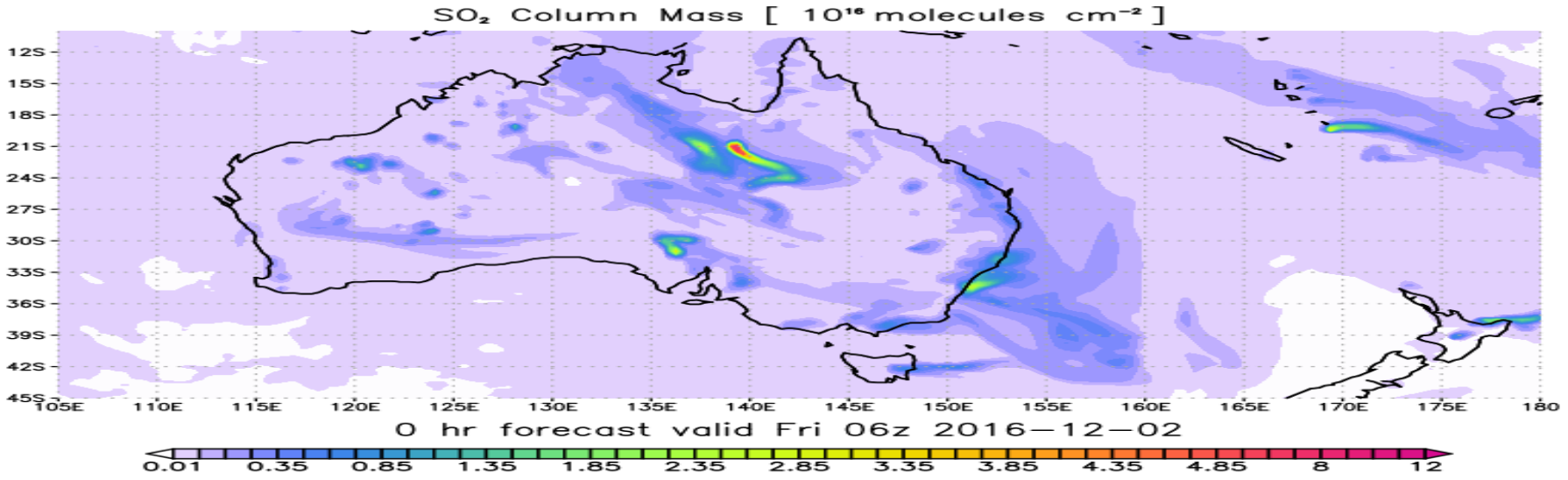


http://portal.nccs.nasa.gov

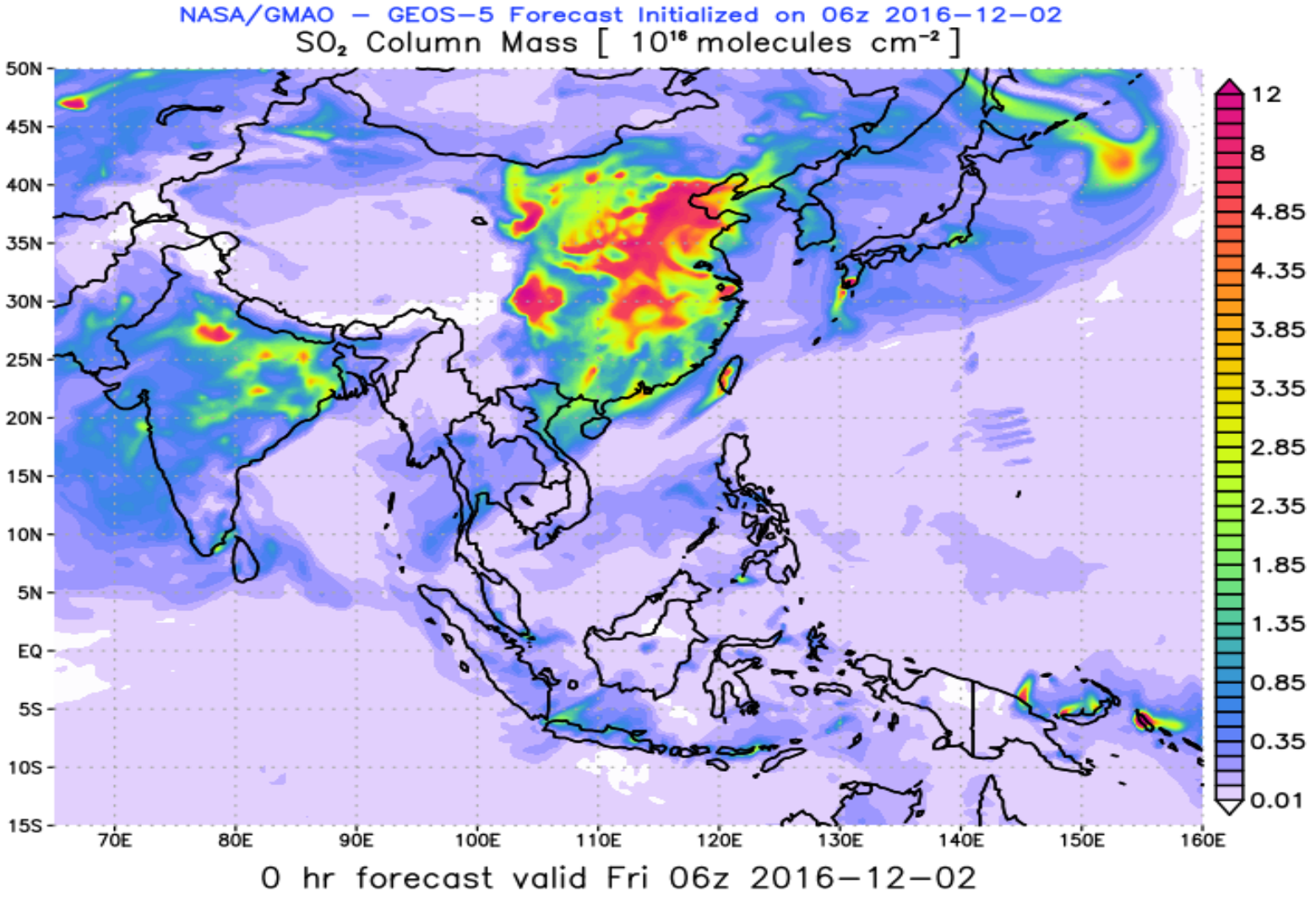
SO2 emissions from all sources are tracked remotely by NASA. Smelters in Peru, Russia, Australia and Mexico remain important sources in 2016.



NASA/GMAO – GEOS-5 Forecast Initialized on 06z 2016-12-02

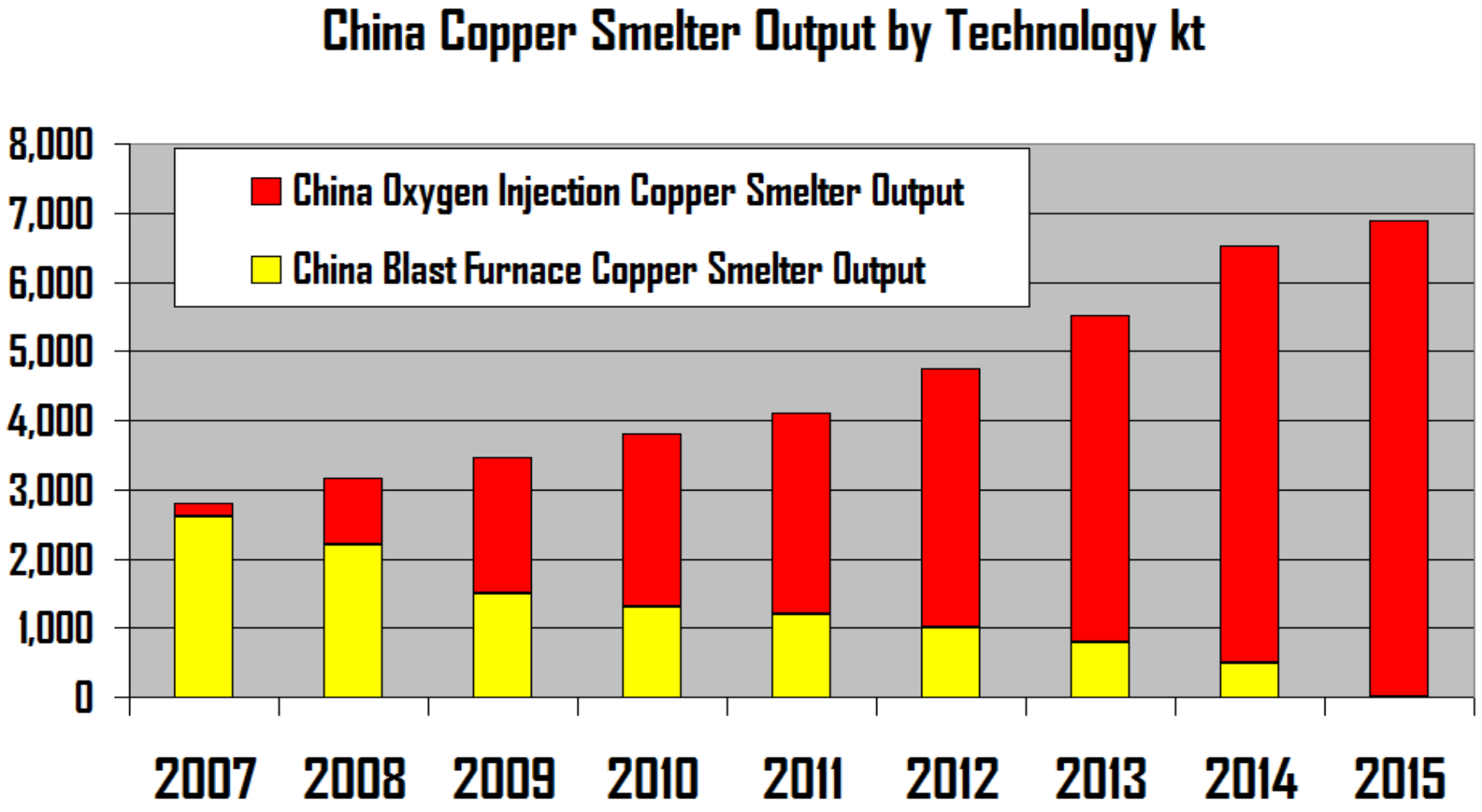


High SO2 emisions observed by NASA across China and India in 2016



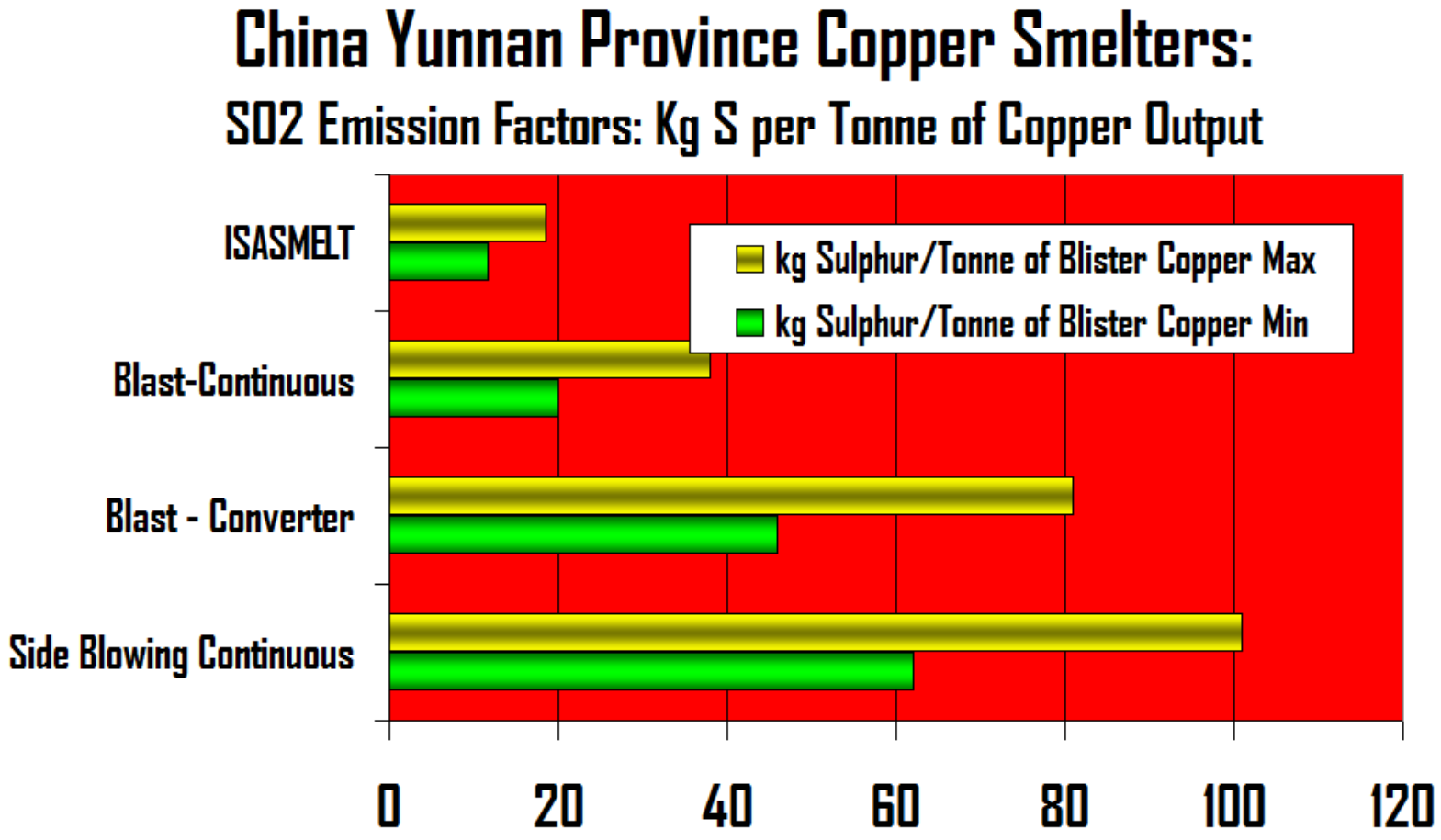
http://portal.nccs.nasa.gov/cgi-fp/fp_2d_chem.cgi?region=sevseas&dtg=2016120206&prod=8so2cmass&model=fp&tau=000&region_old=shout&dtg_old=2016120206&prod_old=8so2cmass&model_old=fp&tau_old=000&loop=0

Chinese 2006 regulation on SO2 capture for copper smelters allowed replacement of blast furnaces by oxygen blowing technology



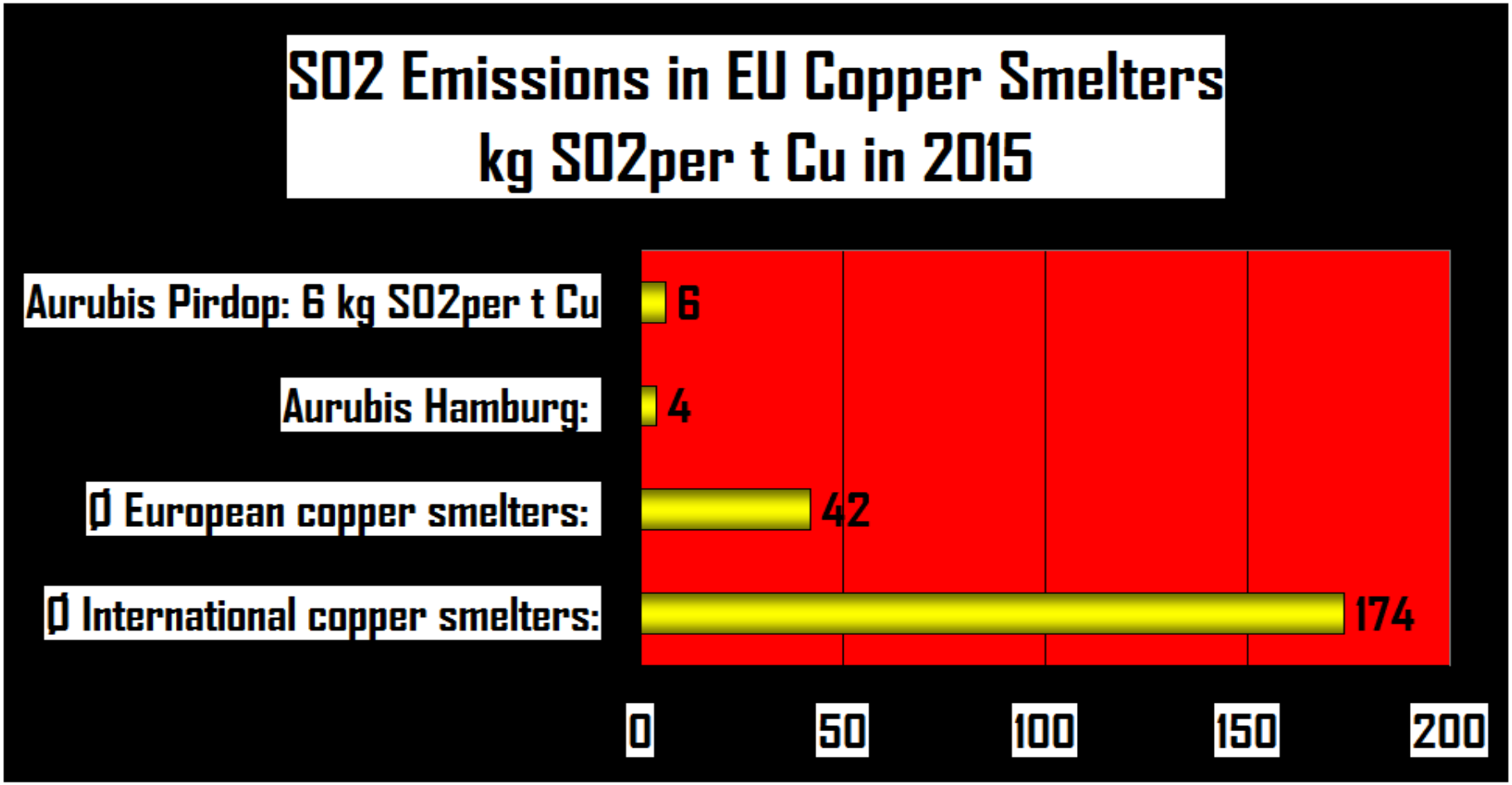
Source: Paper PY1-2, Copper 2016 Conference, Kobe Japan, November 2016

Less SO2 emissions per tonne of copper output reported for some copper smelters in China in 2016



Source: Paper PY1-2, Copper 2016 Conference, Kobe Japan, November 2016

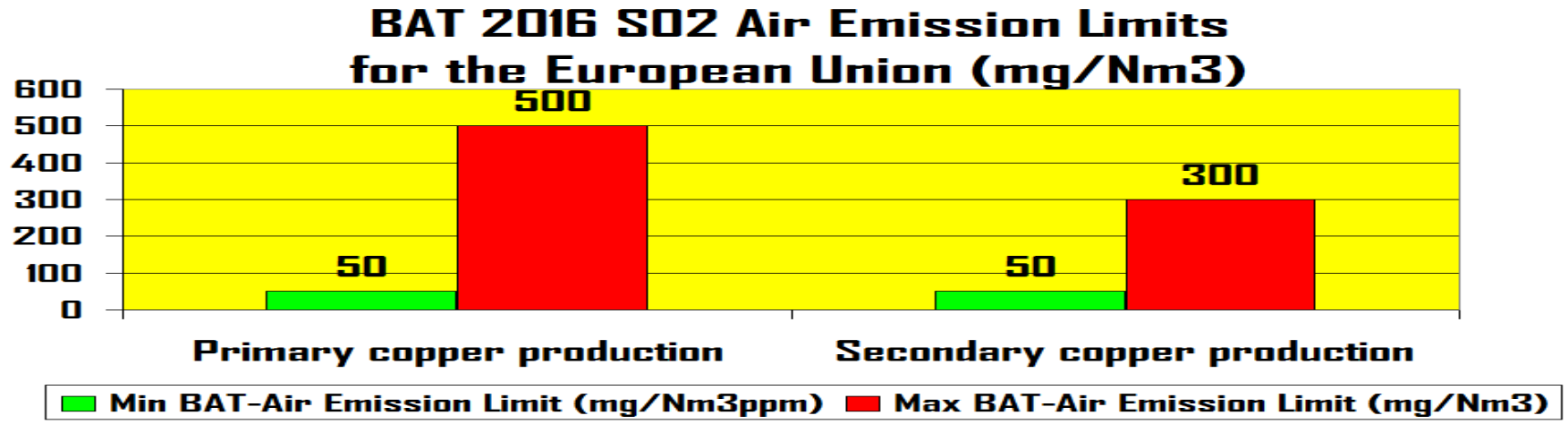
But Chinese smelter emission coefficients still far from 4-6 kg/tonne in more efficient European Union smelters

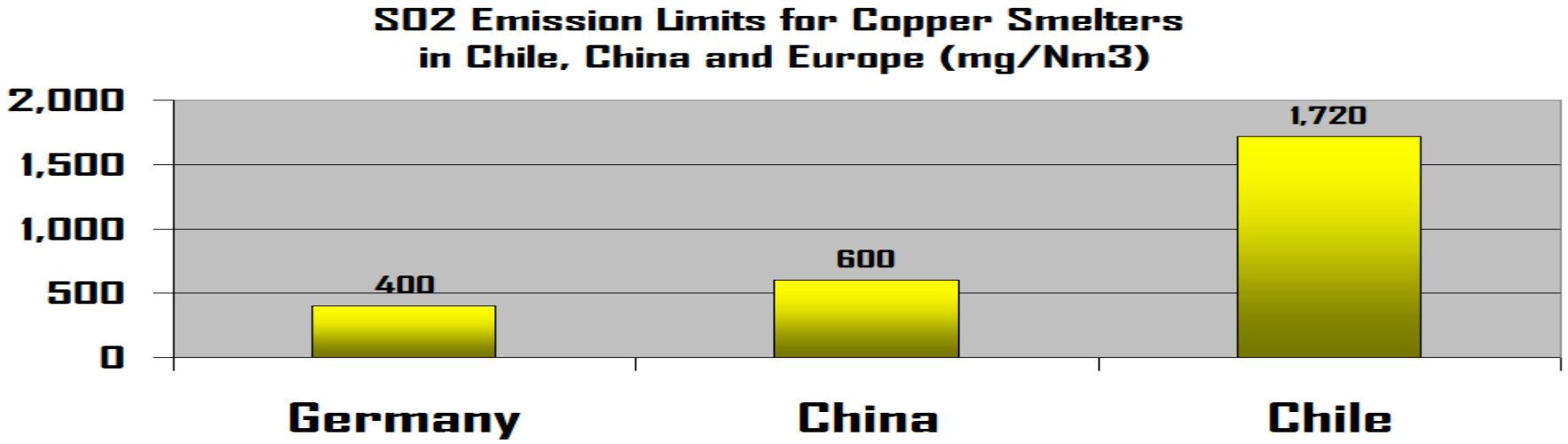


Source: Aurubis Environmental Audits.

https://www.aurubis.com/binaries/content/assets/aurubis-en/dateien/responsibility/environmental-statement_2016.pdf

New SO2 air emission limits in the European Union more flexible for smelters using concentrates. SO2 limits for scrap smelters are not difficult to comply with.

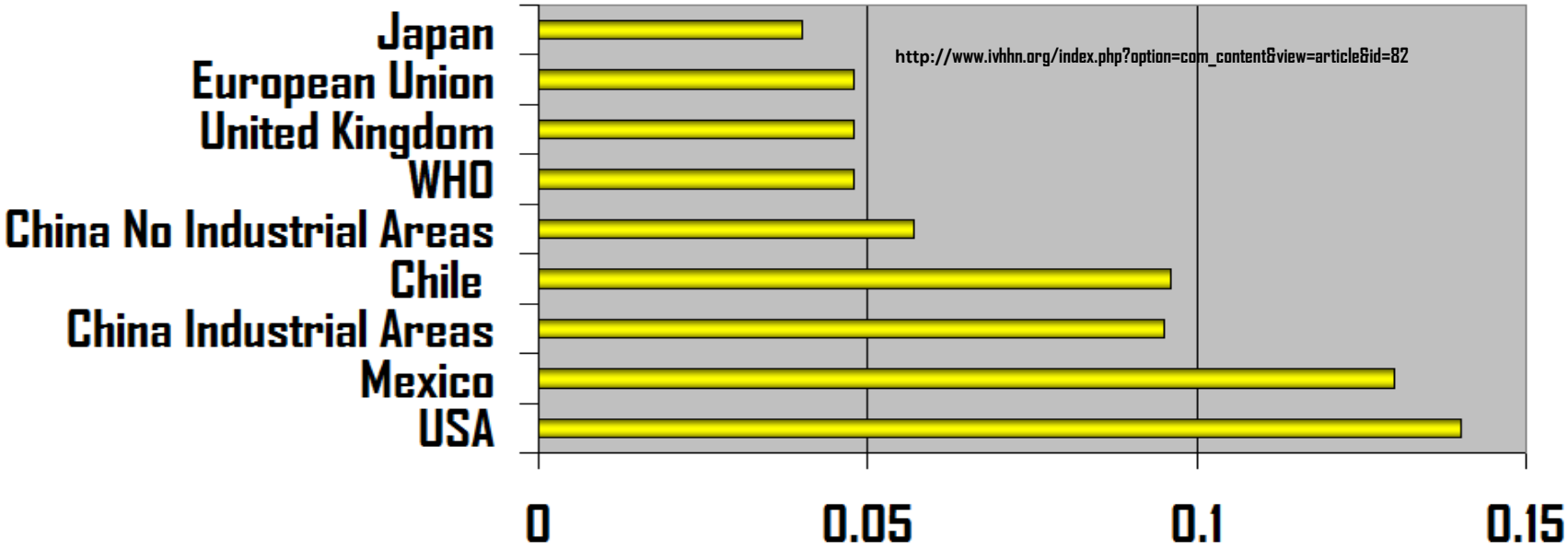




http://www.amegroup.com/Website/FeatureArticleDetail.aspx?fald=141 Chile SO2 Limits: 600 PPM Ministry of Environment 2014

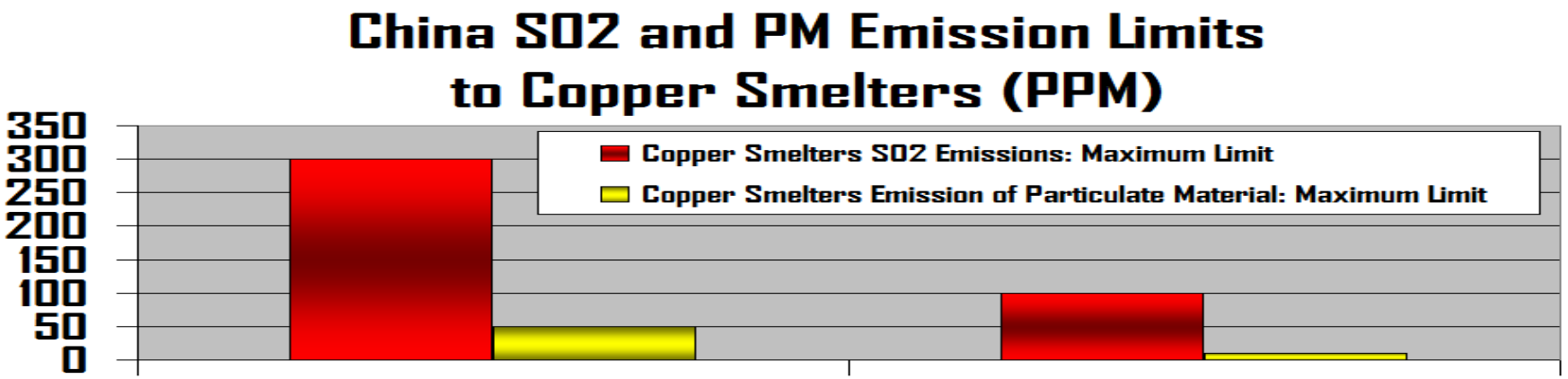
SO2 air quality limits reveal disparities between regions, but some similarities too

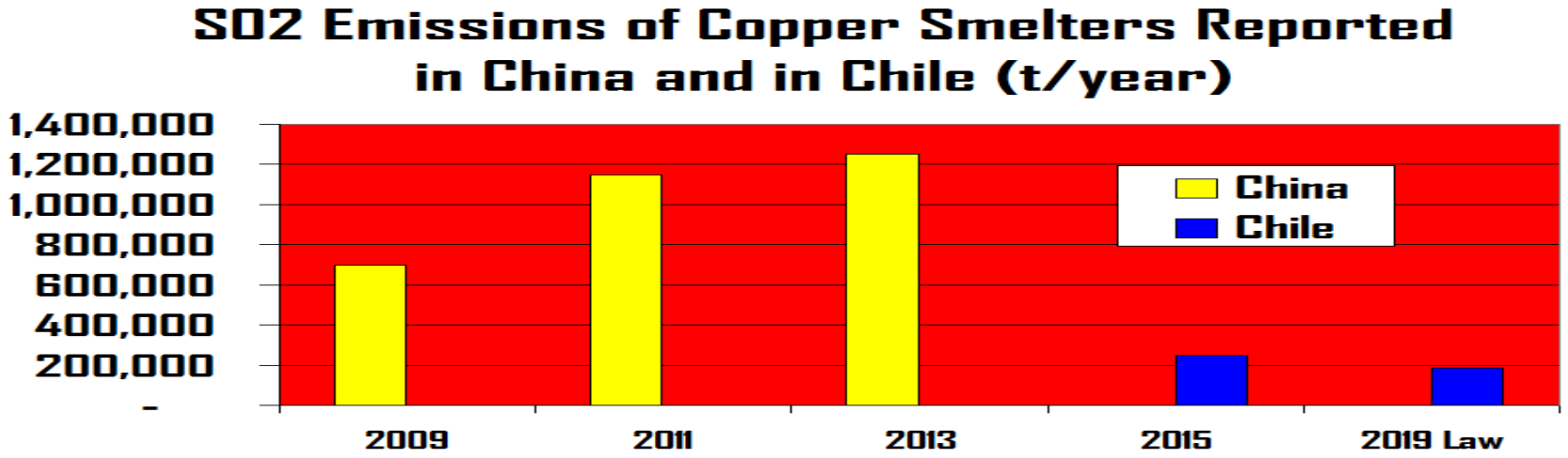
Ambient Air Quality Limits for SO2 in PPM (24 hours average)



Similar SO2 air quality limits: Japan/UE/UK/WHO, China/Chile and Mexico/USA

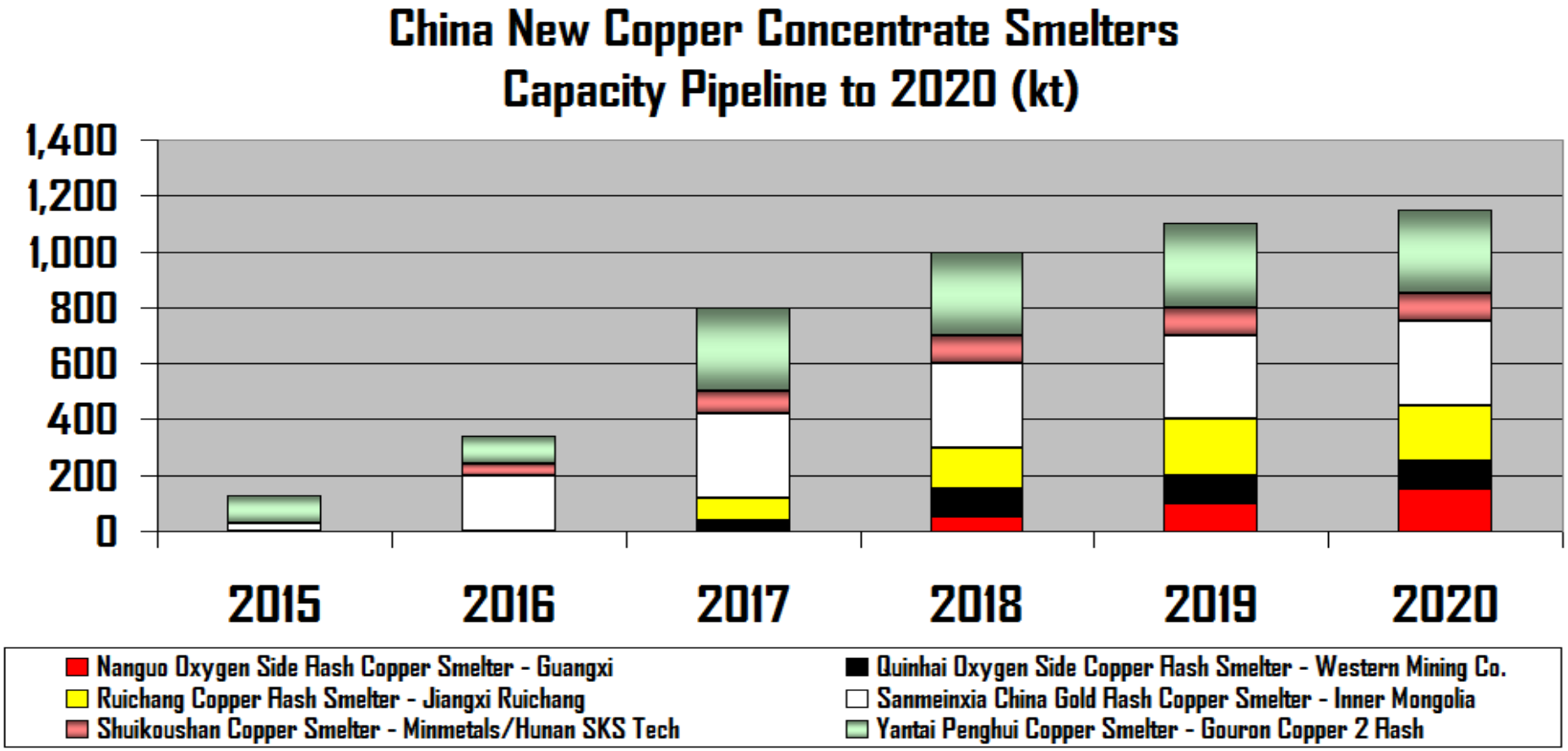
SO2 emissions of copper smelters in China growing slowly in recent years. New 2016 SO2 emission limits = no more smelter investments close to some cities.





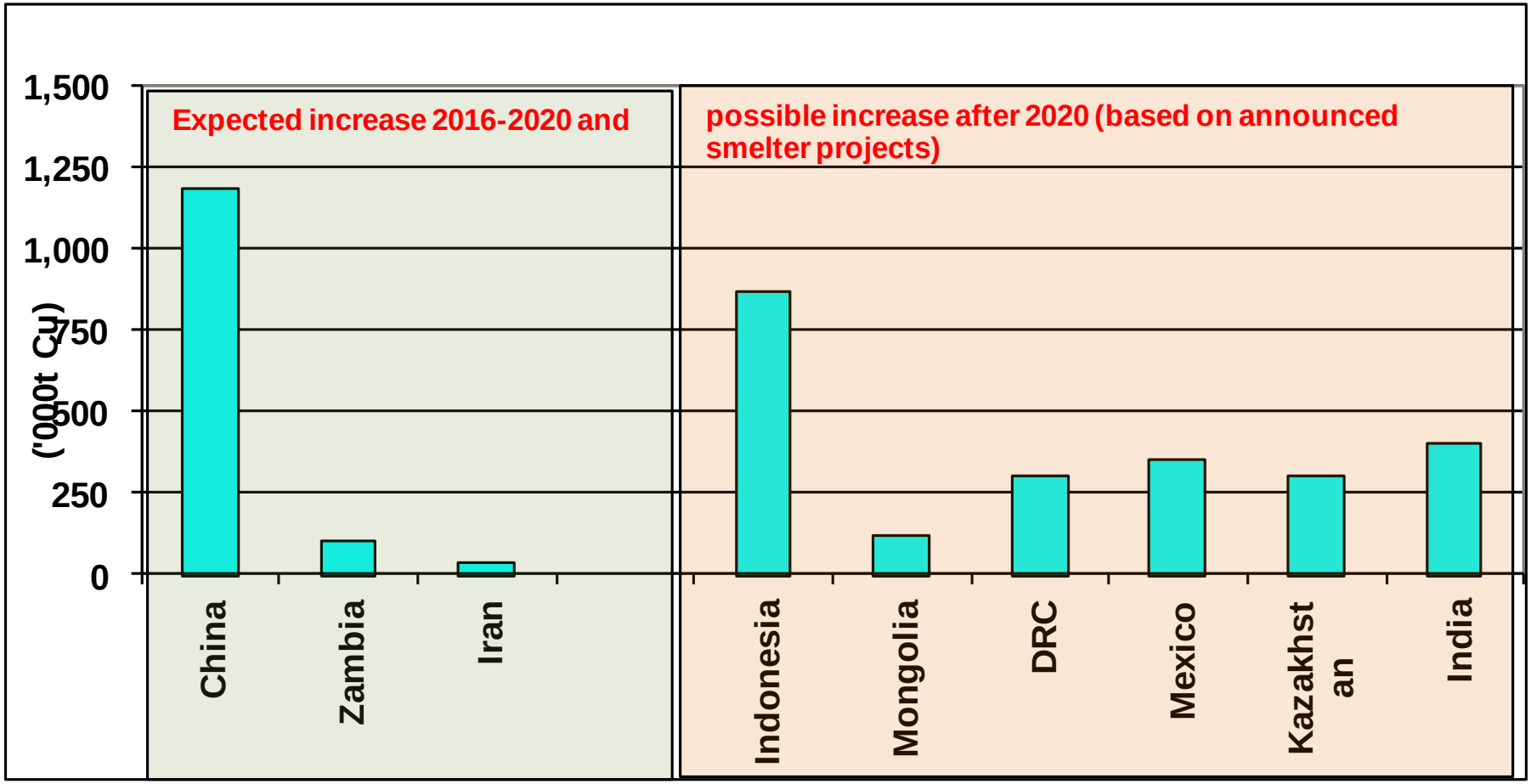
Source: Paper ES3-1, Copper 2016 Conference, Kobe Japan, November 2016

The new copper smelting capacity in China is expected to grow 1.2 million tonnes to 2020 so the demand for concentrates will grow



ICSG Directory of Copper Mines and Plants – February 2017 edition available for sale at www.icsg.org

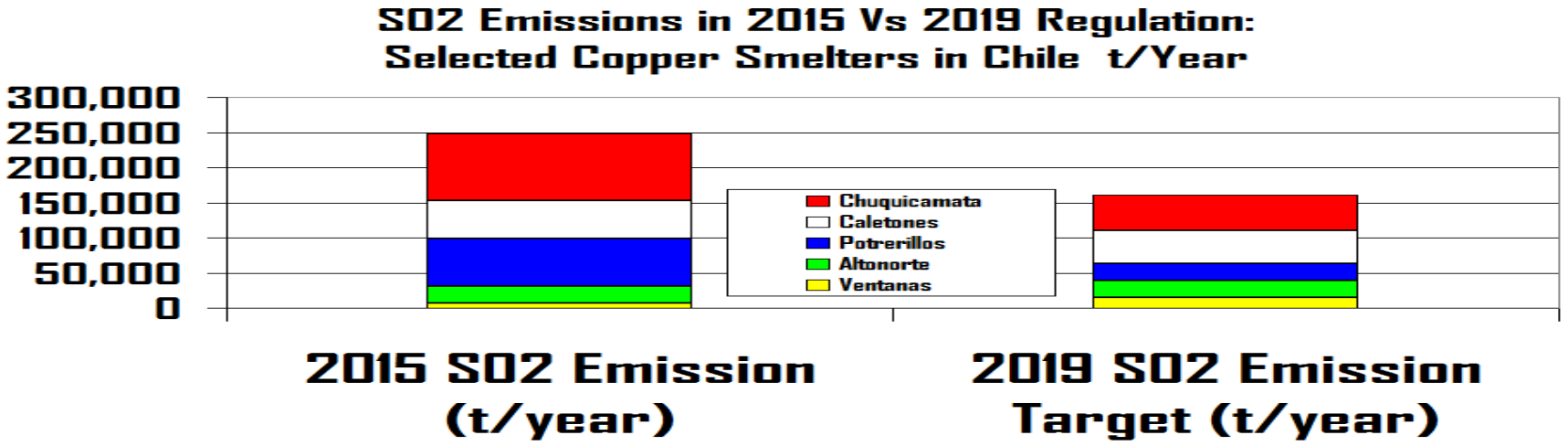
Copper smelting capacity to grow modestly in Zambia and Iran. Smelter plans in Indonesia, India, Mexico, Kazakstan, DRC and others.

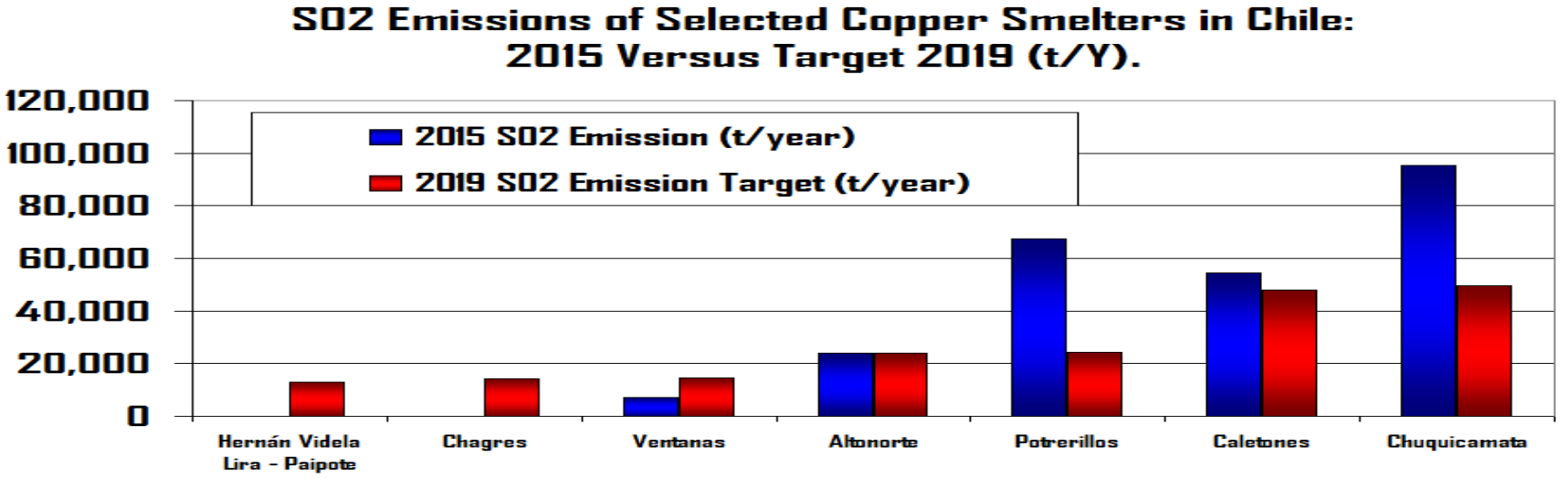


Indonesia copper smelting capacity to grow ~800 kt beyond 2020

Other emerging mining countries to increase smelter capacity beyond 2020.

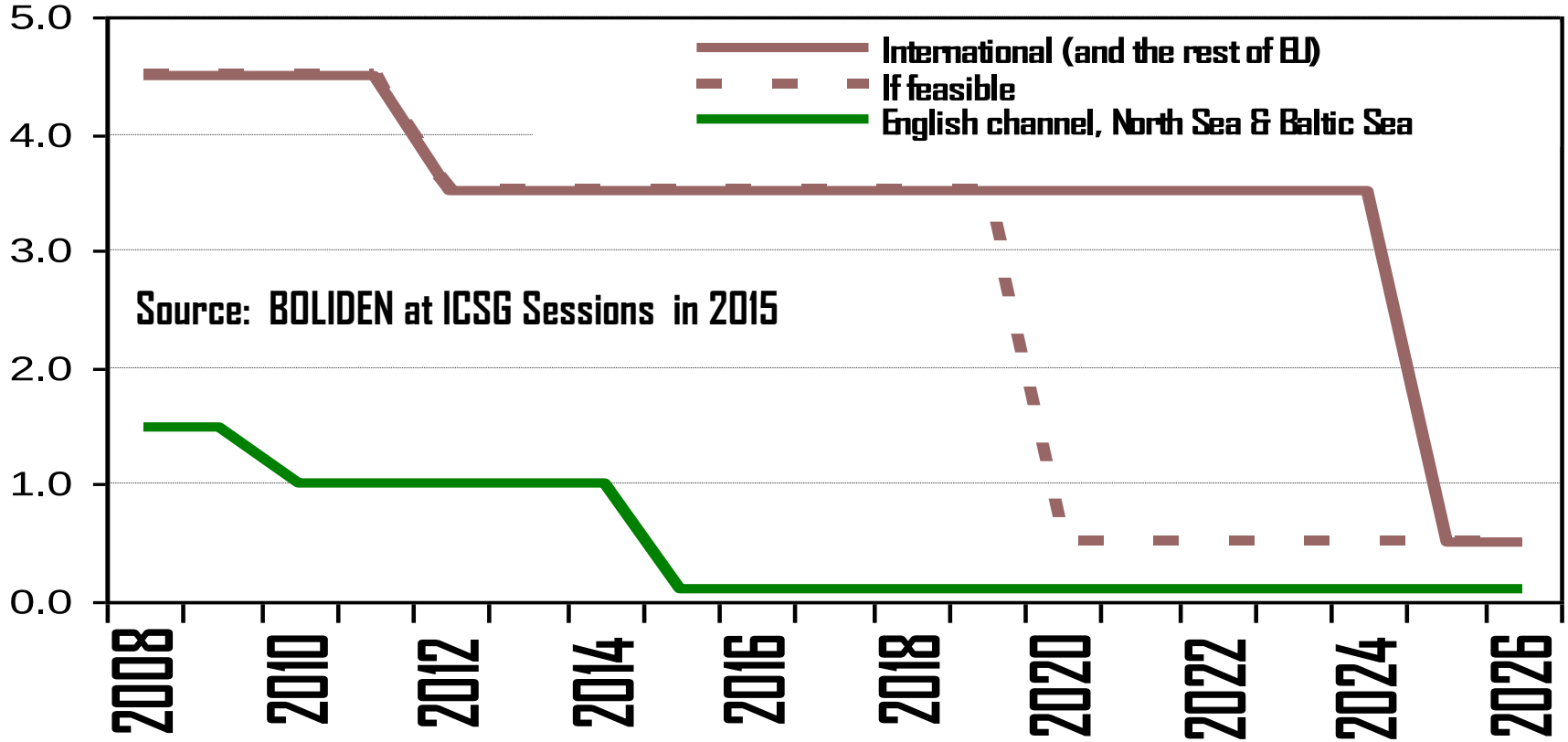
In Chile sulphur emissions controls are agreed smelter by smelter. Sulphur emissions in 2015 still above targets to be enforced in 2019.





Source: ICSG Regulatory Development Report for Chile emissions targets, Plusmining Ltda. for SO2 emissions 2015.

New limits for % of sulphur content in marine fuel came into effect in 2015 in Northern Europe



Impact already on costs of copper concentrate trade from Finland

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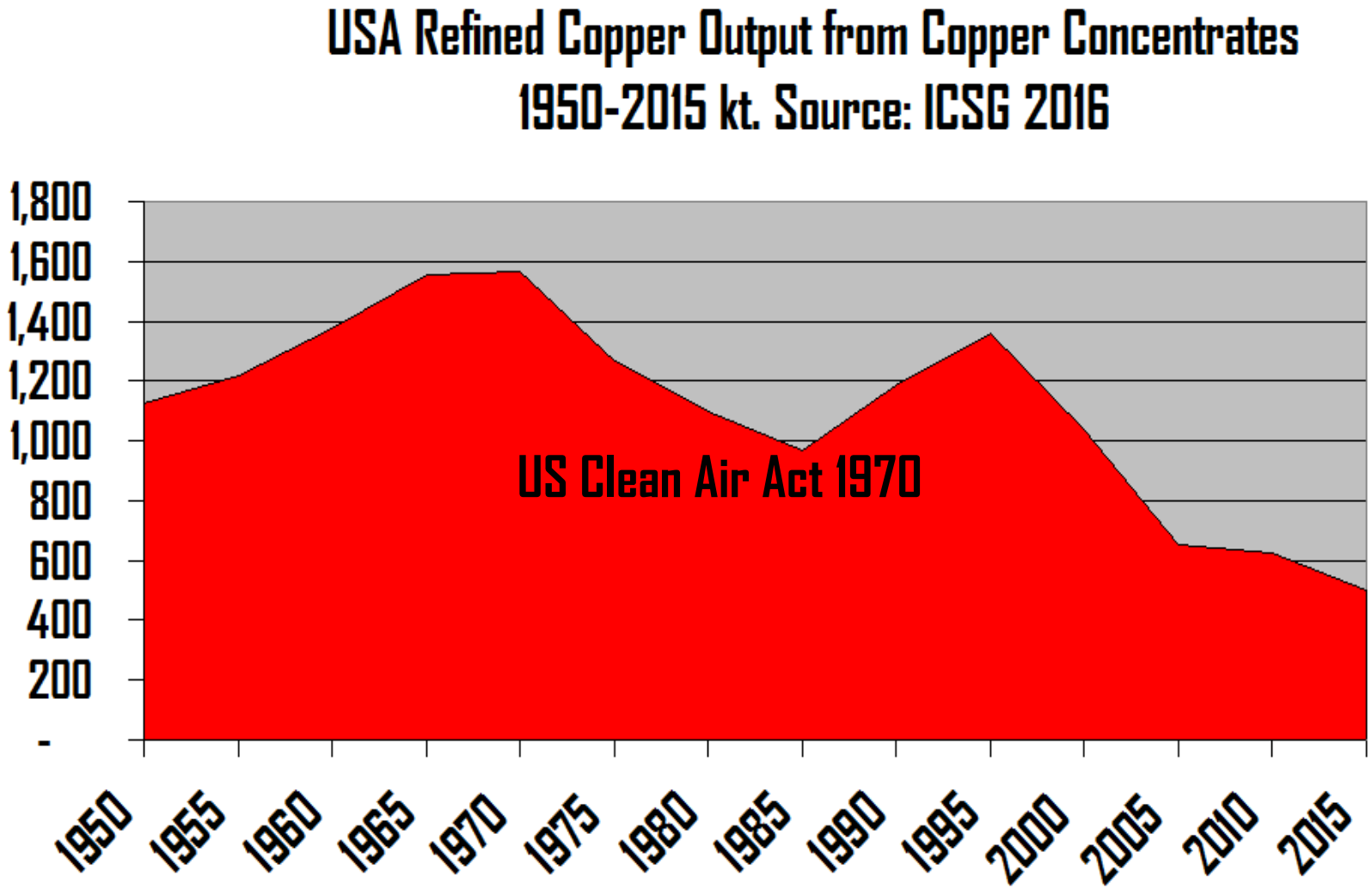
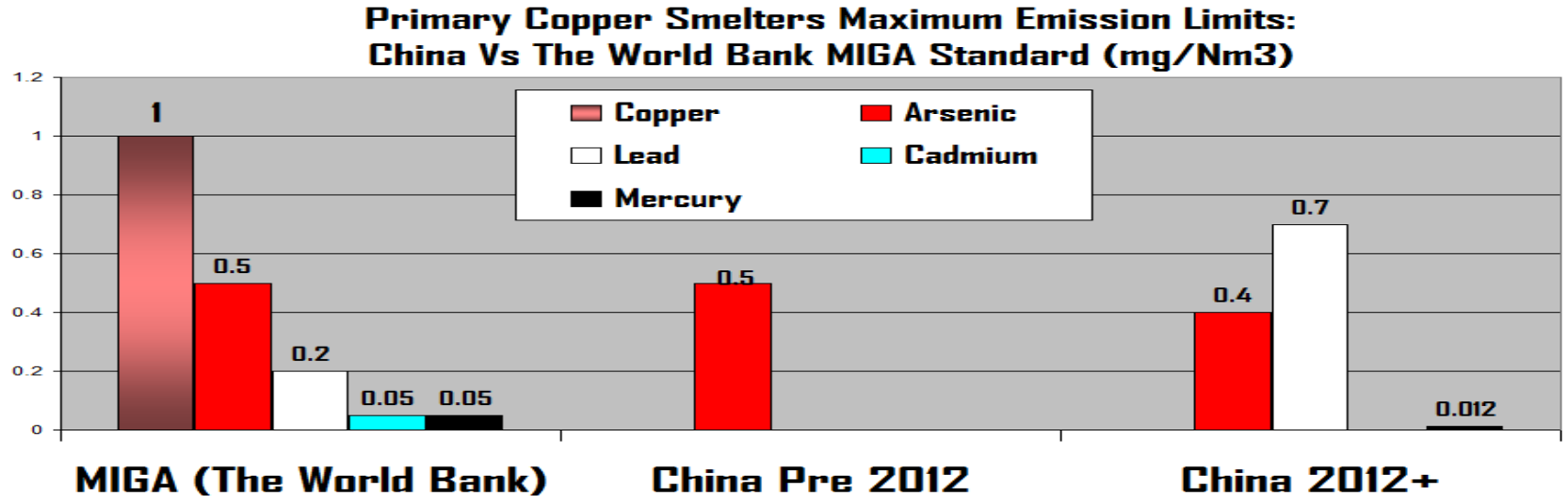
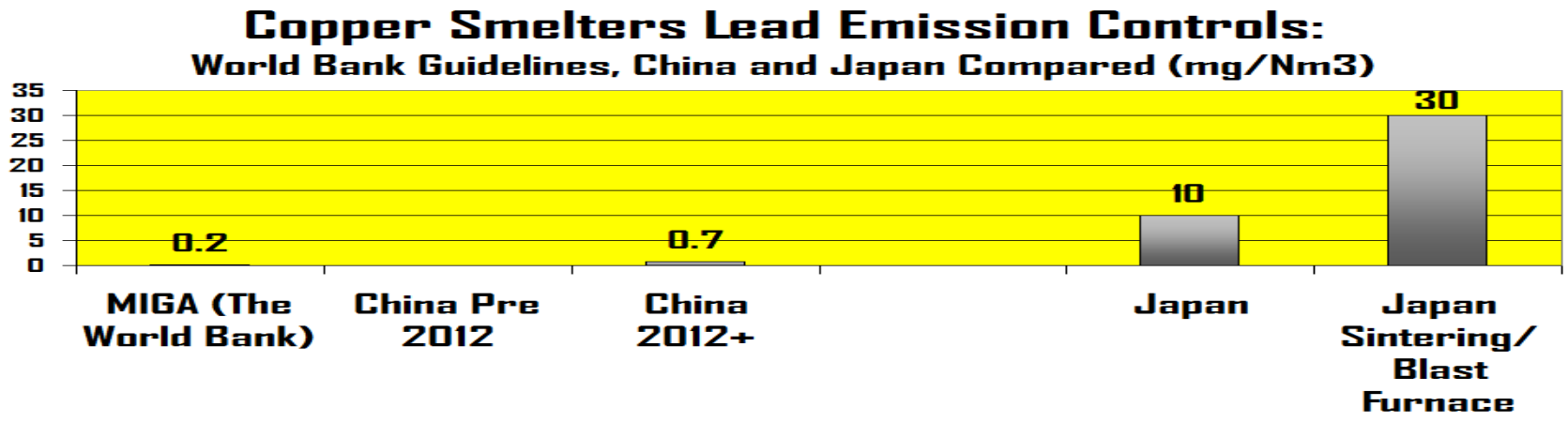
3. Environmental Limits to Smelter Emissions and Technology Regulations

Impurities emission controls: key factor behind US copper output slowdown.



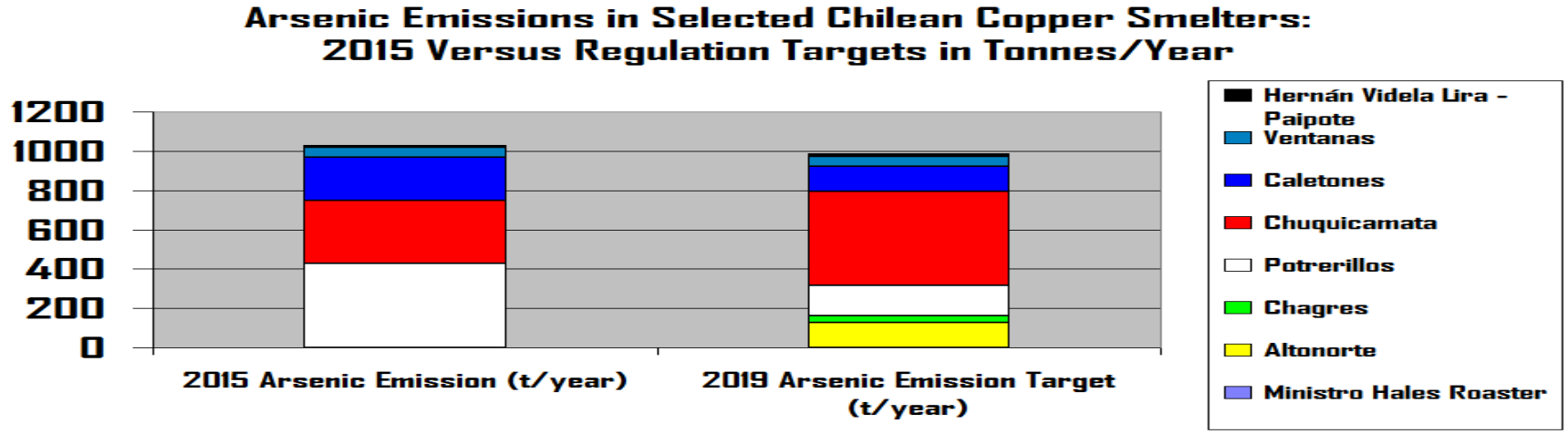
Since 2012 new air emission controls on copper smelters in China. Lead emissions controls in China more strict than Japanese limits.



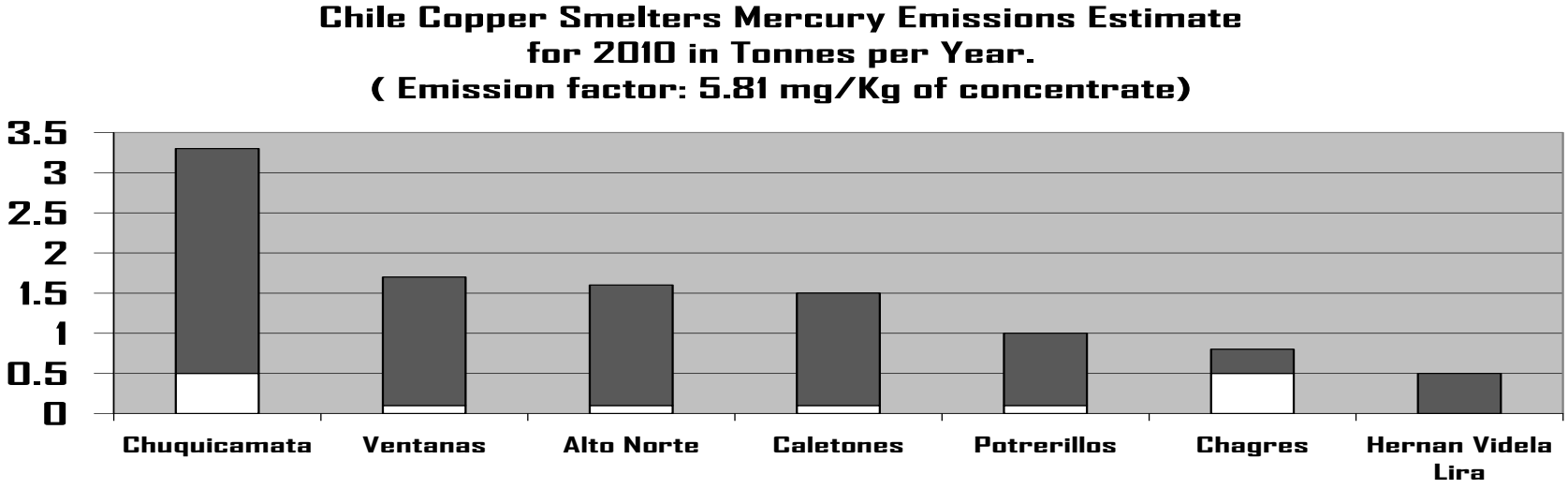


Source: ICSG based on MERIJ Report http://www.copper2016.jp/program/index.html (2016)

In Chile arsenic air emissions targets are defined by law for every smelter. Minamata Convention set mechanisms for mercury emissions reduction.

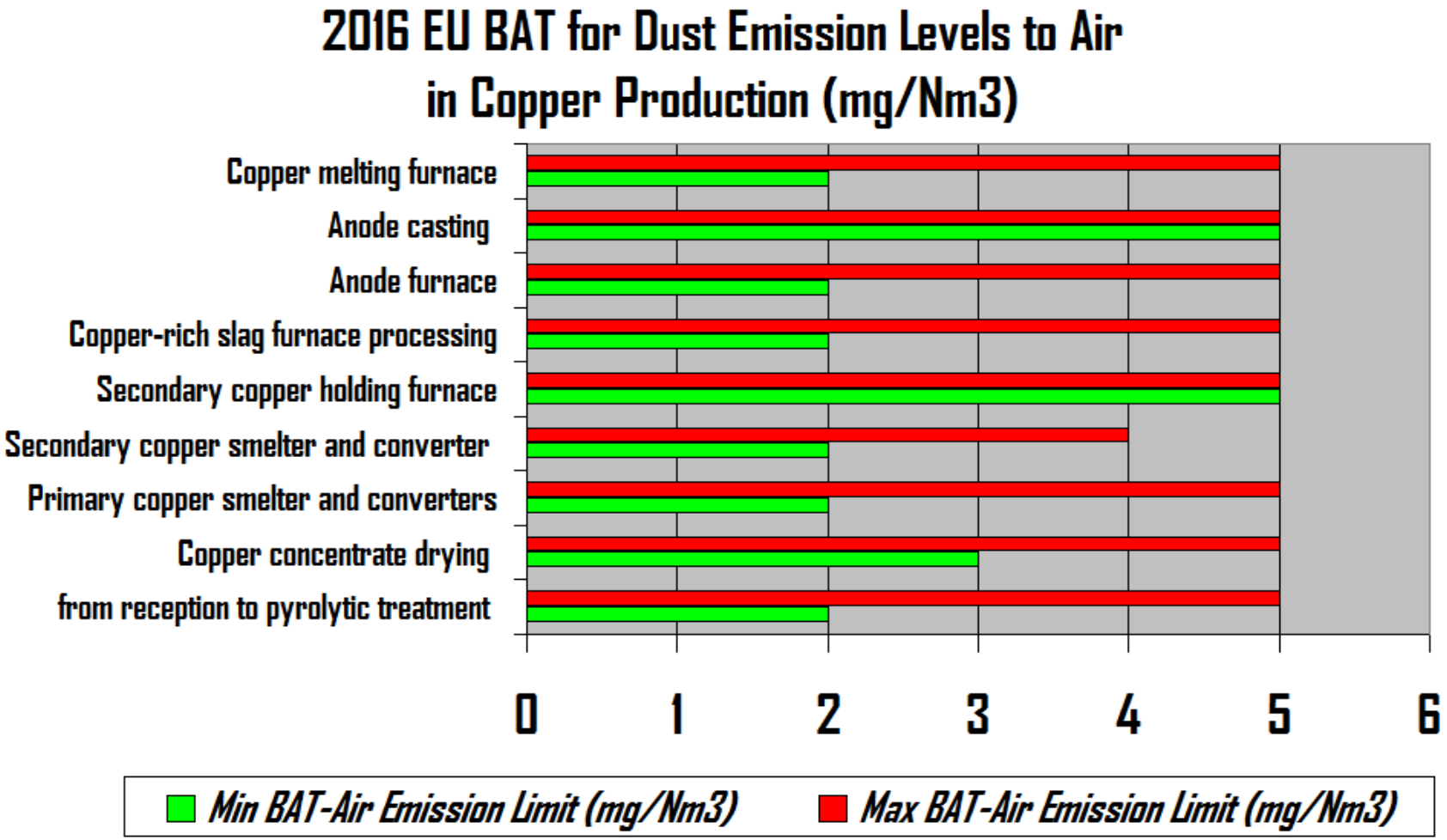


*Only public smelters emission data included in 2015.

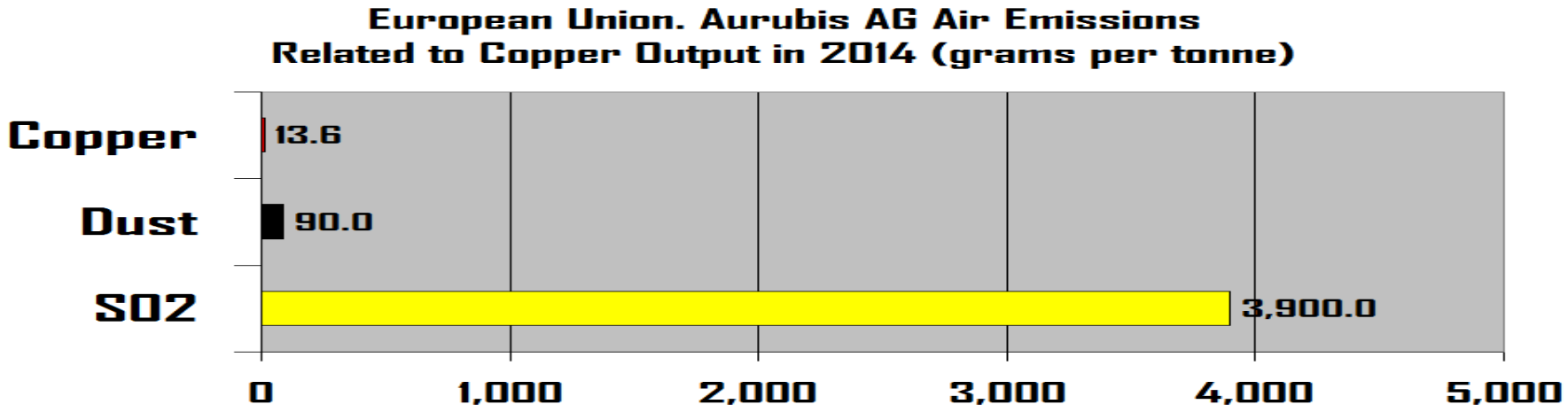


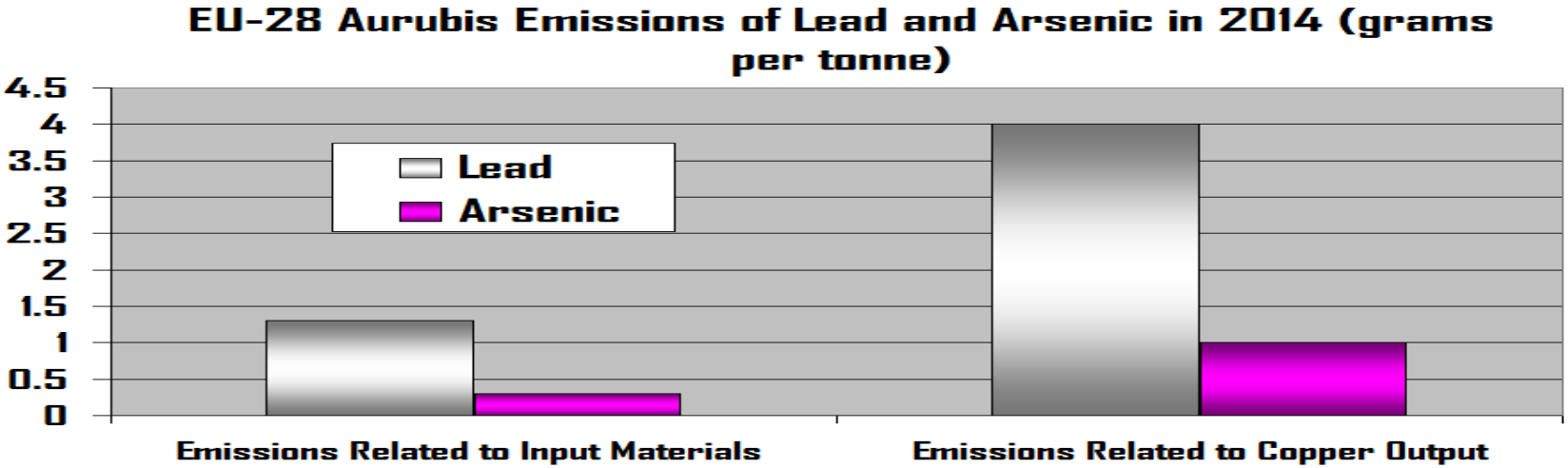
*Source: Chile Ministry of the Environment (2012) http://www.sinia.cl/1292/articles-52008_EstudioBeneficios.pdf

New EU limits for air emission levels of dust from copper smelters. Between 2-5 mg/Nm3 in EU BAT regulation enforced June 2016.



Dust content higher than copper content, arsenic and lead emissions per unit of copper output higher than emissions per unit of input in top EU copper smelters.





Source: Aurubis Environmental Audits.

https://www.aurubis.com/binaries/content/assets/aurubis-en/dateien/responsibility/environmental-statement_2016.pdf

European Union 2016: BATs and new limits for emissions of dioxins, furans and volatile organic compounds in copper plants

EU BAT Emission Limits for VOC, Dioxins and Furans in Copper Plants (2016)

TVOC	3-30	mg/Nm3
PCDD/F	<0.01	mg/Nm3

•**Determine the VOC emissions** in mass balance.

•**To reduce VOC emissions to air from drying, smelting. SX in hydrometallurgical copper production:**

BAT : process reagent (solvent) with **lower steam pressure.**

BAT: **closed equipment as** mixing tanks, settlers and storage tanks

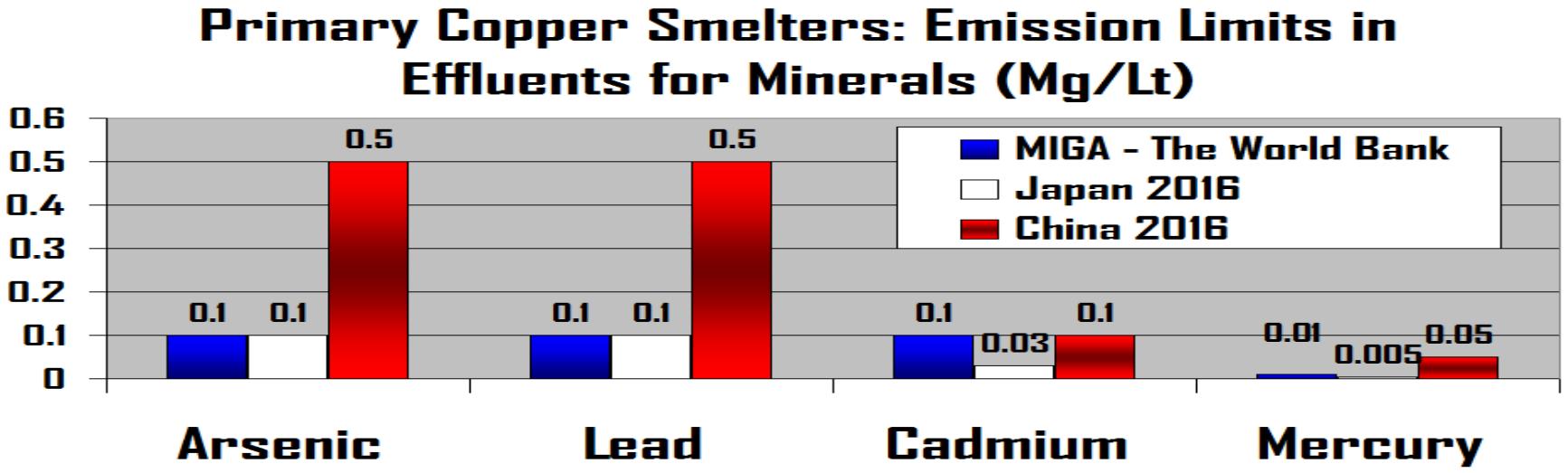
• **BATs to reduce Dioxin and Furan PCDD/F emissions to air:**

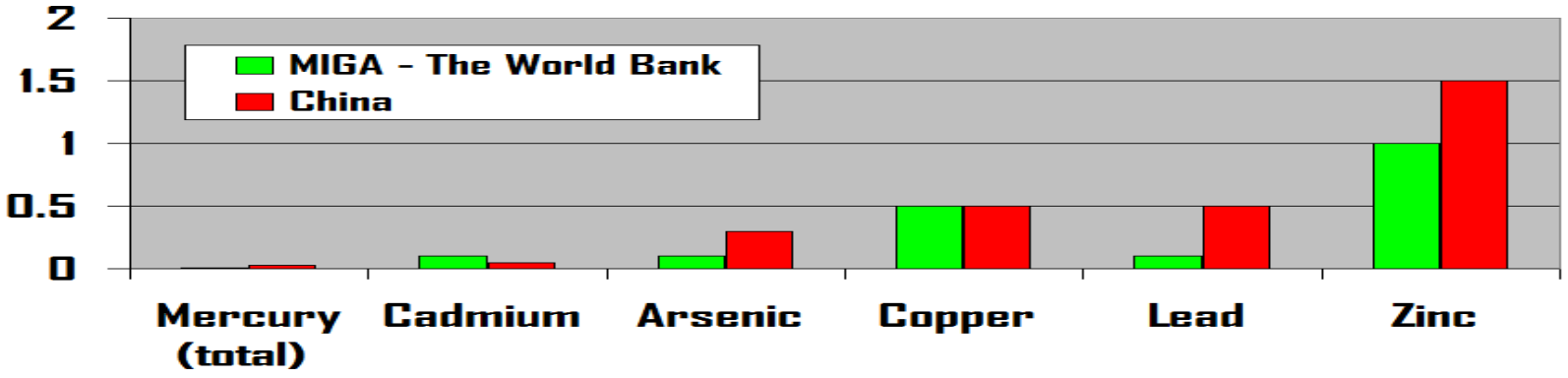
1. Select and feed raw materials **according to the furnace**
2. and according to the **abatement techniques** used.
3. Optimise combustion to **reduce emissions of organic compounds**
4. Use charging systems to give **small additions of raw material**
5. Thermal destruction of PCDD/F in **furnace at high temp** (> 850 °C)
6. Use oxygen injection in the **upper zone** of the furnace
7. **Internal burner system**
8. **Post-combustion chamber** or after-burner
9. or regenerative thermal oxidiser
10. **Avoid** exhaust systems with high dust build-up for temp. > 250 °C
11. Rapid quenching
12. Injection of **adsorption agent** with efficient **dust collection system**

Comparison of water emission controls in copper smelters.

Heavy control in Japan on cadmium and mercury in waste water.

China As and Pb water emission controls for metals above benchmark.





Source: ICSG based on MIGA website (2016) and http://www.copper2016.jp/program/index.html (2016)

The EU-28 established best available techniques (BAT) in 2016 for waste reduction of copper and other metal industries.

- BAT/BET recommended, **or others that ensure at least an equivalent level of environmental protection.**
- **BAT 54 looks to reduce quantities of waste sent for disposal from copper production.**
- **BAT 54** is to organize operations to **facilitate process residues reuse,** or, failing that, **process residues recycling**,

- BAT to increase recovery **yield from scrap,**
- BAT to use energy **efficiently**
- BAT to **reduce air emissions** from furnaces and other devices
- to optimise performance of the **abatement system**

- **BATs to prevent or reduce "diffuse emissions"** from:

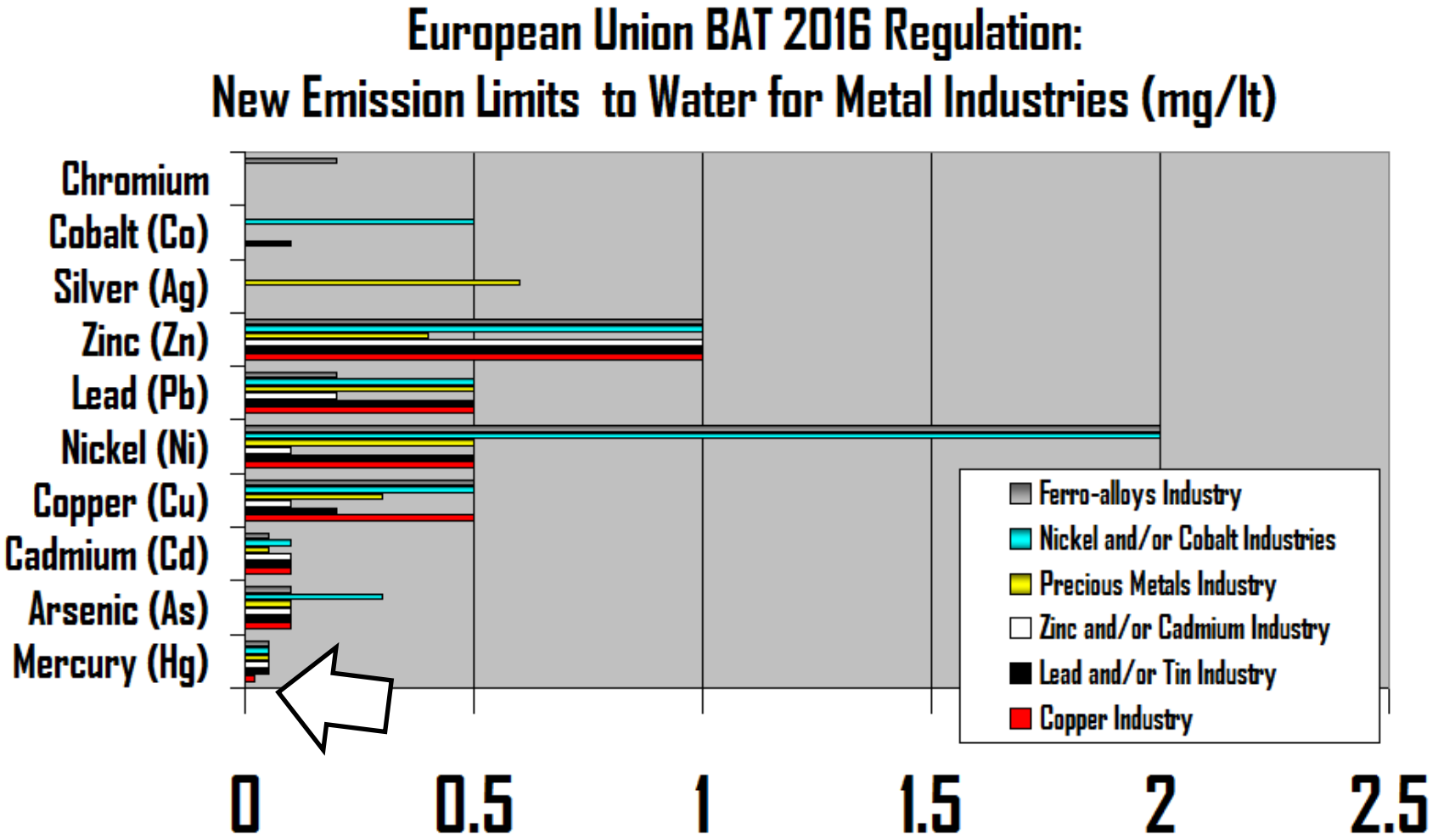
1. blending, drying, mixing, homogenisation, screening and pellets
2. charging, smelting and tapping operations
3. Peirce-Smith and Hoboken converter furnaces
4. matte conversion process, **BAT is use flash furnaces.**
5. a top-blown rotary converter (TBRC) scrap furnace
6. copper recovery with a slag concentrator
7. copper-rich slag furnace treatment
8. anode casting
9. electrolysis cells
10. casting of copper alloy
11. non-acid and acid pickling.

- A wet scrubber or a demister is BAT **to reduce acid gas emissions** to air from exhaust gases from :

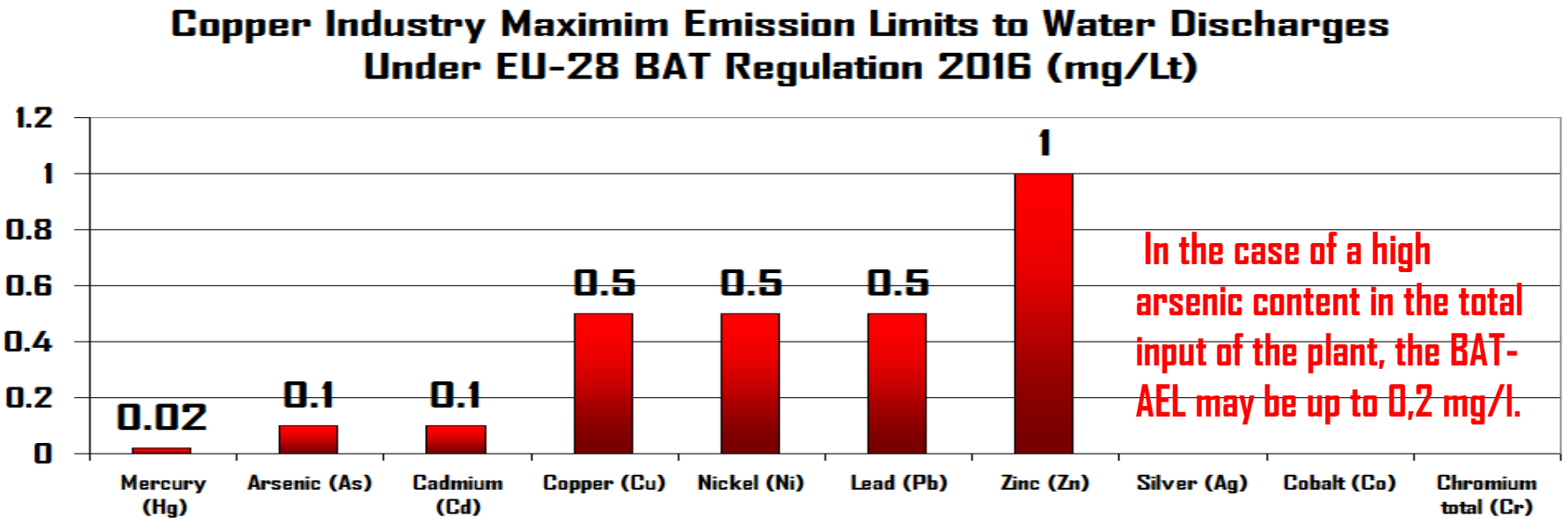
1. the electrowinning cells,
2. the electrorefining cells,
3. the washing chamber of the cathode stripping machine
4. and the anode scrap washing machine.

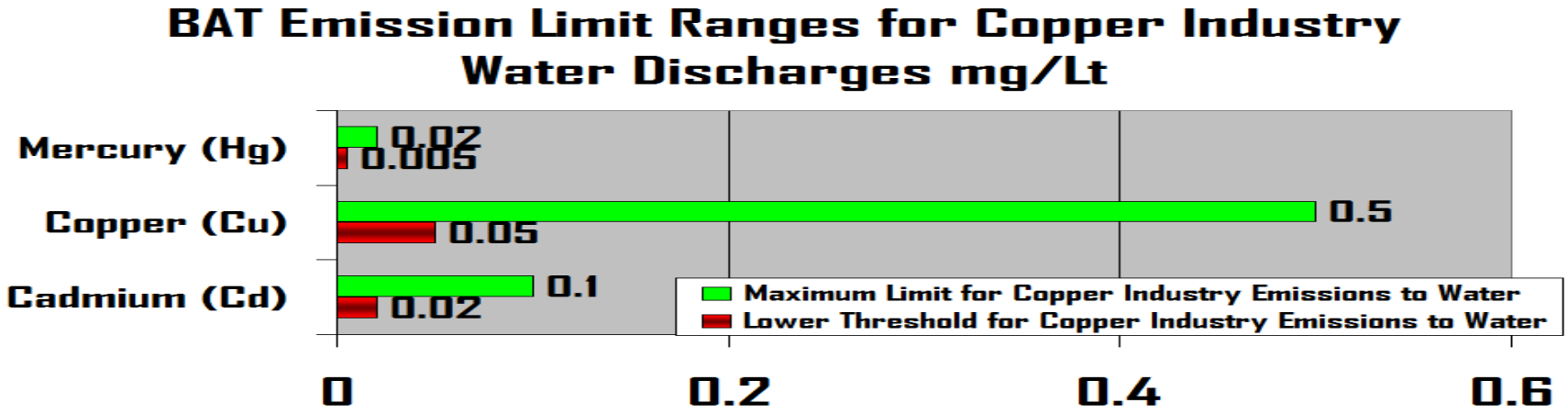
http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016D1032&from=EN

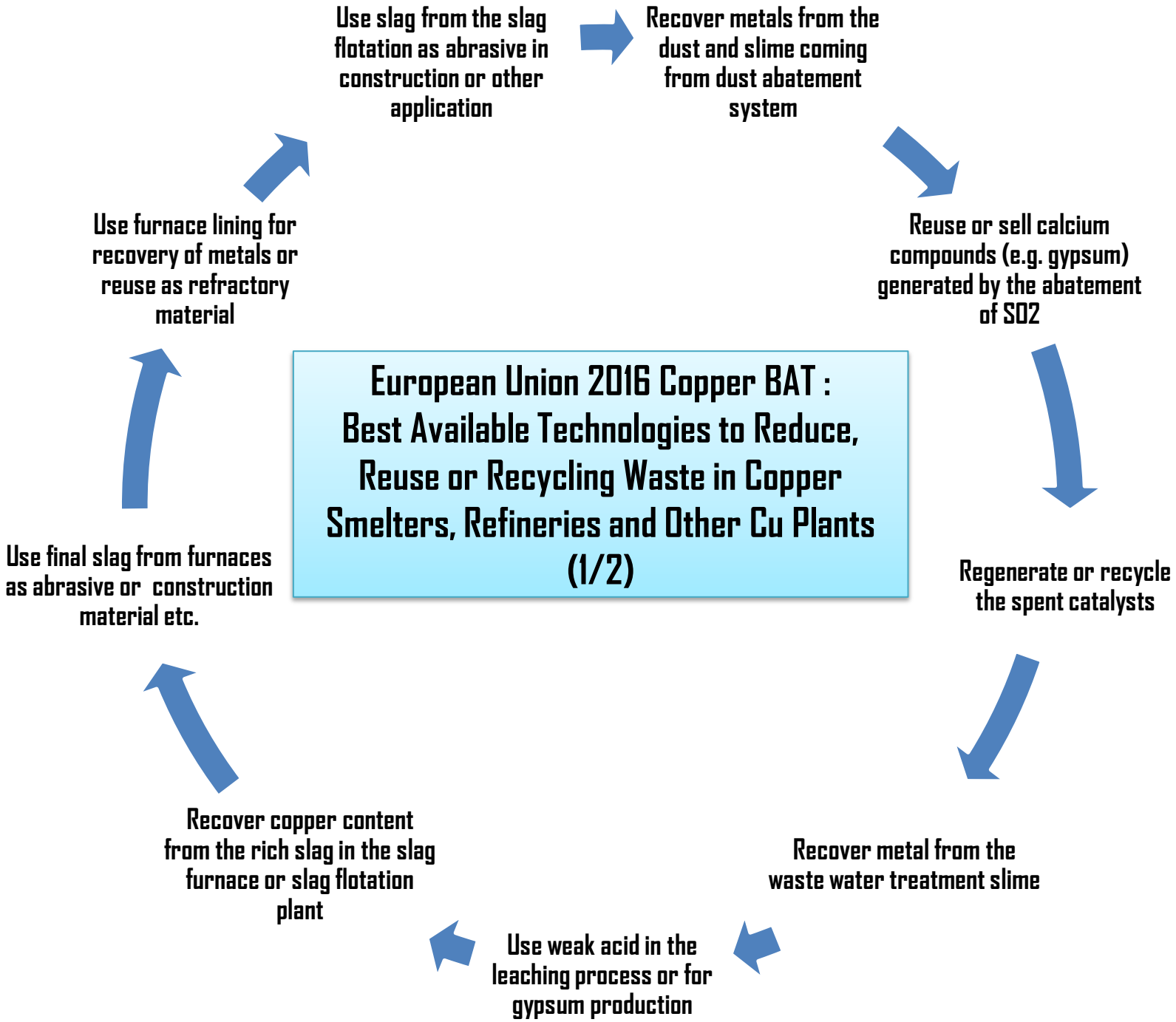
EU BAT 2016: more strict water emission rules for metal industries, in particular for mercury emissions of the copper industry.



EU BAT 2016 allows 0.2 mg/l in water discharges of smelters using high arsenic concentrates but set extremely tight discharge thresholds for Hg, Cd and Cu.

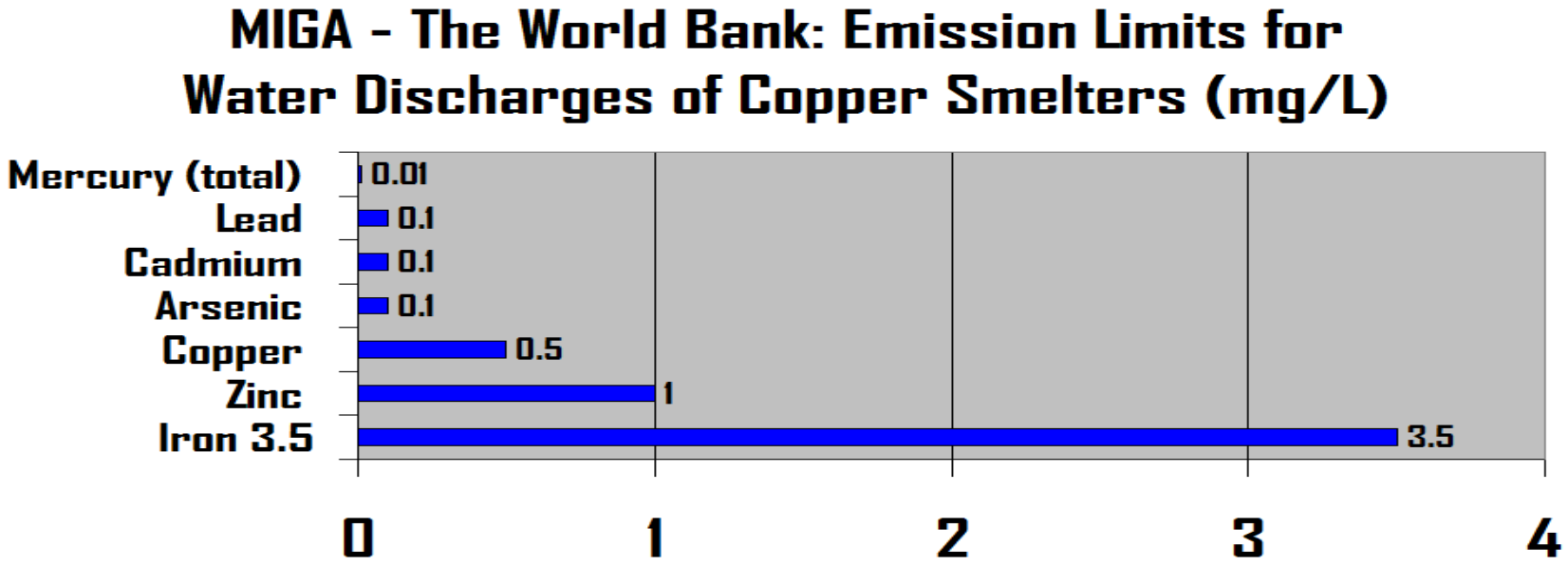





European Union 2016 Copper BAT : Best Available Technologies to Reduce, Reuse or Recycling Waste in Copper Smelters, Refineries and Other Cu Plants (1/2)
Use slag from the slag flotation as abrasive in construction or other application
Recover metals from the dust and slime coming from dust abatement system
Reuse or sell calcium compounds (e.g. gypsum) generated by the abatement of SO2
Regenerate or recycle the spent catalysts
Recover metal from the waste water treatment slime
Use weak acid in the leaching process or for gypsum production
Recover copper content from the rich slag in the slag furnace or slag flotation plant
Use final slag from furnaces as abrasive or construction material etc.
Use furnace lining for recovery of metals or reuse as refractory material


European Union 2016 Copper BAT : Best Available Technologies to Reduce, Reuse or Recycling Waste in Copper Smelters, Refineries and Other Cu Plants (2/2)
Use the skimming from the melting furnaces to recover the metal content
Use spent electrolyte bleed to recover copper and nickel.
Reuse remaining acid for new electrolyte or to produce gypsum
Use spent anode as cooling material in pyro copper refining or remelting
Use anode slime to recover precious metals
Use gypsum from waste water treatment plant in the pyro process or for sale
Recover metals from sludge
Reuse depleted electrolyte from hydromet copper process as leaching agent
Recycle copper scales from rolling in a copper smelter
Recover metals from spent acid pickling solution
Reuse the cleaned acid solution

The World Bank benchmark remains relevant in 2016 to compare waste water emission controls in copper smelters.

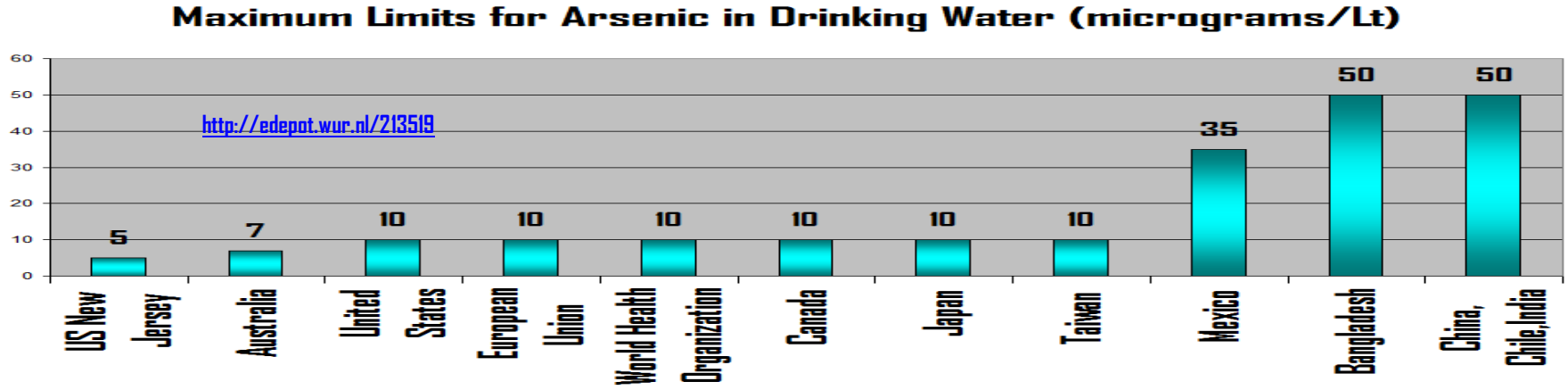


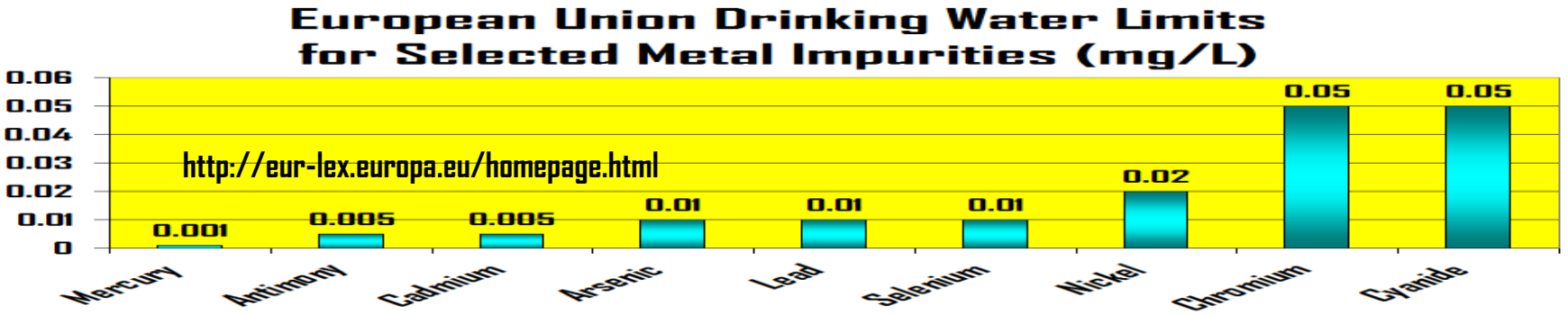
Other emission limits in MIGA standards for primary copper smelter effluents:

- pH Max 9
- Total suspended solids 50 mg/L
- Total metals 10 mg/L
- Temperature increase < or = 31 gr. C

Source: ICSG based on MIGA website (2016)

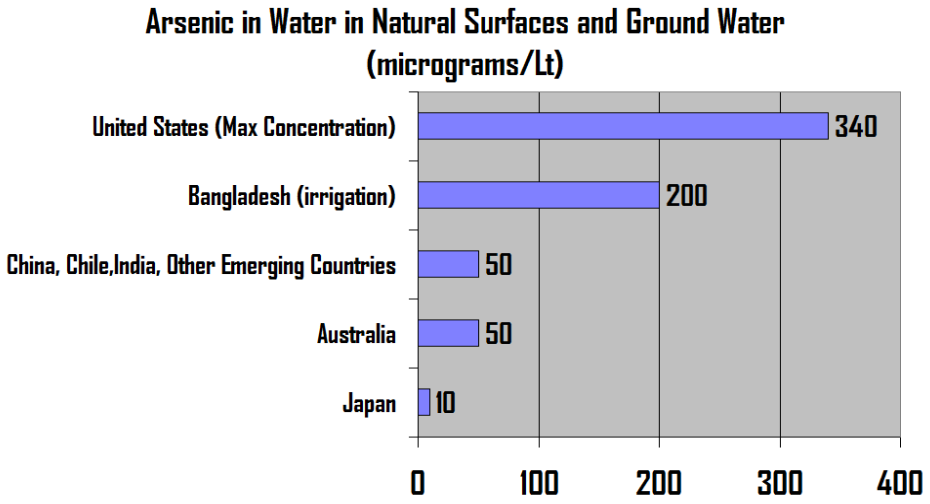
Environmental base lines set limits for Arsenic in drinking water.
EU drinking water limits for As, Pb less restrictive than Cd, Sb, Hg.

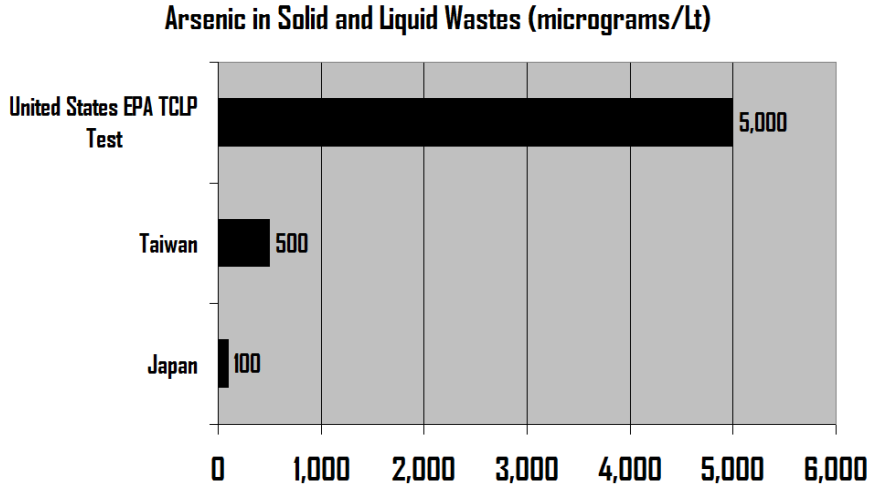


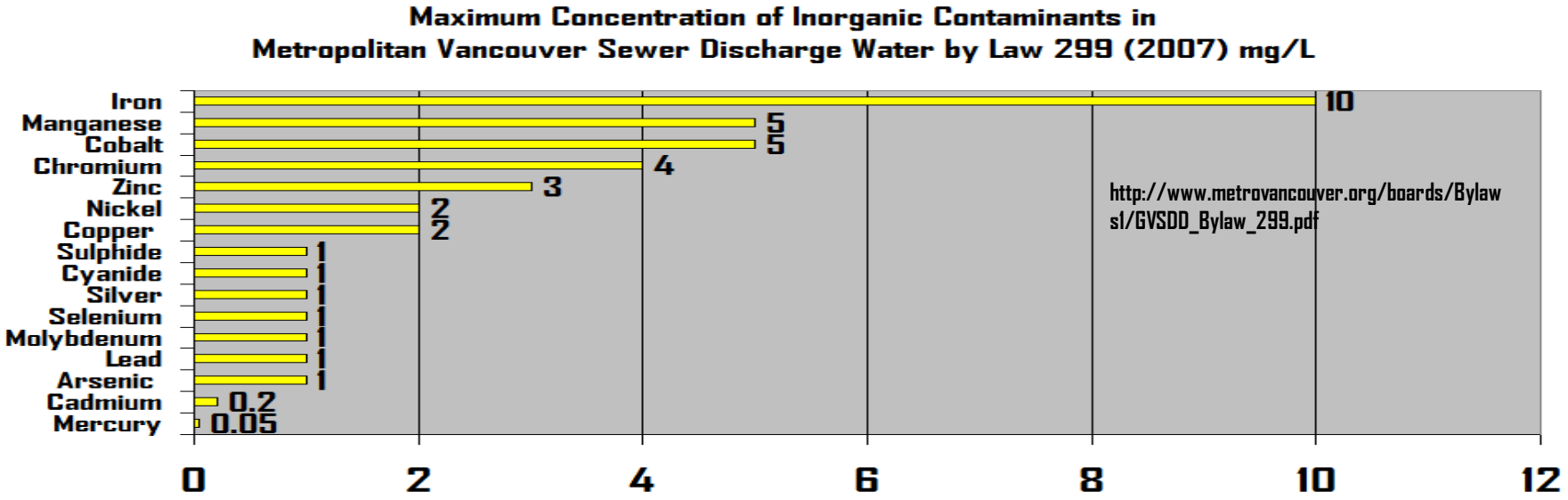


	US EPA	US FDA	European Union	European Union
Llimit for Mercury in Drinking Water	0.002 ppm		0.001 mg/lt	
Maximum Limits for Mercury in Seafood		1 ppm	0.5 mg/kg in Fishery Products	1 mg/kg in Fish

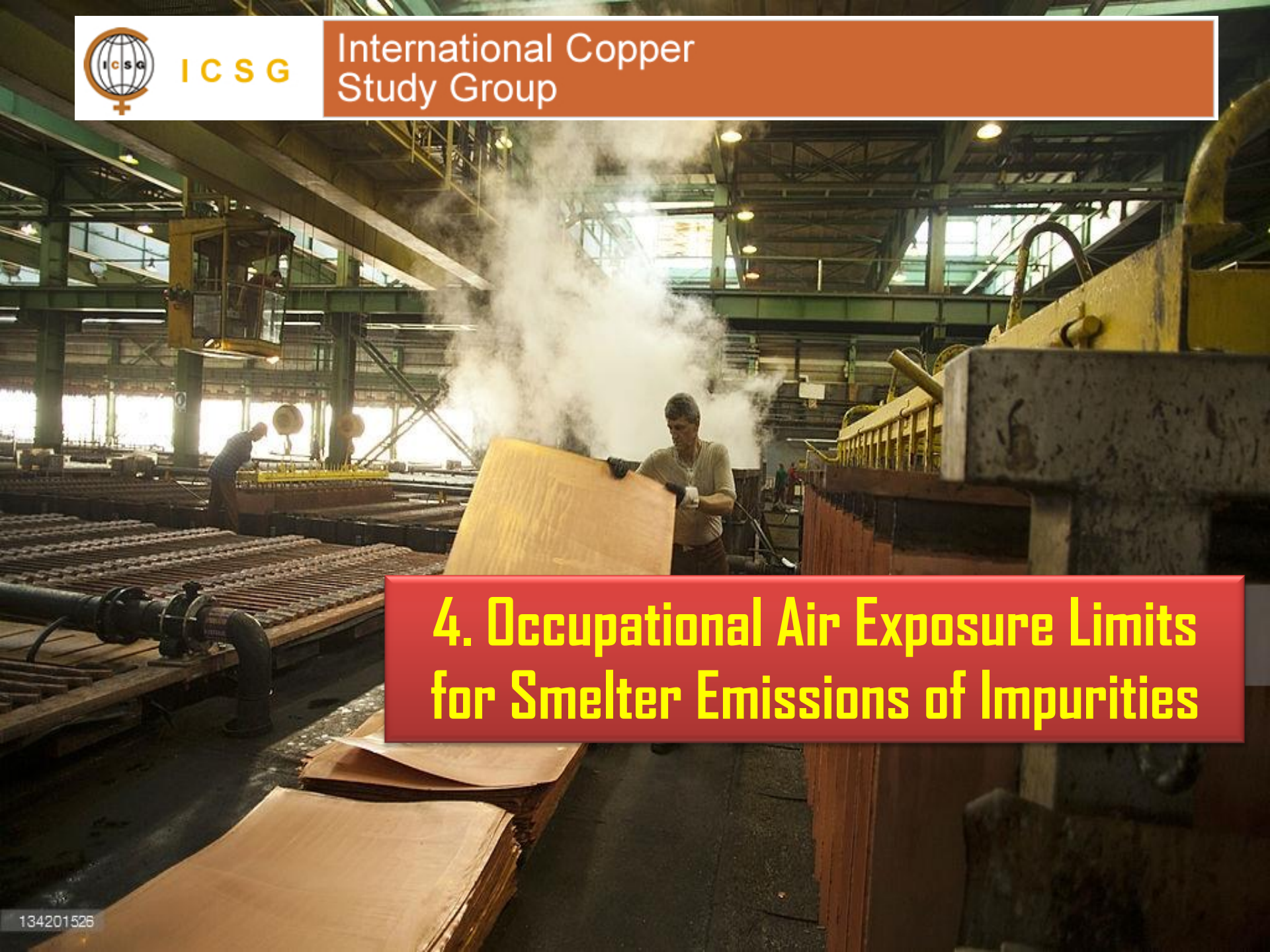
Only Japan has very tight limits to concentration of arsenic in liquid waste, natural surfaces and ground water.



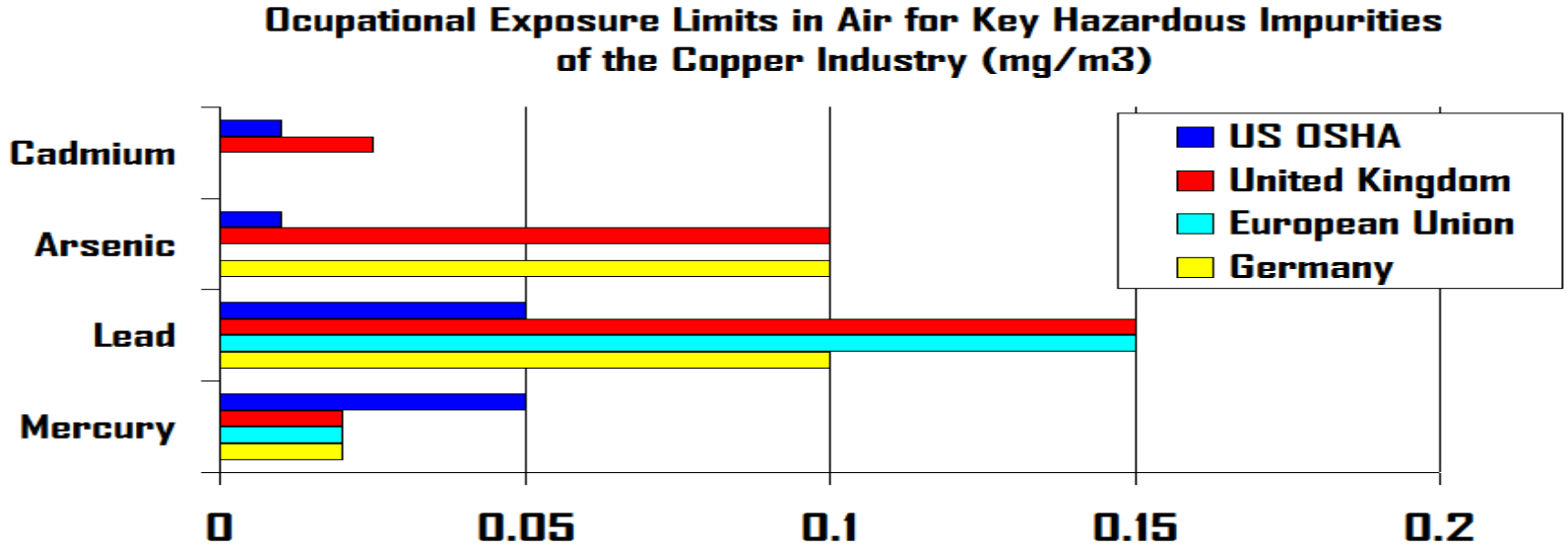


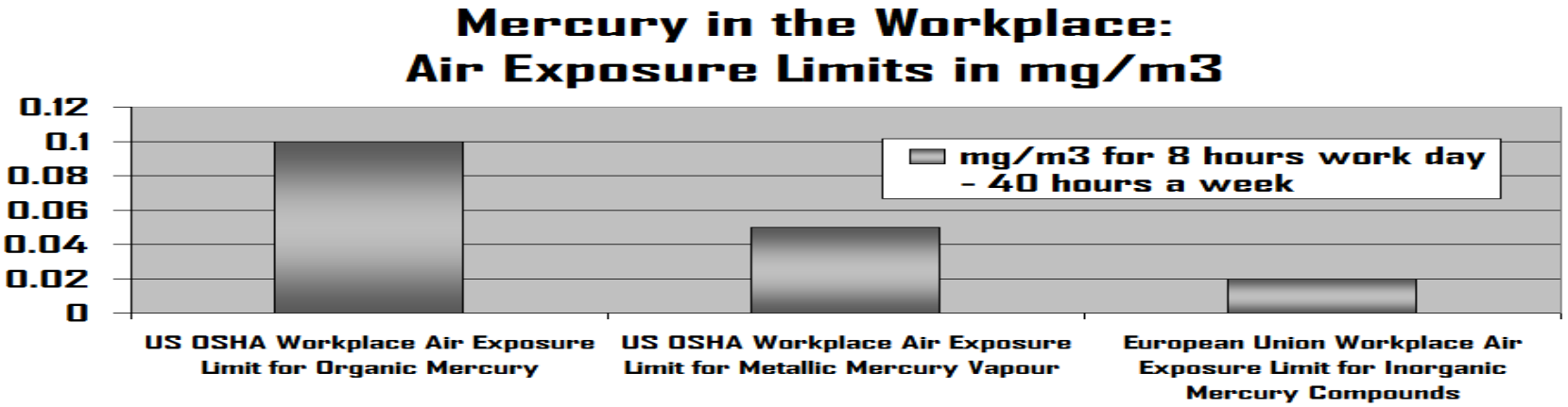


http://edepot.wur.nl/213519


ICSG
International Copper
Study Group
4. Occupational Air Exposure Limits
for Smelter Emissions of Impurities
134201526

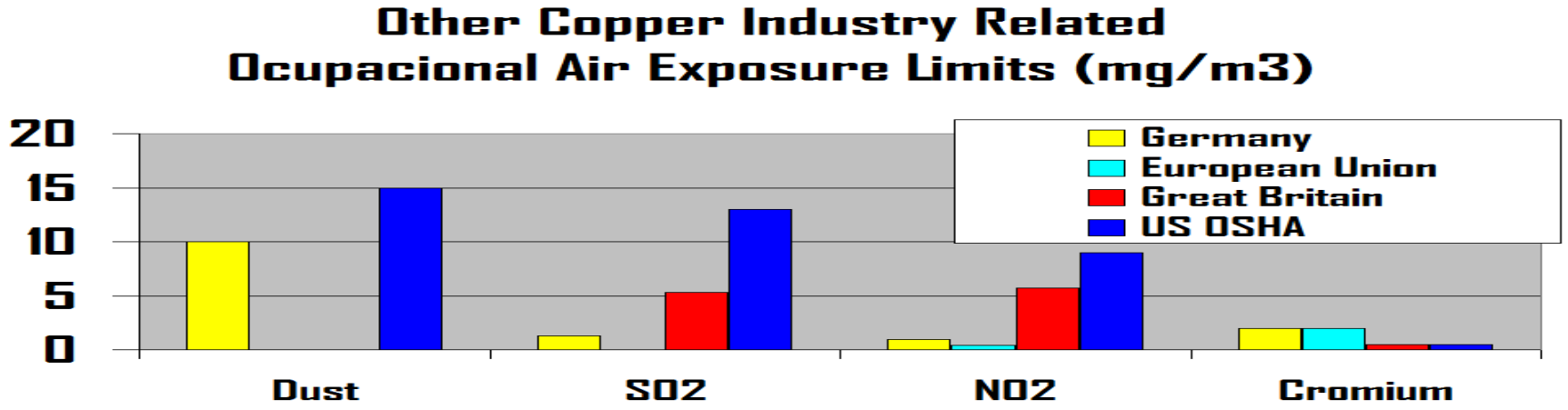
In North America and Europe, occupational air exposure to impurities has been slow to converge to similar limits.





https://oshwiki.eu/wiki/Exposure_to_dangerous_substances_in_the_waste_management_sector

Occupational air exposure limits for impurities relevant for the copper industry tend to be tight in Europe versus US and the UK.



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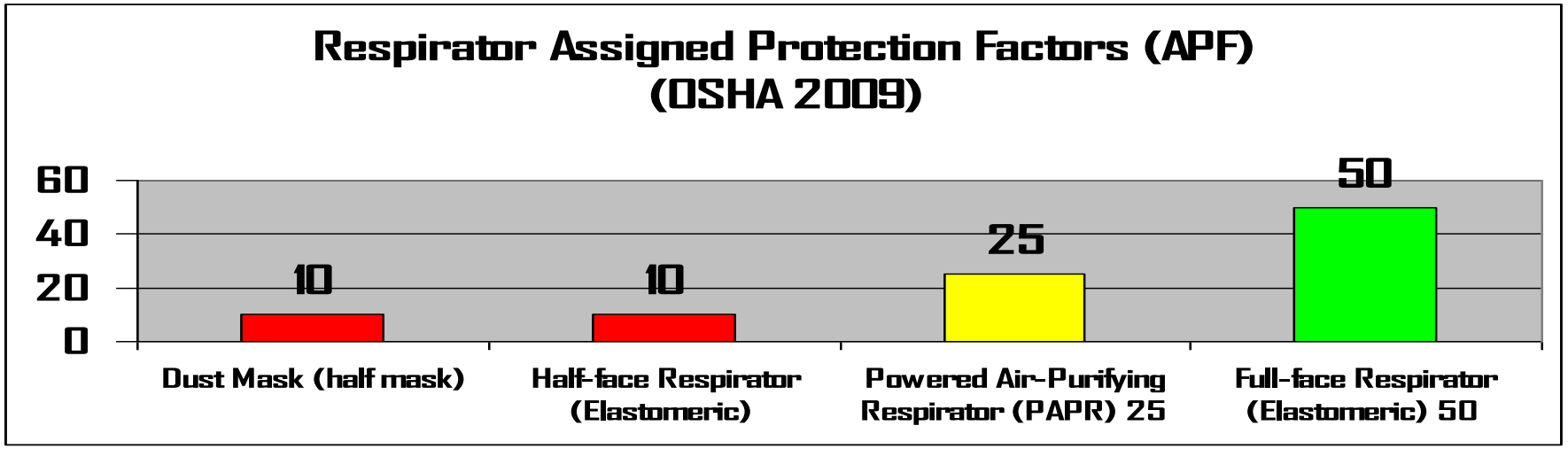
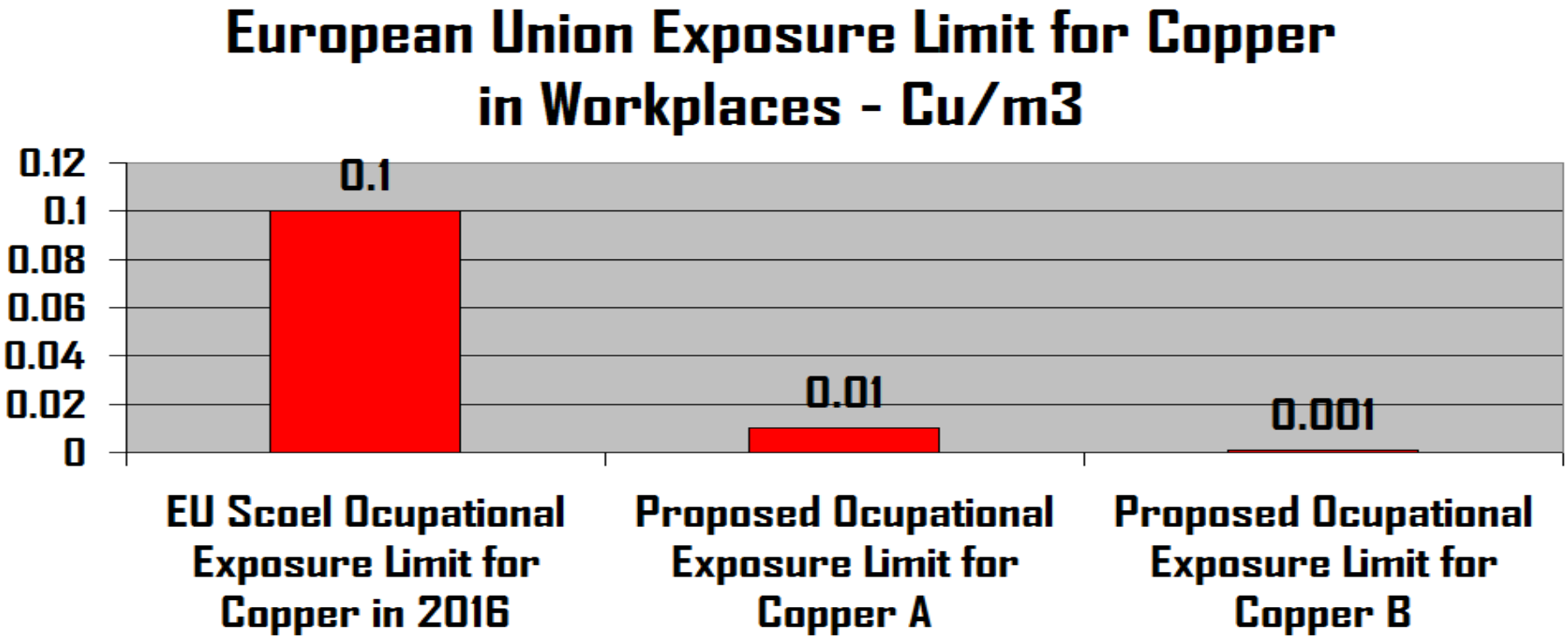


Source: Lind and Ardehali, Barrick Technology Centre, Vancouver BC. COM 2014 . Conference on Metallurgist Proceedings.

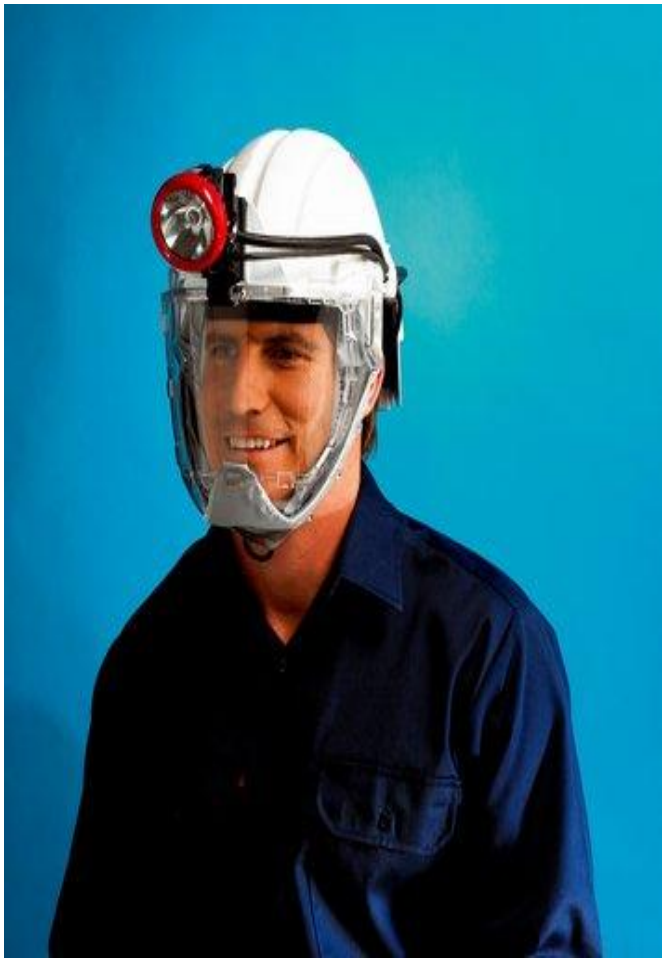
Scientific Committee
on Occupational Exposure Limits

More restictive air exposure limits for copper in the workplace proposed for the European Union in 2016 (mg/Nm3).



Self regulation rules in some mining companies becoming more strict than rules for exposure limits in the workplace.

- **High Arsenic Metallurgical Test Works @ Barrick**



- Use of proper Personal Protective Equipment is **essential**
- and should include **gloves, eye protection, 2 layers of clothing.**
- Laboratory precautions:
- **proper respiratory protection is essential**.

- **Company policy decision:**
- **half-face respirator not enough when dealing with material with arsenic content. 1% or more Arsenic samples requires air stream helmets or other respirators.**

- **No-tolerance for wearing coveralls/lab coats**
- **in eating areas or offices.**
- **Urine Sampling**: ACGIH biological exposure index level
- **for inorganic As is 35 µg/L.**

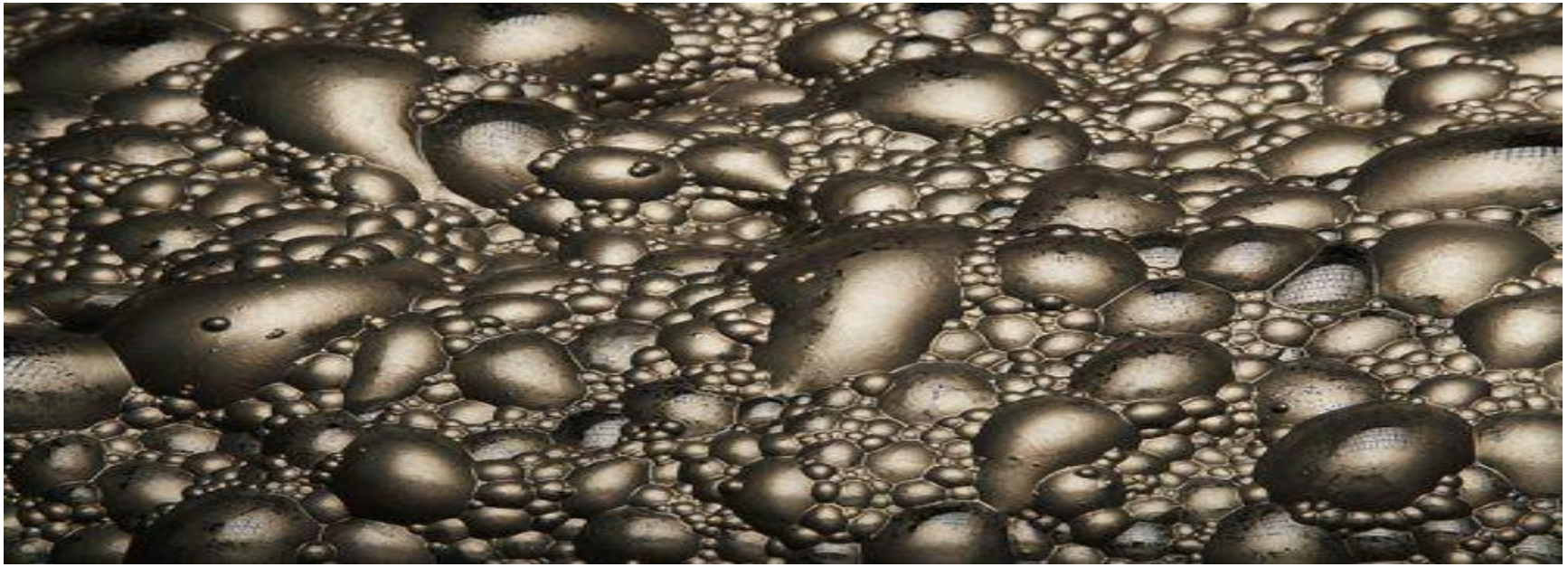
- **Liquid wastes in contact with ores high in arsenic:**

treated as hazardous waste.

Source: Environmental and occupational hygiene in high arsenic metallurgical test works at Barrick Technology Centre – Vancouver BC (Canada) 2016

ICSG

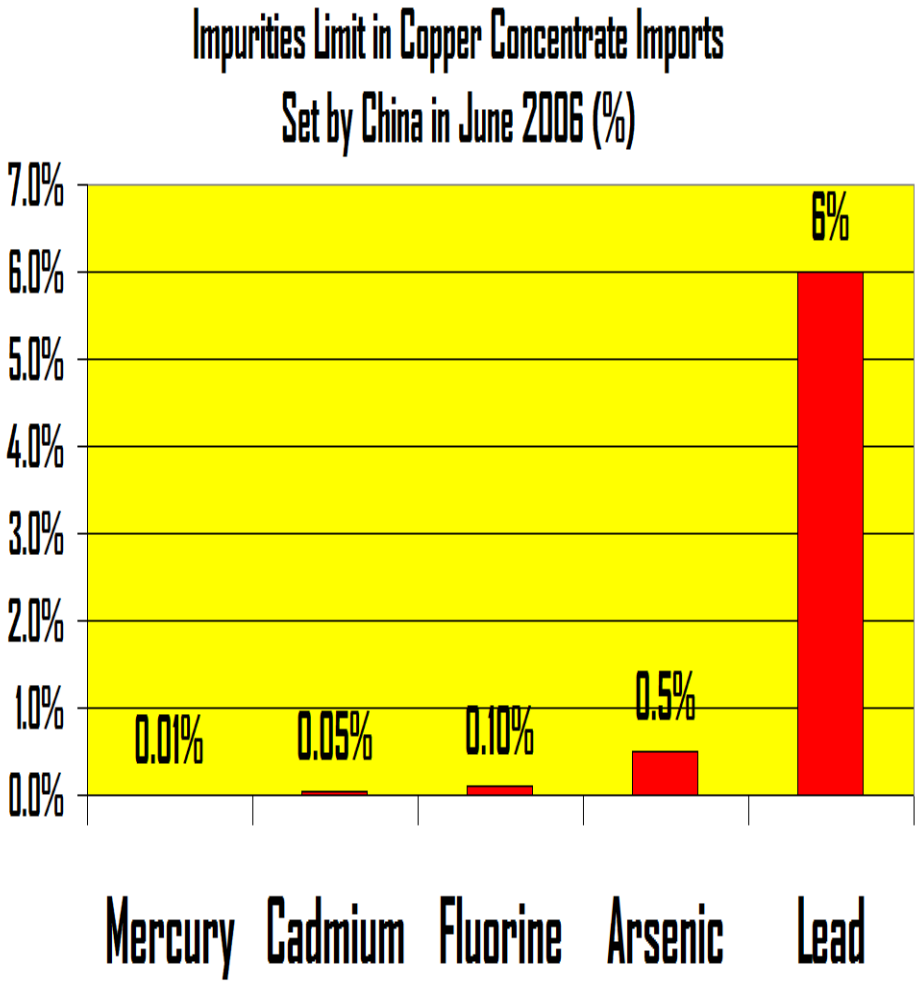
International Copper Study Group

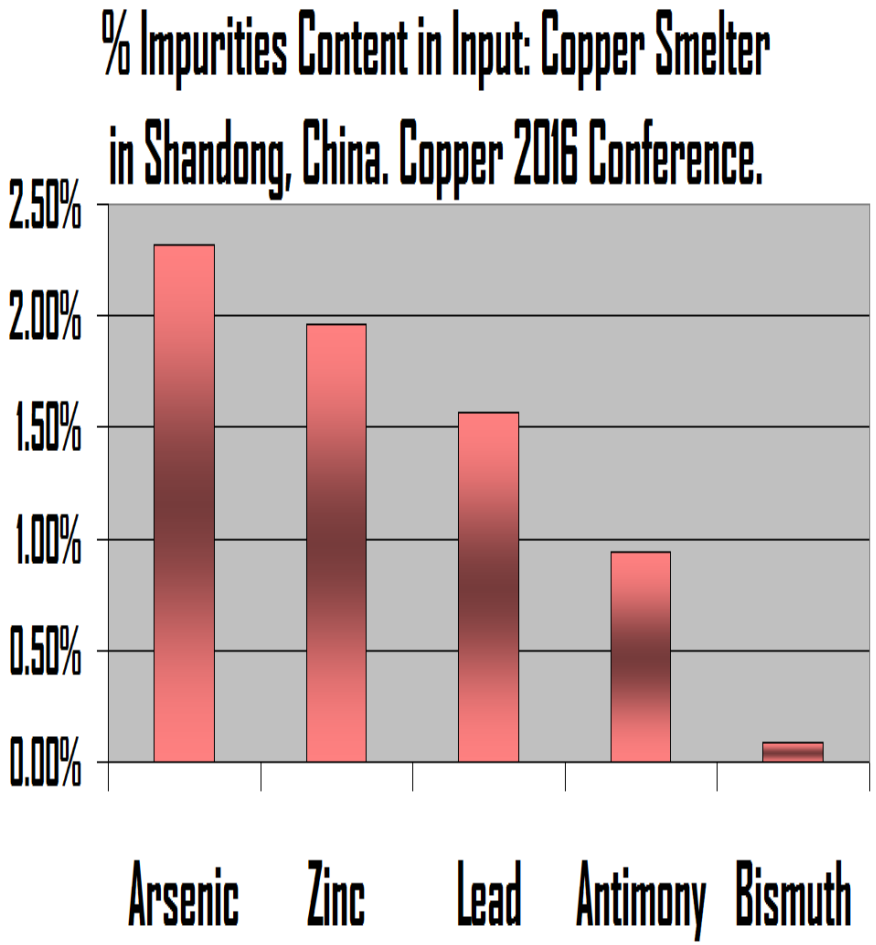


5. Copper Concentrate Trade Limits and New Risks to Transport of Copper Concentrates and Raw Materials

China set import limits for impurities in copper concentrate >10 years ago,

but specialized Chinese smelters are processing complex concentrates and stabilizing wastes.

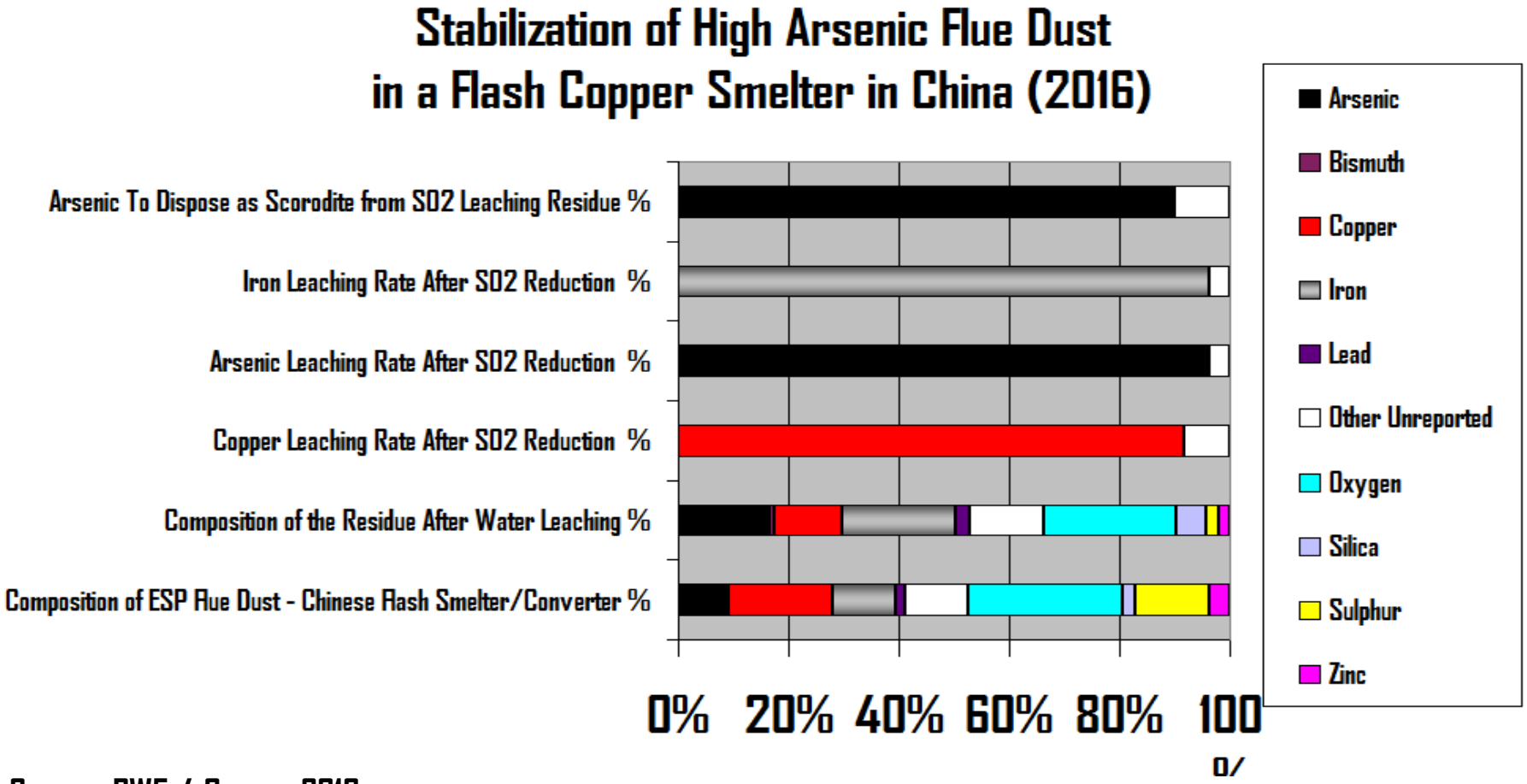




Source: http://www.copper2016.jp/program/index.html (2016)

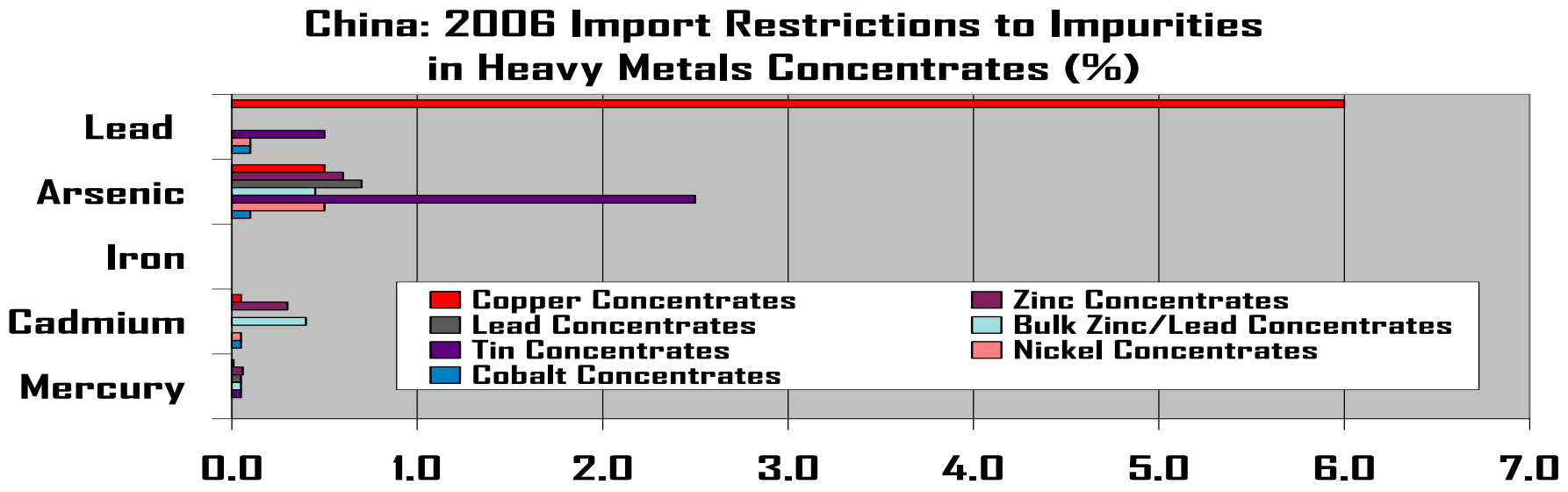
China Flash Copper Smelter Impurities Showcase:

copper smelter flue dust is water leached,
Sulphur is reduced and the residual is re-smelted.
Hazardous arsenic residual to be disposed outside of the smelter.



Source: RW5-4 Copper 2016.

In 2017 China is reviewing current concentrate import limits and might or might not change them from mandatory to recommended. ICSG will track future developments.

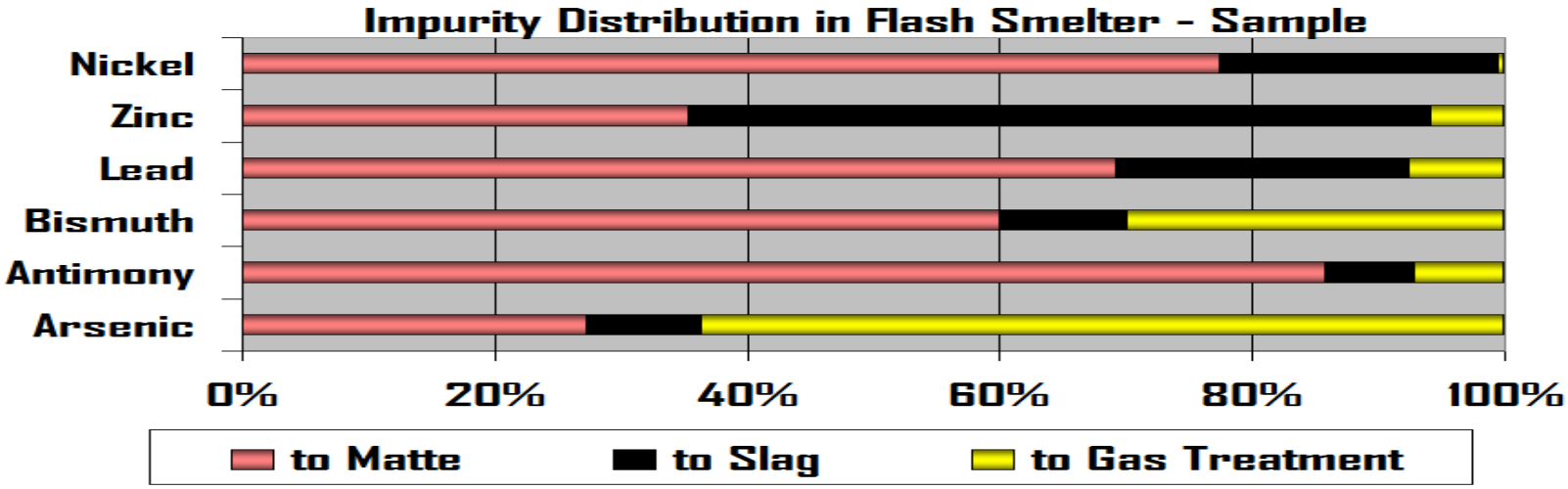


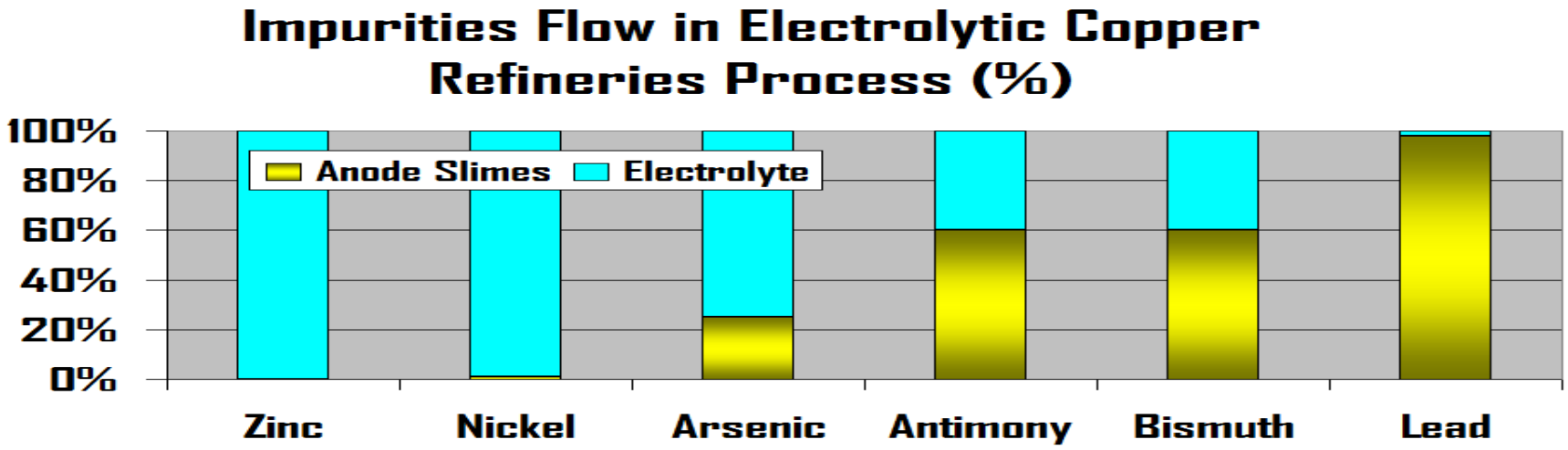
China National Standard GB 20424 – Year 2006

Concentrate Type	Maximum Allowed % of Harmful Element Content				
	Lead	Arsenic	Iron	Cadmium	Mercury
Copper Concentrates	6	0.5	0,1	0.05	0.01
Zinc Concentrates		0.6		0.3	0.06
Lead Concentrates		0.7			0.05
Bulk Zinc/Lead Concentrates		0.45		0.4	0.05
Tin Concentrates	0.5	2.5			0.05
Nickel Concentrates	0.1	0.5		0.05	0.001
Cobalt Concentrates	0.1	0.1		0.05	0.001

Source: Kolisnyk and McDowell, Teck, Orphan Elements and Trends for Cadmium. ICMM CMWG Phoenix Workshop, January 2017.

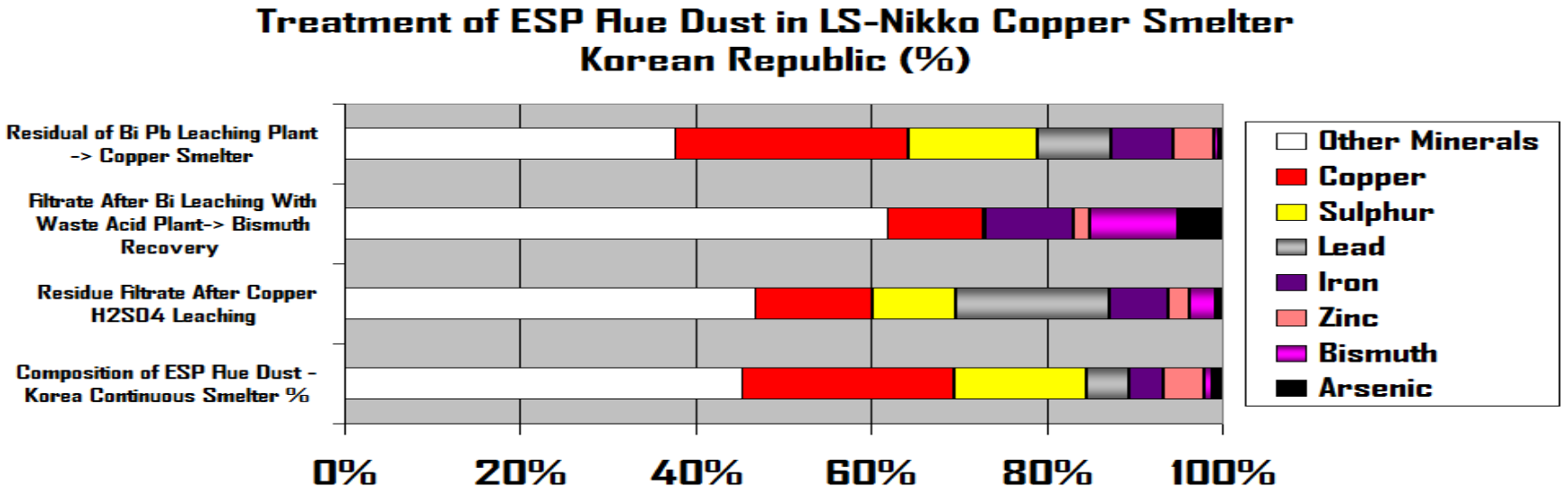
Impact of more impurities in copper smelters and refineries

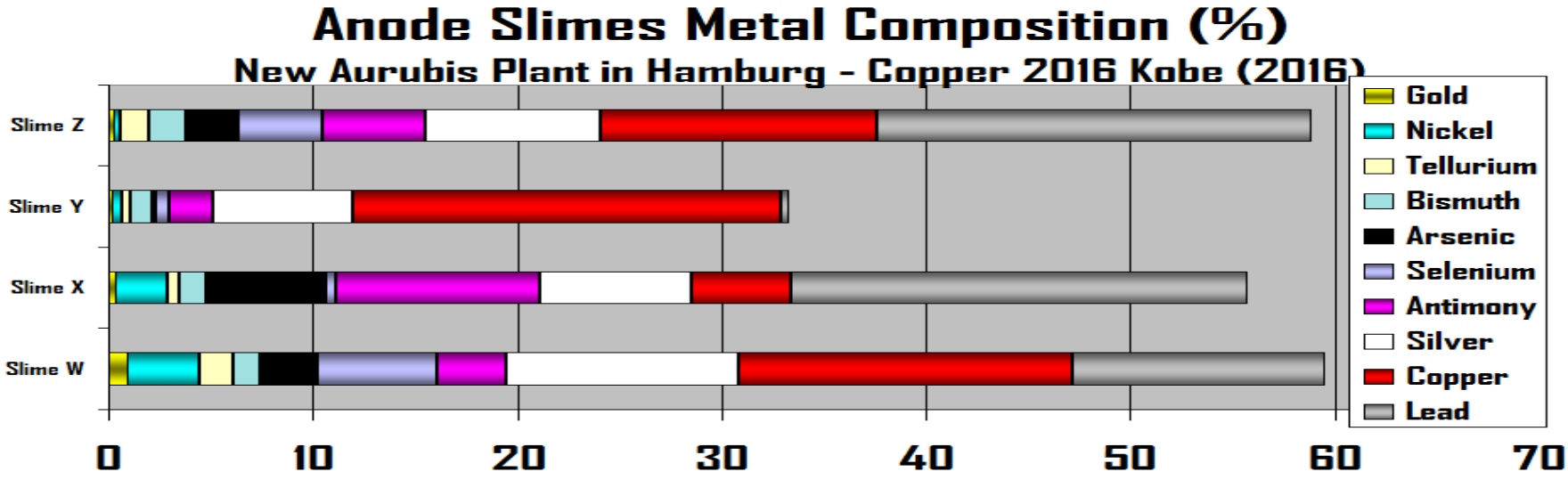




Source: http://www.copper2016.jp/program/index.html (2016)

Copper industry moving faster than trade limits, innovating in waste treatment. Best available technologies observed both in Asia and the European Union





IMO and EU REACH risk assesments are both based on the «GHS»

UN Globally Harmonized System of Classification and Labeling of Chemicals.

GHS Pictogram

Oxidizers

Flammables, Self Reactives, Pyrophorics, Self-Heating, Emits Flammable Gas, Organic Peroxides

Explosives, Self Reactives, Organic Peroxides

Acutely Toxic (severe)

Burns Skin, Damages Eyes, Corrosive to Metals

Gases Under Pressure

Carcinogen, Respiratory Sensitizer, Reproductive Toxicity, Target Organ Toxicity, Mutagenicity Aspiration Toxicity

Toxic to aquatic environment

Acutely toxic(harmful), Irritant to skin, eyes or respiratory tract, Skin sensitizer, Hazardous to the Ozone layer.

INTERNATIONAL MARITIME ORGANIZATION

Some copper concentrates can be harmful to the marine environment and a risk to crews.

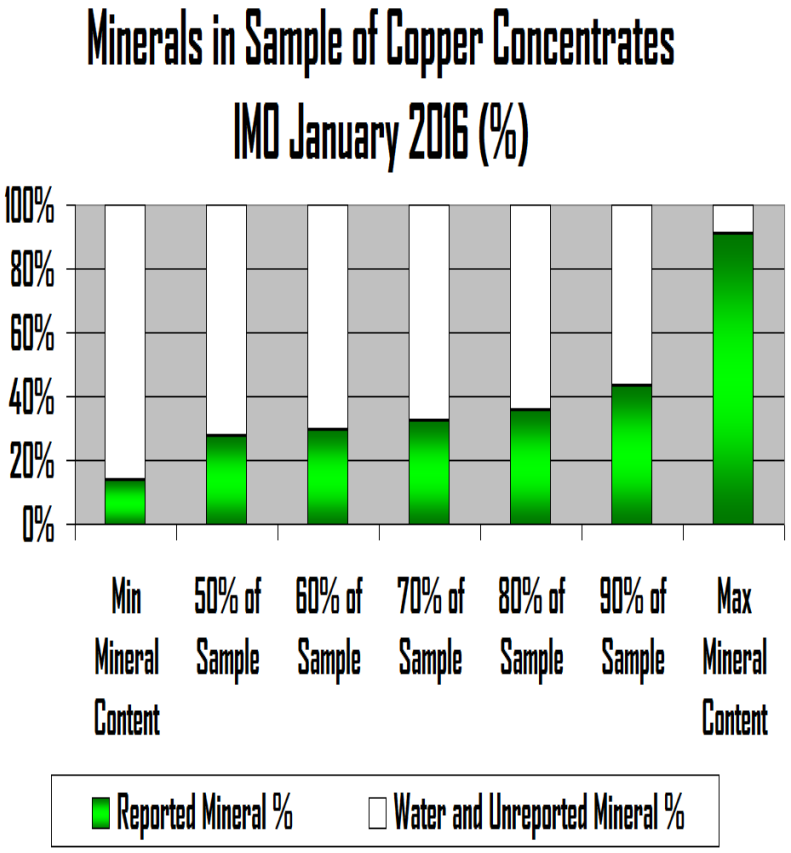
- International Maritime Organization (IMO)
- hazard assessment of solid cargoes

- Trade of Ore and Concentrate regulated by IMO:
  - in packaged form (IMDG Code)
  - in bulk (IMSBC Code and MARPOL Convention)

- 2012 guide to Annex V of MARPOL:
  - 6 of 7 hazard criteria to identify HME relevant to copper ores and concentrates

- IMO hazard assessment based on UN GHS.

But UN GHS has limited guidance for complex materials such as copper ores and concentrates.



IMO Criteria Aiming to Reduce Maritime Risks in Transport of Copper Ores and Concentrates

International Maritime Dangerous Goods Code (IMDG):

packaged copper ores and concentrates.

International Convention for the Prevention of Pollution from Ships (MARPOL) - Annex V

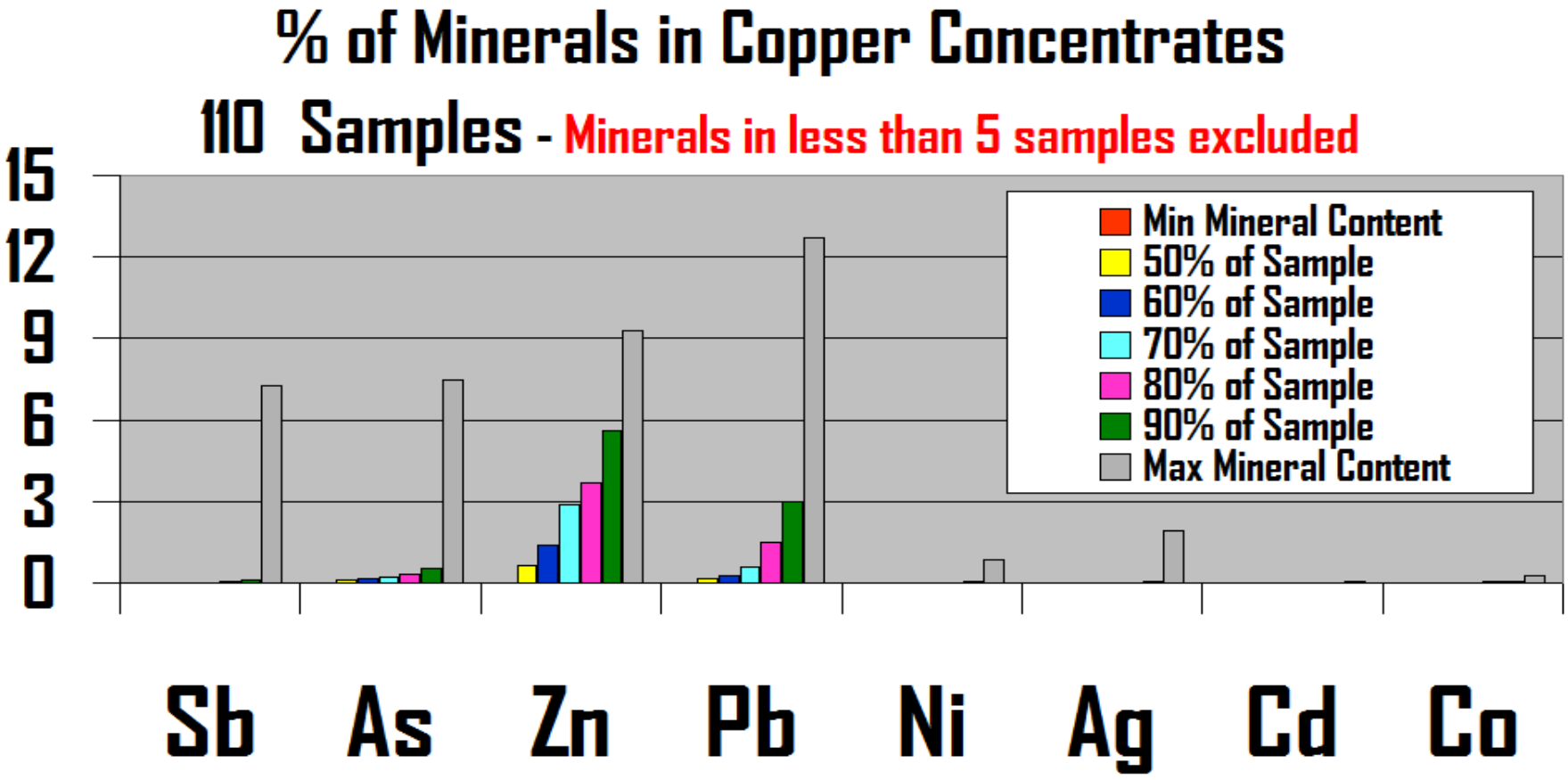
HME: Harmful to the Marine Environment

International Maritime Solid Bulk Cargoes Code (IMSBC)

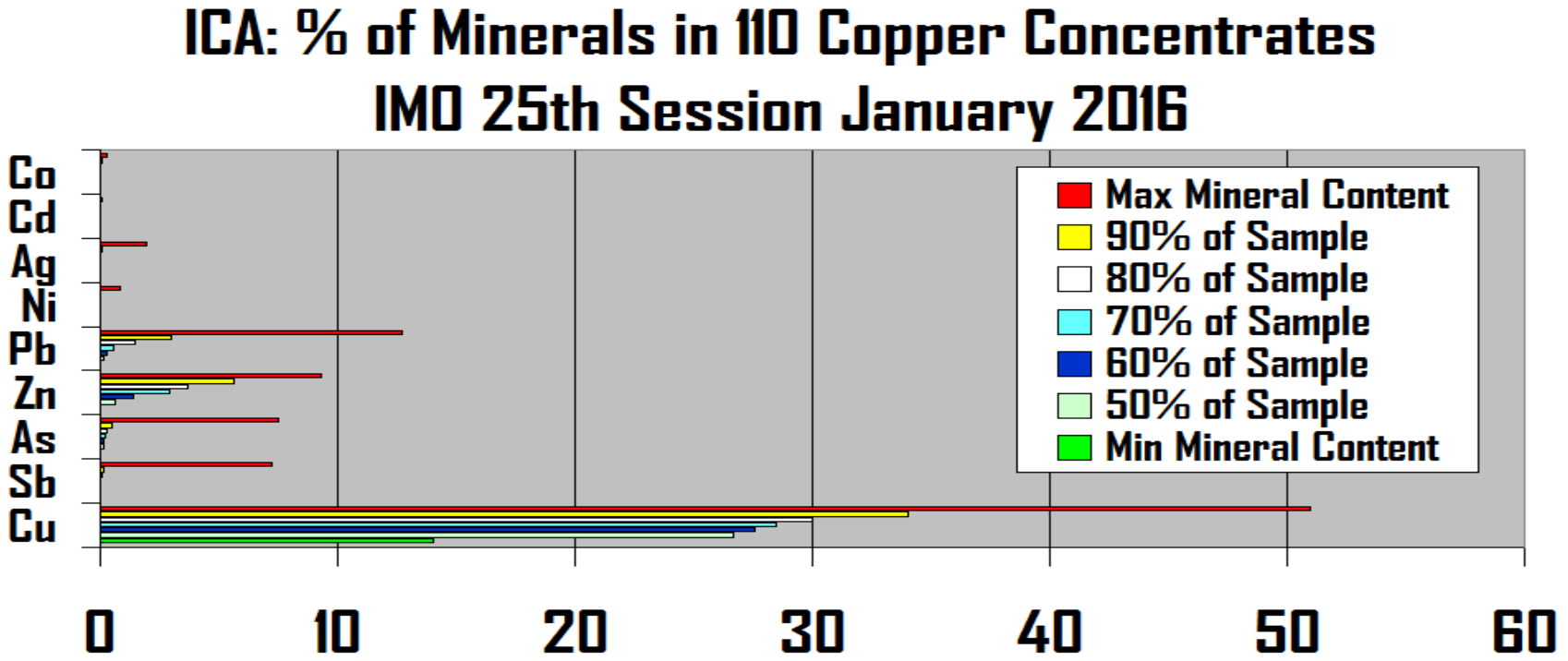
MHB: Materials Hazardous Only in Bulk

Cu Copper Alliance

Materials Hazardous only in Bulk (MHB):Hazard assessment.



Not all, but some copper concentrates and ores are HME and/or are MHB.



- IMO Sub-Committee on Carriage of Cargoes and Containers
- Copper Industry Classification of Cu Concentrates presented to IMO.
- Composition of copper concentrates assessed for 122 samples.
- No mercury (Hg), sulphur (S), gold (Au), other minerals included.

6 MHB hazard classes related to copper concentrates: "toxic solids" criteria clear but not yet "corrosive solids".

Materials Hazardous only in Bulk: MHB hazard classes

1. Combustible solids
2. Self-heating solids
3. Solids evolving into flammable gas when wet
4. Solids that evolve toxic gas when wet
5. **Toxic solids**
6. **Corrosive solids**

- Hazard classification of minerals www.metclas.eu

Copper industry hazard assessment findings:

- **presence of lead, cadmium, arsenic and/or nickel.**

- **Median % of arsenic 0.11 %, some conc. 7.5 % arsenic.**

•Conclusion:

1. **A significant % of the copper concentrates have toxic solids in the samples, so are MHB.**

2. **Further work needed on corrosive solids, and 1, 2, 3, 4.**

MHB sulphide copper ores and concentrates listed as "health hazards" at the IMSBC Code.

- If a copper ore or concentrate is MHB now:
- shipped under the "Metal Sulphide Schedule" of IMSBC Code as GROUP B Cargo of IMSBC Code (=MHB):
- persons exposed to wear eye protection, filter masks, protective clothing.

•Some concentrates are MHB but not listed as hazards in the "Metal Sulphide Schedule".

• Change in IMSBC "Metal Sulphide Schedule" in 2016 IMO meeting:

• "some metal sulphide concentrates may have acute and long-term health effects."

IMSBC Code: Material Hazardous only in Bulk MHB Criteria	
Industry Experts* Assessment	
Hazard Included in IMSBC Metal Sulphide Schedule	Additional MHB for Metal Sulphide Concentrates
Self Heating Solids	
	Acute Toxicity - Inhalation, Dermal
	STOT Re - Inhalation, Dermal
	Carcinogenicity
	Reproductive Toxicity
Corrosive to Metals	

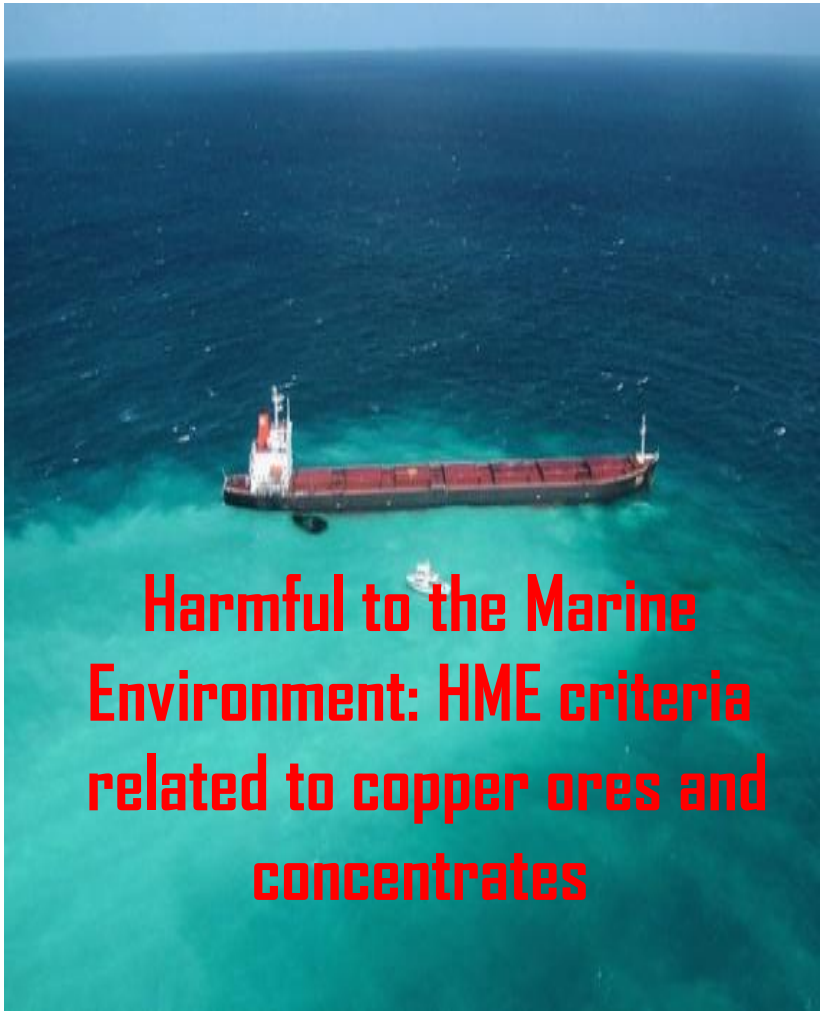
* ICA, IIMA, ILA, IZA, Nickel Institute

Endpoint	Classification triggers
Mutagen cat 1A and 1B	≥ 0.1%
Carcinogen Cat 1A and 1B	≥ 0.1%
Reproductive Toxicant Cat 1	≥ 0.3%
STOT Cat 1	≥ 10 %

Human Health Hazard HME Assessment Criteria

- MARPOL V: Harmful to Marine Environment (HME) if mutagenic, carcinogenic or STOT* repeated exposure.
- IMDG Code: acute hazard oral, dermal or inhaled/Skin Corrosion Irritation
- IMSBC Code: all above + serious eye damage, +STOT* single exposure.
- IMSBC Code: A: liquefy, B: chemical hazard, C: no A no B.
- * STOT
- Specific target organ toxicity

IMO Hazard Assessment of Copper Ores and Concentrates for Marine Transport: MARPOL Annex V



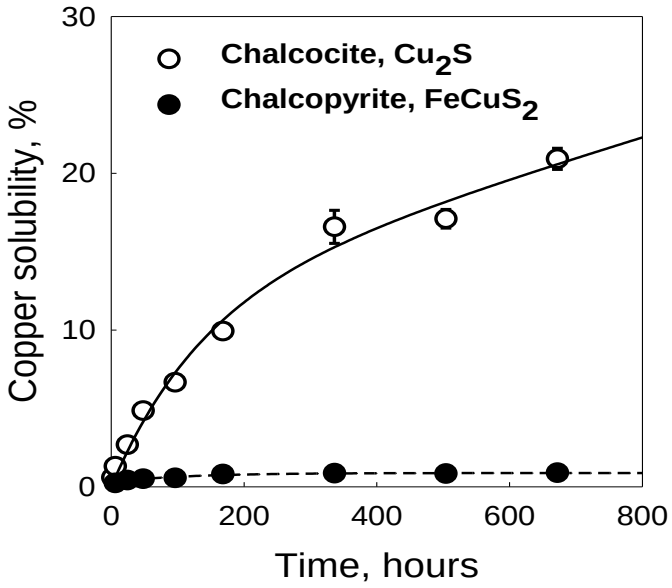
1. **Acute Aquatic Toxicity** Category 1; and/or
2. **Chronic Aquatic Toxicity** Category 1 or 2; and/or
3. **Carcinogenicity Category** 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
4. **Mutagenicity Category** 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
5. **Reproductive Toxicity** Category 1A or 1B combined with not being rapidly degradable and having high bioaccumulation; and/or
6. **Specific Target Organ Toxicity** Repeated Exposure Category 1 combined with not being rapidly degradable and having high bioaccumulation;

Which copper ores and concentrates are considered HME? What treatment and who is responsible?

Copper Concentrates HME Assesment

- **Chalcopyrite : Non-HME**

- **Chalcocite > 28% : aquatic acute 1 = HME**

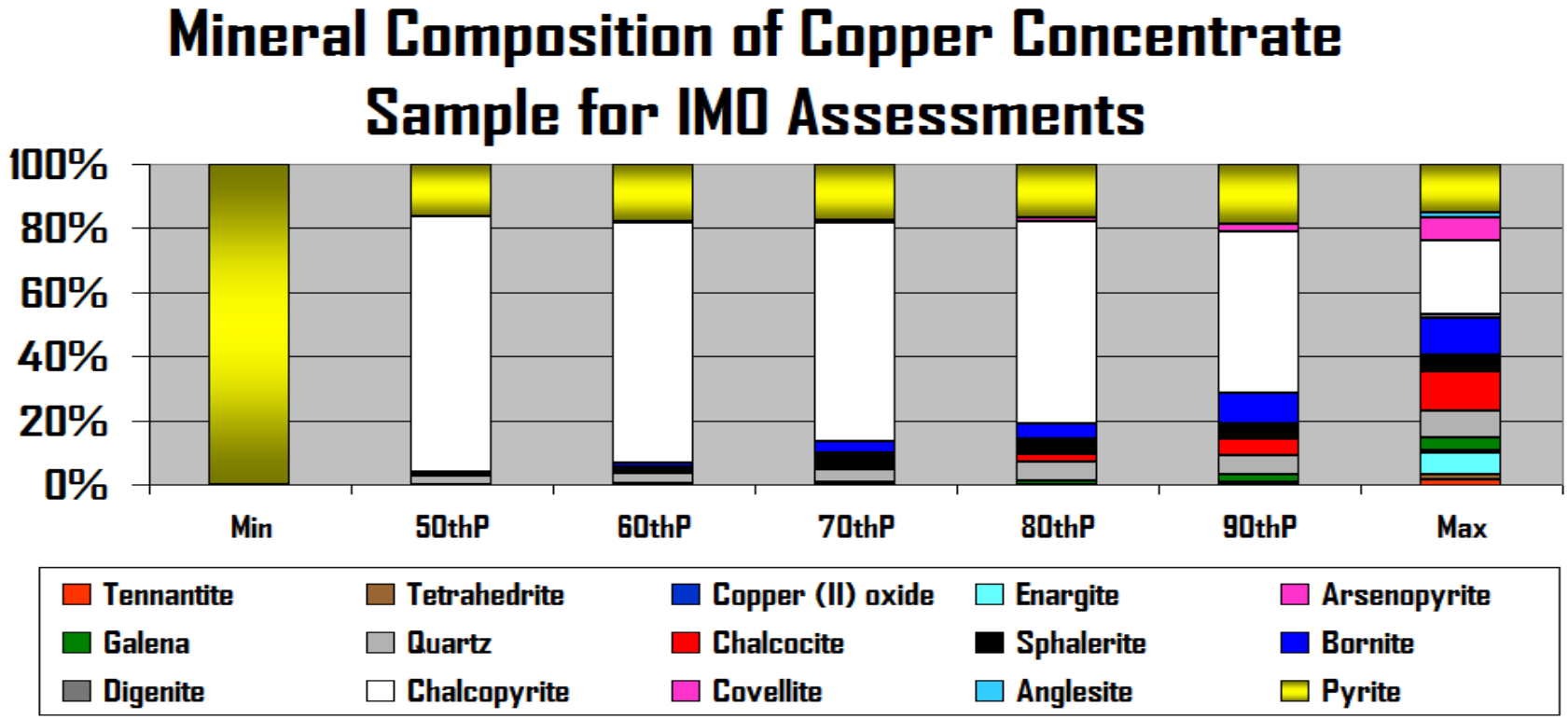


HME Concentrates Water Treatment:

costs covered in shipping contracts.

Shipper (cargo owner) responsible for HME/non HME declaration.

IMO January 2017: 20% of copper concentrates merit to be Hazardous to the Marine Environment (HME) given Ecotoxicity Reference Values as "Aquatic Acute 1".



Chalcopyrite (non-HME) most of the sample of Cu concentrates.
Chalcocite (HME) small share of the sample presented to IMO.

In 2016, IMO Sub-Committee on Carriage of Cargoes and Containers included corrosive solids as "MHB".

- Changes to IMSBC "Metal Sulphide Schedule": health effects.
- Method for MHB criteria "corrosive solids" to copper ores and concentrates risk assessment.
- UN GHS test developed for corrosive liquids, but never validated for corrosive solids.
- ICMM developed new corrosive solids test protocol in 2016 with testing labs.

EU REACH hazard classification and toxicity labelling proposals issued for every one of the copper raw and intermediate materials.

Copper, Anode & Blister, Copper Matte, Black Copper, Copper Slimes, Copper Speiss, Slags, Copper Refining, Copper Scale,Copper Flue Dust, Copper electrolytes, Copper Sulfuric Acid, Copper Residues, Copper Cupro, Copper Final Slags

Example 1: Flue Dust Recovered from Exhaust Gas Streams

Hazard Class and Category Code(s)	Hazard Statement
Acute Tox. 3 (oral) Acute Tox. 3 (inhalation)	H301: Toxic if swallowed H331: Toxic if inhaled
Skin Corr. 1B	H314: Causes severe skin burns and eye damage.
Eye Damage 1	H318: Causes serious eye damage.
Skin Sens. 1	H317: May cause an allergic skin reaction.
Repr. 1A	H360: May damage the unborn child. Suspect damaging fertility. (Route of exposure: oral or inhalation).
Muta. 2	H341: Suspected of causing genetic defects.
Carc. 1A	H350: May cause cancer.
STOT Rep. Exp. 1	H372: Causes damage to organs through prolonged or repeated exposure. (Affected organs: central nervous system, blood and kidneys; Route of exposure: inhalation or ingestion).
Aquatic Acute 1	H400: Very toxic to aquatic life.
Aquatic Chronic 1	H410 Very toxic to aquatic life with long lasting effects

Example 2: Spent Electrolytes from Copper Refineries

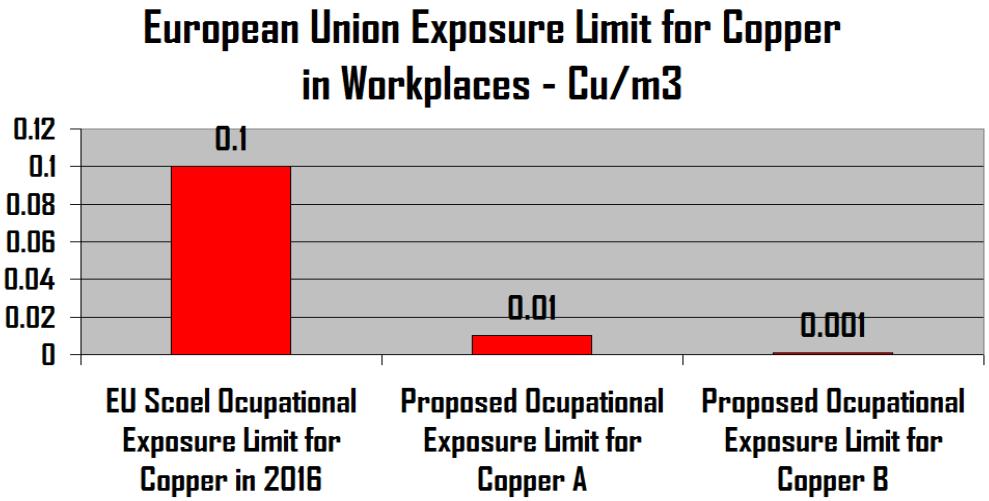
Hazard Class and Category Code(s)	Hazard Statement
Acute Tox. 4 (oral)	H302: Harmful if swallowed
Skin Corr. 1A	H314: Causes severe skin burns and eye damage
Eye Damage 1	H318: Causes serious eye damage
Resp. Sens. 1	H334: May cause allergy or asthma or breathing difficulties if inhaled
Skin Sens. 1	H317: May cause an allergic skin reaction
Repr. 1B	H360: May damage fertility or the unborn child (Route of exposure: oral and dermal)
Muta. 2	H341: Suspected of causing genetic defects
Carc. 1A	H350: May cause cancer
STOT Rep. Exp. 1	H372: Causes damage to organs in prolonged or repeated exposure
Aquatic Acute 1	H400: Very toxic to aquatic life
Aquatic Chronic 1	H410: Very toxic to aquatic life with long lasting effects

Some European Union regulations under discussion are a challenge to the trade flows of copper concentrates related to Western Europe.

- Mercury a restricted substance since 2017 in REACH.

European Chemicals Agency: if a metal contains >0.3% lead, might be classified as "toxic to reproduction". Compliance by 1 March 2018.

If copper is classified as a biocide in the EU in 2017 it will require a special UN GHS classification.



Cu Copper Alliance

Mining companies and copper industry organizations: aware of copper impurities and working on the most urgent regulatory issues.

Regarding occupational inhalation limits for copper,
Germany MAK and SCOEL proposals to lower the OEL by a factor of 10X.
ICA expert panel assessing the state of the science to respond

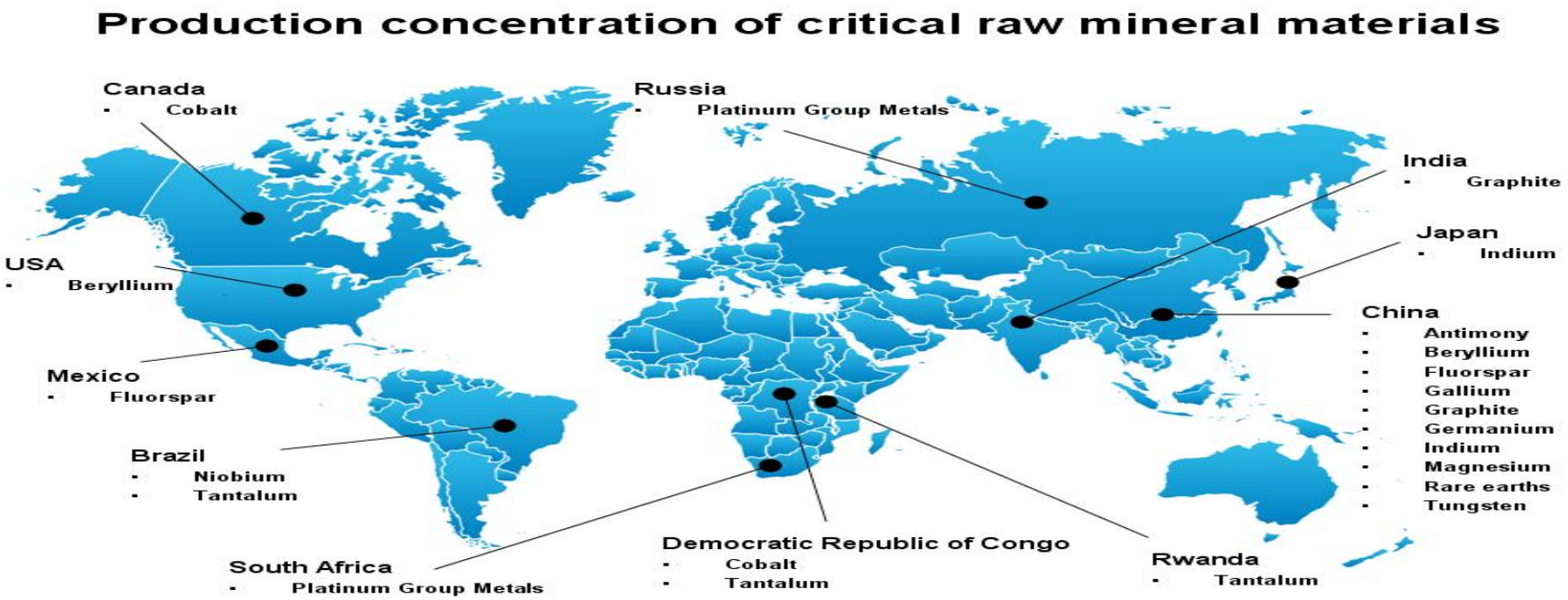
Best practices on impurities management.:
ICMM members actively exchanging information

Industry response to the risk of copper concentrates classification as hazard (MHB) under IMO and related transport regulations:
ICA and ICMM joint project to assess corrosivity of copper concentrates

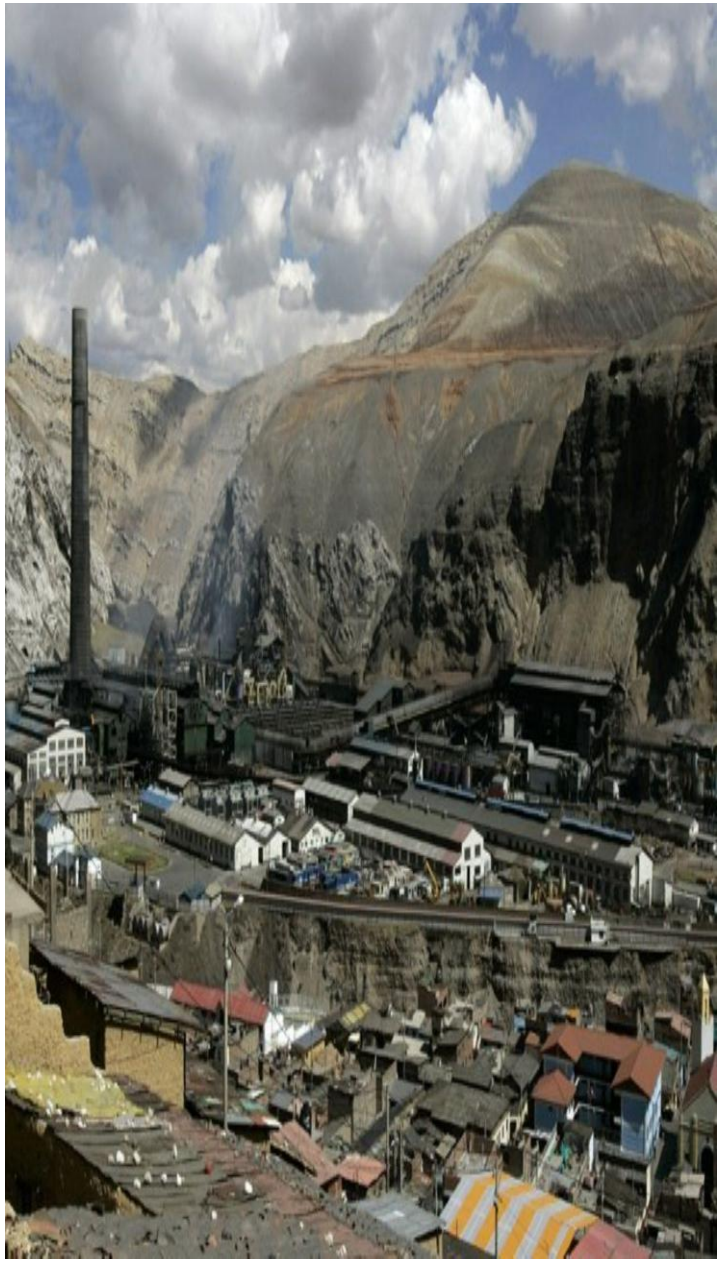
Companies reduced their own staff capabilities on impurities in 2014-2016
ICA more involved in concentrates and smelting issues

ICSG research advances on regulation on impurities
Consultation with ICA

Cobalt, antimony and beryllium: copper industry impurities and by-products classified as Critical Raw Materials (CRM) by the European Union since 2010: classification as a critical material of all forms of cobalt expected.



- CRMs at risk regarding supply shortage in the next 10 years.
- When a copper industry impurity becomes a "Critical Raw Material"?
  - When a CRM is available only as a byproduct of more abundant metals
    - Used in **small quantities** in specialized high-technology applications
    - Has **no suitable substitute** or substitutes across its spectrum of uses.



Old technologies can survive operational for long periods in sectors of the economy protected from stringent regulation or international emission standards or indirectly subsidized.

But when the standards are shared, old smelters using concentrates have difficulty to compete without

- technology innovations
- re-locations
- outdated plant closures.

Next ICSG meeting,
Copper mine supply and refined copper market forecasts:

27-28 April 2017
Lisbon, Portugal.

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A Joint Seminar with Copper, Lead, Zinc and Nickel Study Groups will be held on Thursday 27 April on the topic of "Meeting the Challenge of Mining and Smelting/Refining Waste".