Coatings: Factors Driving Industry Change

Particularly Relevant for the Surface Finishing Sector:

Article: “How Industries Change”

- Economics
- Technology
- Regulation

Anita McGahan
Harvard Business Review
October 2004
### Regulatory Pressures: A Short List for Coatings

#### Metals & Chemicals in the Value Chain – Impacts

<table>
<thead>
<tr>
<th>Suppliers</th>
<th>Materials</th>
<th>Processes</th>
<th>Industrial Customers/OEMs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Use Controls</strong></td>
<td><strong>Regulatory Controls</strong></td>
<td><strong>Materials / Product Controls</strong></td>
<td></td>
</tr>
<tr>
<td>- EU REACH</td>
<td>- Air – CAA</td>
<td>- EU ELV</td>
<td></td>
</tr>
<tr>
<td>- US TSCA</td>
<td>- Water – CWA</td>
<td>- EU RoHS / WEEE</td>
<td></td>
</tr>
<tr>
<td>- EPA Chemicals List</td>
<td>- Waste Mgmt – RCRA</td>
<td>- EU CLP</td>
<td></td>
</tr>
<tr>
<td>- Conflict Minerals</td>
<td>- Worker Safety – OSHA</td>
<td>- US CPSC Restrictions</td>
<td></td>
</tr>
<tr>
<td>- DEA Sodium Hypo</td>
<td>- Facility Security – DHS</td>
<td>- State Chemicals Lists</td>
<td></td>
</tr>
<tr>
<td>- K REACH</td>
<td>- Remediation – CERCLA</td>
<td>- SIN List</td>
<td></td>
</tr>
</tbody>
</table>

**Regulatory Drivers = Incremental, yet Transformative Change**
Automotive Coatings

Key Technologies for Functional and Decorative Applications
Without nickel and without coatings, you would have no cell phone. Nickel is essential for any battery (Li-ion, Ni metal hydride, Ni-Cd). It makes lead-free solder possible while also preventing electromagnetic interference and corrosion. Without Ni, your cell phone would quickly become a useless piece of electronic junk.

Without coatings, modern electronics would not exist. Almost everything you see and feel on your cell phone is some type of coating. All electronics are built from coatings of different materials. Without coatings, your touch screen would be just a sheet of glass.

Nickel in Electronics

Coatings & Alloys

3. Li ion battery anode LiCoO\textsubscript{2}/\textsubscript{3}NiO\textsubscript{2}/\textsubscript{3}MnO\textsubscript{2}

4. Antenna - NiTi shape memory alloy

5. EMI shielding - Ni paint or Cu plate with Ni overlay, or composite case made of Ni plated carbon fibers in plastic

6. Wire bond, every chip - Ni/Pd/Au coating

7. Diffusion barrier, every chip and board – lead-free solder cannot be done without electroless Ni immersion Au coating (ENIG)

8. Microphone - electroless/electroplated Ni on mylar

9. Circuit board, SIM card - Ni plate on Cu for oxidation protection

10. Ceramic capacitors - Ni on electrodes, interconnects

11. Decorative coatings - paint, anodize, electroless Ni for plating on plastic, Cr trim

12. Conformal polymer coatings to protect from water and inhibit tin whiskers from non-lead solder

13. Inks to print information onto components, chips, circuit boards

14. No Nickel, No Electronics

No Coatings, No Cell Phones

Nickel Surface Finishes are Wide Ranging

Emerging Global Regulatory Developments for Nickel

The National Association for Surface Finishing
1800 M Street, Suite 400 S
Washington, D.C. 20036
P: (202) 457-8404     F: (202) 530-0659     NASF.org

Insight. Expertise. Results.
Cadmium Trends

Cd
Cadmium
112.411
Coatings Technology Roadmap
Cadmium Elimination

Cd Alternatives

- High strength steel (>180 ksi)
  - LHE Zn(14-16)Ni electroplate
  - No-bake ZnNi brush plate
  - IVD Al
  - Thermal spray Al
  - Cold spray Al alloys
  - AlumiPlate (Al electroplate)
  - Metallic ceramics

- Steel < 180 ksi
  - Acid Zn8Ni electroplate
  - Zn plate
  - IVD Al
  - Thermal spray Al
  - Cold spray Al alloys
  - AlumiPlate (Al electroplate)

- Electrical connectors
  - LHE Zn(14-16)Ni electroplate
  - AlumiPlate (Al electroplate)
  - Electroless Ni-PTFE
  - ZnNi + surface mineralization

- Fasteners
  - LHE Zn(14-16)Ni electroplate
  - Dip-spin Al/Zn flake polymers

Role of Nickel-based replacements
Coatings Technology Roadmap
Chromium VI Elimination

Hex Cr Alternatives

Passivation
- Cr3+ passivates
- Cr-free passivates
- Paint adhesion promoters
- Zn passivates
- Phosphate alts and sealers
- Fastener Zn alts
- Zn-rich primers

Anodizing and sealing
- CAA alts
- Cr6-free anodize sealers
- PEO coatings
- Mg coatings
- Nano-electroplates
- Composite electroplates
- Thermal spray
- Vacuum coatings
- Heat treats
- Cirrus

Chrome plating
- Trivalent hard Cr
- Electroless Ni

Stainless passivation
- Nitric acid
- Citric acid

Welding
- Alt weld methods
- Cr-free weld rod

Role of Nickel-based replacements
Example: Chromium Trioxide ("Chromic Acid")

**REACH Authorization**

- **2013**: Inclusion in Annex XIV REACH
- **2014**: Conclusion of Consortium works
- **2015**: Start of Consortium Submission of Applicants
- **2016**: Latest Application Date (March 21st)
- **2017**: Sunset Date (Sept 21st)

- Chromium trioxide listed as SVHC in 2013
- Any use not explicitly authorized is banned after the sunset date: September 21, 2017
U.S. Cr VI Success: “Cleaner” Chemical Processing
99.7% Reduction in Cr6 Air Emissions, 1995 – 2012 (tons per year)

U.S. Cr6 Electroplating Industry Emissions
(from 1995 NESHAP to present, in tons per year)

A Major Clean Air Act Success – 173 TPY to lower than 0.5 TPY
Total U.S. emissions reduced by > 99.7 % in a small business sector

Update: March 2012 industry data collection effort appears to show that U.S. Cr6 emissions may be reduced from 0.5 tons (1100 lbs) to as low as 150 to 250 lbs.
Chromium (VI) Usage Trends:
Still in use, but applications shrinking

Worldwide Consumption

- Anti-corrosion and conversion coatings
- Paints
- Textile & leather
- Wood preservation

2002
184,000 tons

2011
90,000 tons

45,000 tons used in surface finishing

2002
184,000 tons

2011
90,000 tons
Classification of Nickel & Nickel Compounds

Nickel Metal – Does Not Meet the Criteria for REACH SVHC
– Carcinogen. Cat. 3
– Toxic by inhalation (prolonged exposure)
– May cause sensitization by skin contact
– Harmful for aquatic organisms (nickel powder; particle diameter < 1 mm)

Soluble Nickel Compounds (Plating & Finishing) / Insoluble Compounds meet the Criteria for potentially being identified as SVHCs
– Carcinogen. Cat. 1
– Toxic for reproduction. Cat. 2
– Mutagenic. Cat. 3
– Toxic by inhalation (prolonged exposure)
– May cause sensitization by inhalation and skin contact
– Very toxic for the aquatic organisms

Only Nickel Compounds have a classification (carcinogenicity by inhalation) that prompts consideration under REACH as potential Substances of Very High Concern (SVHC)
Grouping of the SIN List chemicals

How many chemicals are being manufactured in the world? Nobody knows. About 150,000 chemicals were pre-registered under REACH and more than 13,000 have been registered so far. The SIN List contains more than 800 individual CAS numbers. To facilitate for companies and other users of the SIN List, ChemSec wants to make the SIN List even more user-friendly and we have therefore grouped the substances on the SIN List.

GROUPING OF THE SIN LIST
Chemicals can be divided into groups based on their structure, which in turn can be used to their toxicological effects. A group may be justified on more than one base, for example; overall structure, a common functional group, common precursors or the likelihood of common breakdown products.

The justification of groups has traditionally been made in a manual way by careful examination of chemical structures and their effects. For large data sets, computational methods can facilitate this process much more. Known are quantitative structure activity relationship (QSAR).

The SIN List has been grouped with the aim to make it more user-friendly and to create the basis for the SHINEarty tool. Since the substances have been put on the SIN List because of their hazardous properties, this is also what we chose to base the grouping on. The SIN List chemicals were manually divided into groups that meet the most accurate division. For each chemical, the structural elements responsible for the hazardous properties were identified. This was done by consulting scientific literature and experts from the Department of Chemistry and Molecular Biology, University of Gothenburg and the Swedish Environmental Institute (SI). Feeling, the substances were divided into 9 groups. All substances that about 60% were assigned to one or more groups. None of the components contain several of these group specific structural elements, one chemical can belong to multiple groups.

Structure element
A structural element is a part of a molecular structure that is important for a certain property. The elements can be a small defined functional group or consist of smaller parts of the molecule connected or placed in a specific way. In the context of the SIN List, these structural elements are thought to be responsible for the hazardous properties.

THE GROUPS OF THE SIN LIST ARE:

- Electrophiles
- Amino carbonyl compounds
- Antimony compounds
- Aromatic amines
- Asymmetric compounds
- Azo compound
- Beryllium compounds
- Bisphenols
- Boron compounds
- Cadmium compounds
- Chromium compounds
- Cobalt compounds
- Copper compounds
- Cyclic compounds
- Dibenzofuran (DBF)
- Diaryl ether compounds
- Diazo compounds
- Dienes
- Dinitrogen compounds
- Dithiocarbamates (DTC)
- Divalent non-halogenated aromatic compounds
- Divalent non-halogenated heteroaromatic compounds
- Divalent non-halogenated alicyclic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds
- Divalent halogenated heteroaromatic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds

The SIN List and Nickel

THE GROUPS OF THE SIN LIST ARE:

- Electrophiles
- Amino carbonyl compounds
- Antimony compounds
- Aromatic amines
- Asymmetric compounds
- Azo compound
- Beryllium compounds
- Bisphenols
- Boron compounds
- Cadmium compounds
- Chromium compounds
- Cobalt compounds
- Copper compounds
- Cyclic compounds
- Dibenzofuran (DBF)
- Diaryl ether compounds
- Diazo compounds
- Dienes
- Dinitrogen compounds
- Divalent non-halogenated aromatic compounds
- Divalent non-halogenated heteroaromatic compounds
- Divalent non-halogenated alicyclic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds
- Divalent halogenated heteroaromatic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds

THE GROUPS OF THE SIN LIST ARE:

- Electrophiles
- Amino carbonyl compounds
- Antimony compounds
- Aromatic amines
- Asymmetric compounds
- Azo compound
- Beryllium compounds
- Bisphenols
- Boron compounds
- Cadmium compounds
- Chromium compounds
- Cobalt compounds
- Copper compounds
- Cyclic compounds
- Dibenzofuran (DBF)
- Diaryl ether compounds
- Diazo compounds
- Dienes
- Dinitrogen compounds
- Divalent non-halogenated aromatic compounds
- Divalent non-halogenated heteroaromatic compounds
- Divalent non-halogenated alicyclic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds
- Divalent halogenated heteroaromatic compounds
- Divalent halogenated alicyclic compounds
- Divalent halogenated aromatic compounds
**2008-2012**  
**French review process**  
- No proposal to list Nickel compounds on the REACH Candidate List  
- Avoided ramifications of REACH framework associated with listing as Substance of Very High Concern

**2012-2014**  
**Advancement of Risk Management Options** (RMO) Analysis to analyze Ni risks  
- Discussions with representatives of Ni producers & downstream users  
  (e.g., aerospace, automotive, plating, battery, catalyst)  
- Dialogue encompassed several nickel containing chemicals  
- Focused on nickel sulfate and nickel oxide as their properties are similar to larger Ni compound universe and represent the relevant uses
2012 – 2014 – Risk Management Option Analysis

- Focus on workplace exposure
- Consider OELs

2014 Conclusion

Draft Conclusion: **OELs are the most proportionate Risk Mgmt Option**
France has used EU Scientific Committee (SCOEL) recommendations for Nickel RMO.

French authorities used SCOEL 2011 recommendations to calculate RMO risks:

- **0.01 mg/m³** for Nickel compounds based on respiratory carcinogenicity effects
- **0.005 mg/m³** for nickel metal and nickel compounds based on respiratory toxicity

The SCOEL values have not been adopted but have been under discussion...
Current Status and Outlook – Nickel Sulfate & Nickel Oxide

✓ Final French recommendation on RMO delayed through 2015
✓ Now expected later in 2016?

Emerging Issues – Should French RMO Analysis be Expanded?

✓ France pursued in-depth RMOAs for Ni sulfate and Ni oxide to identify risks
✓ Will use the conclusions for also finalizing the RMOAs for 5 additional Ni substances (Ni dinitrate, dihydroxide, dichloride, bis(dihydrogen phosphate), hydroxycarbonate)

Important Factor – Continuous Industry Stakeholder Engagement

✓ Broad range of downstream nickel users
✓ Industry role – Technical input critical to inform decision making
German Introduction of RMOA for additional substances

- Reviewing other Ni compounds – Nickel sulfide and Nickel subsulfide

Outlook & Questions

- Regulatory consistency – ensure that member states apply same solution for substances with identical characteristics and uses
- Industry – Workplace legislation should be recognized as an alternative to REACH authorization
- KEY QUESTION: What criteria should be used to determine the appropriate path?
EU & US: Nickel Allergy Discussion

EU limitations on nickel release

Focus: “Products intended to come into **direct** and **prolonged** contact with the skin (Restriction under REACH, Annex XVII, Entry 27, test methods: EN 12472 & 1811)”

- Primary focus has been jewelry to introduce replacements
- Ni-free coatings for certain decorative uses
- Nickel release, not nickel content, is key

U.S. Consumer Product Safety Commission has noted it will not propose a U.S. standard (June 2016)
STATE CHEMICALS POLICY:
Trends and Profiles

April 2013
# Maine: Nickel Listed as Chemical of High Concern

Nickel Metal or Nickel Compounds – It Makes a Difference

<table>
<thead>
<tr>
<th>List of Chemicals of High Concern</th>
<th>Toxicity</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS</td>
<td>Chemical</td>
<td>NIC</td>
</tr>
<tr>
<td>108-88-3</td>
<td>Toluene</td>
<td>✓</td>
</tr>
<tr>
<td>116-89-5</td>
<td>Tri(2-chloroethyl) phosphate</td>
<td>✓</td>
</tr>
<tr>
<td>117-61-7</td>
<td>DI-(2-ethylhexyl) phthalate, DEHP</td>
<td>✓</td>
</tr>
<tr>
<td>118-74-1</td>
<td>Hexachlorobenzene</td>
<td>✓</td>
</tr>
<tr>
<td>120-47-0</td>
<td>Ethyl paraaben</td>
<td>✓</td>
</tr>
<tr>
<td>131-65-9</td>
<td>2,3,4-trihydroxybenzophenone, BP-2</td>
<td>✓</td>
</tr>
<tr>
<td>131-66-0</td>
<td>2,4-Dihydroxybenzophenone</td>
<td>✓</td>
</tr>
<tr>
<td>131-76-4</td>
<td>Methyl isobutylcarbinol</td>
<td>✓</td>
</tr>
<tr>
<td>140-66-9</td>
<td>1,1,2,3-Tetrahydro-2H-cyclopenta[d][1,3]oxazine</td>
<td>✓</td>
</tr>
<tr>
<td>556-67-3</td>
<td>Octamethylene tetramine</td>
<td>✓</td>
</tr>
<tr>
<td>608-92-8</td>
<td>Benzene, pentachloro-</td>
<td>✓</td>
</tr>
<tr>
<td>1165-19-4</td>
<td>2,3,5,6,7,8-Hexachlorobiphenyl, 2,3,5,6,7,8-Hexachlorobiphenyl</td>
<td>✓</td>
</tr>
<tr>
<td>1654-04-4</td>
<td>Methyl tert-butyl ether, MTBE</td>
<td>✓</td>
</tr>
<tr>
<td>1753-22-1</td>
<td>phenol</td>
<td>✓</td>
</tr>
<tr>
<td>1808-28-6</td>
<td>Phenol, di-ethyl-</td>
<td>✓</td>
</tr>
<tr>
<td>239-66-6</td>
<td>2-Naphthalenol, 1-(3-methyl-2-nitrophenyl)methyl</td>
<td>✓</td>
</tr>
<tr>
<td>5465-77-3</td>
<td>2-ethylhexyl-4-ethylhexylmethacrylate</td>
<td>✓</td>
</tr>
<tr>
<td>7400-97-0</td>
<td>Mercury &amp; mercury compounds</td>
<td>✓</td>
</tr>
<tr>
<td>7456-02-0</td>
<td>Nickel &amp; nickel compounds</td>
<td>✓</td>
</tr>
<tr>
<td>7440-58-2</td>
<td>Arsenic &amp; Arsenic compounds</td>
<td>✓</td>
</tr>
<tr>
<td>7440-41-7</td>
<td>Beryllium &amp; Beryllium compounds</td>
<td>✓</td>
</tr>
<tr>
<td>7440-45-5</td>
<td>Cadmium</td>
<td>✓</td>
</tr>
<tr>
<td>1444-79-7</td>
<td>Cadmium</td>
<td>✓</td>
</tr>
<tr>
<td>29513-16-6</td>
<td>Butylated hydroxyanisole</td>
<td>✓</td>
</tr>
</tbody>
</table>

## Priority Chemicals

- Benzene, pentachloro-
- 2,3,5,6,7,8-Hexachlorobiphenyl, 2,3,5,6,7,8-Hexachlorobiphenyl
- Methyl tert-butyl ether, MTBE
- phenol
- Nickel & nickel compounds
- Arsenic & Arsenic compounds
- Beryllium & Beryllium compounds
- Cadmium
- Butylated hydroxyanisole

## Chemicals of Concern

- Toluene
- Tri(2-chloroethyl) phosphate
- DI-(2-ethylhexyl) phthalate, DEHP
- Hexachlorobenzene
- Ethyl paraaben
- 2,3,4-trihydroxybenzophenone, BP-2
- 2,4-Dihydroxybenzophenone
- Methyl isobutylcarbinol
- 1,1,2,3-Tetrahydro-2H-cyclopenta[d][1,3]oxazine
- Octamethylene tetramine
- Benzene, pentachloro-
- 2,3,5,6,7,8-Hexachlorobiphenyl, 2,3,5,6,7,8-Hexachlorobiphenyl
- Methyl tert-butyl ether, MTBE
- phenol
- Nickel & nickel compounds
- Arsenic & Arsenic compounds
- Beryllium & Beryllium compounds
- Cadmium
- Butylated hydroxyanisole
### IRISTrack Detailed Report

#### Nickel, soluble salts Assessment Milestones and Dates

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Projected Start Date</th>
<th>Projected End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft Development (hazard identification)</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Release lit search and evidence tables</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Draft Development (dose-response analysis)</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Agency Review</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Interagency Science Consultation</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Public Comment Period</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>External Peer Review</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Final Agency Review/Interagency Science</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
<tr>
<td>Discussion and Posting Final Assessment</td>
<td>TBD **</td>
<td>TBD **</td>
</tr>
</tbody>
</table>
TSCA Work Plan for Chemical Assessments: 2014 Update
Coatings under Review

EPA reviewing discharge limits
Report & Proposal in 2017

Areas of Focus

Existing and new processes
Tighter requirements possible
Ongoing technical dialogue
Perspective from other sectors: U.S. Department of Defense on coatings development

https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms

SERDP and ESTCP’s Weapons Systems and Platforms program area supports the development and demonstration of innovative technologies that enable the Department of Defense to:

- reduce or eliminate the use of hazardous materials in its production and maintenance processes
- reduce hazardous waste streams
- better understand and mitigate emissions and other environmental impacts that result from its operations
- ensure that alternative technologies, materials, and processes are adequately vetted from an environmental perspective
WELCOME TO THE SURFACE TECHNOLOGY ENVIRONMENTAL RESOURCE CENTER

The STERC provides the metal finishing industry with environmental compliance information. The site includes overviews of the regulations, tips on how to comply, best practice solutions that can help the environment while saving you money, and links to other resources that can help this sector. The STERC also highlights new rules and compliance deadlines.

To supplement these compliance assistance resources, we have developed educational courses, including online and hard copy books, covering a range of production and environmental topics. These are on sale through the STERC bookstore.

This website was developed and is maintained by the National Center for Manufacturing Sciences. Funding for this project has been provided by EPA under the National Compliance Assistance Centers program. For more information, or to pass along suggestions, please contact Bill Cheesewright, Administrative Director, wcheesewright@mcsa.org.

URGENT REGULATORY INFORMATION

Presented by the National Association for Surface Finishing

Federal Initiative to Increase Criminal Enforcement of OSHA Activities
The U.S. Department of Justice (DOJ) recently joined with the Department of Labor to announce a new initiative to increase the number of criminal prosecutions for worker endangerment and worker safety cases. The Occupational Safety and Health Act of 1970 (OSHA Act) provides for criminal sanctions for three types of conduct impacting worker safety...

California Congressman Adam Schiff to Speak at NASF Washington Forum Reception
Join industry leaders and your peers at the Washington Forum on April 19-21. For briefings on what policies will be impacting the industry this year and take the opportunity meet with lawmakers and federal agency officials...

EPA Proposed Regulatory Clarifications for Hazardous Waste Generators

EVENTS & LIVE TRAINING

NASF Airline and Aerospace Finishing April 4-7, 2016

INDIANAPOLIS, INDIANA

NASF Washington Forum April 19-21, 2016

WASHINGTON, D.C.

NASF SUR/FIN® June 6-8, 2016
Advanced Surface Technology

A holistic view on the extensive and intertwined world of applied surface engineering

by Per Møller & Lars Pleth Nielsen
National Association for Surface Finishing
Programs & Activities in 2016-17

ADVOCACY
• U.S. and Global Reach
• Federal and State Issues
• Regulatory Alerts

OUTREACH
• Alliances and Partnerships
• Supply Chain
• Scholarships
• Bright Design Challenge

EDUCATION
• On-Site Training
• Custom Courses
• Web-Based Education
• Certifications

COMMUNICATIONS
• E-News
• Alert Bulletins
• Trade Journal Partnerships

EVENTS
• Bright Design Challenge
• Leadership Conference
• Washington Forum
• SUR/FIN® Conference
• Chapter Events

Emerging Initiatives
• Web-Based Resource Center
• Sustainability “Benchmarking” with USEPA
• Automotive Coatings Technology Roadmap
• Global Surface Technology Roundtable
THANK YOU
Christian Richter
crichter@thepolicygroup.com