Université Libre de Bruxelles
Institut de Gestion de l’Environnement et de l’Aménagement du Territoire
(IGEAT)

Management of Chemical Risks in the Supply Chain

The Case of Hexavalent Chromium in the Implementation of the RoHS Directive on Electrical and Electronic Equipment

Gestion du risque chimique dans la chaîne d’approvisionnement.
Le cas du chrome hexavalent dans la mise en œuvre de la Directive RoHS relative aux appareils électriques et électroniques.

Nathalie CLIQUOT

Session de septembre

20 August 2007

Table of content

Table of Figures

Acknowledgments

I would like to thank Aaron McLoughlin and Professor Jacques Kummer for having guided my reflections.

I am also particularly grateful to Claire for her help with the interviews, and to Justin for his kind support.

Introduction

Directive 2003/95/EC on the restrictions of some hazardous substances in electrical and electronic equipment (the RoHS Directive) was adopted on the 27th of January 2003 by the European Parliament and the Council after years of elaboration and negotiations. It provides for a ban of six families of hazardous substances including lead, mercury, cadmium and hexavalent chromium in electrical and electronic equipment starting on the 1st of July 2006, leaving a bit more than three years to the Member States, the European Commission and the industry to carry out what turned out to be a titanic effort for the electronic sector.

The present master's thesis intends to focus on those three years of implementation process highlighting the difficulties of implementing a substance ban for one of the RoHS substance, hexavalent chromium, in the complex global supply chain of the electronic sector.

In their 1973 book pioneering the study of the implementation of public policies, *Implementation: How Great Expectations in Washington are Dashed in Oakland; Or Why it's Amazing that Federal Programs Work At All, This Being the Saga of the Economic Development Administration as Told by Two Sympathetic Observers Who Seek to build Morals on a Foundation of Ruined Hopes*[1], Pressman and Wildavsky analyse the struggle of the Economic Development Administration to implement public policy for unemployed minorities. The book demonstrates the importance of the implementation phase for public policy. It also points out all the obstacles that are still to be resolved at a stage that policy-makers consider sometimes as the "easy bit".

In view of the current evaluation and review of the RoHS Directive, this research aims to examine if the objectives and expectations of EU policy makers in Brussels have been "dashed" by a "made in Monde"[2] production process or if, on the contrary, European product standards are strengthened by global supply chains networks.

[1] Jeffrey L. Pressman and Aaron Wildavsky, *Implementation: How Great Expectations in Washington are Dashed in Oakland; Or Why it's Amazing that Federal Programs Work At All, This Being the Saga of the Economic Development Administration as Told by Two Sympathetic Observers Who Seek to build Morals on a Foundation of Ruined Hopes,* (University of California Press, Berkeley, 1973)

[2] Suzanne Berger, *Made in Monde, les nouvelles frontières de l'économie mondiale*, (Editions du Seuil, Paris, 2006)

At a time when the electronic industry is facing the new challenge of implementing the REACH Regulation[3], with potentially the need to restrict the use of thousands of chemicals in their products, the study of the RoHS Directive can already provide a good idea of the potential impact of the changes yet to come.

Methodology

On 14 June 2006, I had the opportunity to participate in a conference organized by the Center for Sustainable Design in Brussels on 14 June 2006 on "Product-related Envrionmental and Social aspects in Supply Chain Managements: Lessons for the Electronic sector".

In particular, Kris Pollet, Director for EU Law and Policy at Pollet Environmental Consulting, gave a presentation on "Managing RoHS in the supply chain: lessons from Taiwan". He presented the results of a survey of interviews carried out in Taiwanese companies in the electronic sector. The outcome was outstanding, if most companies had heard about RoHS, more than half of the companies had misconceived the extent of the effort required to reach RoHS compliance.

After this conference, I decided to refine this preliminary analysis of communication issues in the supply chain and conduct a series of interviews in the electronic sector. In April and May 2007, I carried out a series of semi-directive interviews with representatives of the electronic sector including Sony, Hewlett Packard, Cisco, Epson, Dell, Ericsson in April and May 2007. Interviewees were selected on the basis of their participation in the discussions of the European Information & Communications Technology Industry Association (EICTA) on chemicals. It is interesting to point out that the same persons are usually also in charge of RoHS and REACH.

In addition to the interviews, I had informal contacts with environment NGOs in charge of the RoHS directive suchs as representatives from the Health and Environment Alliance (HEAL), Greenpeace, and the European Environment Bureau (EEB).

I complemented the interview process with a selected bibliography on hexavalent chromium, the RoHS Directive, supply chain management and Corporate Social Responsibility (CSR). With a view to better grasp the issues the industry was faced with, I reviewed the specialized press in the electronic sector (Electronics weekly, Electronic

[3] Regulation (EC) No 1907/2006 of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

news on Purchasing), as well as specialized blogs and web-sites on the implementation of the RoHS Directive.

Approach

Adopting the multidisciplinary approach of the Institut de Gestion de l'Environnement et de l'Amménagement du Territoire (IGEAT), this thesis will first focus on highlighting the objectives of the RoHS Directive and the rationale for the ban of hexavalent chromium.

To this end, the first chapter will examine the risk arising from the use of hexavalent chromium in electrical and electronic equipment. The second chapter will provide a historical overview of measures taken by European policy-makers prior to the RoHS Directive to address the risk caused by hexavalent chromium. This will facilitate the understanding of the singularity of the RoHS Directive. The third chapter will provide a detailed analysis of the objectives and legal requirements under RoHS.

The second part of this thesis will be dedicated to the implementation of the ban of hexavalent chromium, focusing on global supply chain networks in the electronic sector.
The fourth chapter will review concrete implementation issues of the RoHS directive in the supply chain of the electronic sector. It will start by providing an overview of global supply chains in the electronic sector and assessing the vulnerability of major brand firms when it comes to implementing a substance ban. Then, it will examine in more details the many issues that remained to be solved to implement the RoHS ban including interpreting the legal provisions of RoHS, finding suitable alternatives to RoHS substances and communicating through the supply chain.

1 The chemical risk associated with the use of hexavalent chromium in electrical and electronic equipments (EEE)

Hexavalent chromium or Cr (VI) is famous for being at the centre of Erin Brockovich's investigations in the United States. Erin Brockovich campaigned against the release of Cr (VI) in drinking waters and the potential threat to the health of hundreds of inhabitants of the Southern California town of Hinkley forms the plot of the eponymous Hollywood film[4].

The film pictures hexavalent chromium as a toxic substance causing cancer to humans. Indeed, hexavalent chromium compounds are classified as known human carcinogens by the International Agency for Research on Cancer (IARC).

Despite this toxicity, hexavalent chromium is used in a wide range of applications for instance in dies, paints, bricks or for metal plating. It is also used in electrical and electronic equipments mainly as an anti-corrosive agent. This use of hexavalent chromium in electrical and electronic equipment is now restricted on the European market by the RoHS Directive.

This chapter will aim to provide some background information on hexavalent chromium. It will introduce key chemistry concepts such as the oxidation state of an atom to illustrate the difference between hexavalent chromium and other form of chromium, which is relevant for risk assessment. It will include an overview of the chemical properties of hexavalent chromium as well its production and uses.

The second objective of this chapter will be to facilitate the understanding of the risk associated with the use of hexavalent chromium in electrical and electronic equipment. This will require a brief review of the definition and methodology for the risk assessment of chemicals.

1.1 What is hexavalent chromium?

1.1.1 The oxidation states of chromium

[4] Steven Soderbergh, *Erin Brockovich*, Universal Picture, 2000.

This section is particularly intended for non-chemists as it introduces key chemistry concepts with a view to facilitate the understanding of the risk assessment of hexavalent chromium.

Hexavalent chromium or Cr (VI) is the name given to chemicals compounds which contain an atom of chromium (Cr) in its +6 oxidation state.[5] For non-chemists, two useful conclusions for the management of risk arising from hexavalent chromium can already be drawn from this definition.

First, hexavalent chromium is not a single "substance". A variety of compounds can contain an atom of chromium with a specific electronic configuration and thus be labelled as "hexavalent chromium".

The second conclusion is that chromium is a chemical element that exists in several "states" and hexavalent chromium is one of this "state". It is therefore key to understand which "state" of chromium needs to be regulated.

Let's start by examining the concept of oxidation state, which is linked to the structure of atoms and their electronic configuration.

An atom can be defined as the smallest particle conserving the characteristics of a given chemical element. It comprises a nucleus with protons (particles charged positively) and neutrons (neutral particles) and a "cloud" of electrons (particles charged negatively) revolving around the nucleus.

According to the principle of quantum mechanics, the electrons follow a certain configuration when they revolve around the nucleus. They are gathered into several layers around the nucleus and each layer or "shell" corresponds to a level of energy necessary. The "distribution" of electrons in each layer follows a rule[6] given by the charge of the nucleus.

---

[5] Wikipedia "Hexavalent chromium" available from http://en.wikipedia.org/wiki/Hexavalent_chromium

[6] I found the illustration by Pablo Jensen very useful to better understand some of the basic principles of quantum mechanics like the equation of Schrödinger and the Pauli principle. To explain the electronic configuration and the various levels of energy, Jensen uses the image of a building with several floors corresponding to different energy levels.

Pablo Jensen, *Des atomes dans mon café crème, la physique peut-elle tout expliquer?* (Paris : Editions du Seuil, 2001) 82-94

For instance, in the figure below, the atom of sodium has an electronic configuration with three levels of energy. There are two electrons in the first level, eight electrons in the second level and one electron in the outermost level, a layer also called the "valence shell".

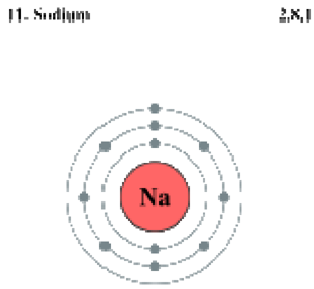


Figure 1 The electronic configuration of a sodium atom

Source: Wikipedia[7]

Chromium is a chemical element that has an atomic number of 24. The atomic number (Z) represents the number of protons found in the nucleus of an atom. In an atom of neutral charge, the number of protons would also equal the number of electrons. In a chromium atom of neutral charge, the number of electrons would therefore be 24.

As indicated by the table below, the electronic configuration for an atom of chromium indicates that there are five electrons in the outermost shell, and one electron in the previous level of energy.

Element	Z	Electron configuration	Short electron conf.
Chromium	24	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$	[Ar] $4s^1\ 3d^5$

Figure 2 The electronic configuration of chromium

Source: Wikipedia[8]

However, the number of electrons of an atom can vary as atoms can gain or loose electrons. The electrons of an atom located in the outermost levels of energy can be attracted by other atoms' nucleus. These transfers of electrons from one atom to another

[7] Wikipedia, "electron shell" available from http://en.wikipedia.org/wiki/Electron_shell

[8] Wikipedia, "electron configuration" available from http://en.wikipedia.org/wiki/Electron_configuration

are called oxidation in the case of a net loss in electron or reduction in case of a net gain in electron.

In this context, the oxidation state indicates the degree of oxidation of an atom in a chemical compound[9]. It reflects the hypothetical charge of that an atom would have if all bonds to atoms of different elements around it were 100% ionic that is, if all atoms around a given atom were capturing its electrons. In the case of hexavalent chromium, an oxidation state of +6 means an atom will potentially loose six electrons. To simplify, hexavalent chromium can be seen as an atom of chromium that has lost 6 electrons to other atoms when associated in a chemical compound.

Examples of hexavalent chromium compounds

- ammonium dichromate ((NH4)2Cr2O7);
- calcium chromate (CaCrO4);
- chromium trioxide or chromic acid (CrO3);
- lead chromate (PbCrO4);
- potassium chromate (K2CrO4);
- potassium dichromate (K2Cr2O7);
- sodium chromate (Na2CrO4);
- strontium chromate (SrCrO4); and
- zinc chromate (ZnCrO4).
- lithium chromate (LiCrO4)

Figure 3 Examples of hexavalent chromium compounds

The oxidation state is in fact theoretically calculated for a given compound ("formal oxidation states") according to a given set of rules. Oxidation states can also be benchmarked on the basis of spectroscopic and crystallographic data. This is called spectroscopic oxidation state.

Hexavalent chromium is not the only "oxidation state" for chromium. According to a recent risk assessment on hexavalent chromium commissioned by the Department of Environment, Food and Rural Affairs (DEFRA) in the UK, "chromium can be found in three oxidation states:

- metallic (Cr (O)) is found mainly in alloys such as stainless steel but also in chrome plated objects;

[9] Wikipedia, "oxidation state" available from http://en.wikipedia.org/wiki/Oxidation_state

- trivalent (Cr(III)) occurs naturally in the environment and is the most stable in nature and biological systems. It is an essential micro-nutrient in the body and combines with various enzymes transforming sugar, protein and fat. Cr(III) is also used in a number of commercial products including dyes, pigments and salts for leather tanning; and
- hexavalent (Cr(VI)) occurs in a range of compounds that are used in industrial process such as chrome plating."[10]

It is particularly important to point out that, depending on the physico-chemical properties of the surroundings of a chromium atom (acidity and pH for instance, presence of certain chemicals elements such as chlorine or sulfates), as well as biological elements (some bacteria are said to transform hexavalent chromium into trivalent chromium), it can pass from one oxidation state to another (for instance from trivalent chromium to hexavalent chromium and vice and versa).

1.1.2 The cycle of chromium

Chromium occurs everywhere in nature. "There is an environmental cycle for chromium, from rocks and soils to water, biota, air, and back to the soil. However, a substantial amount (estimated at 6.7 x 106 kg per year) is diverted from this cycle by discharge into streams, and by runoff and dumping into the sea. The ultimate repository is ocean sediment." [11]

This cycle is illustrated in the table below. It is particularly interesting to point out that naturally occurring chromium is almost always present in its trivalent state while hexavalent chromium in the environment is considered to be "almost totally derived from human activities".[12]

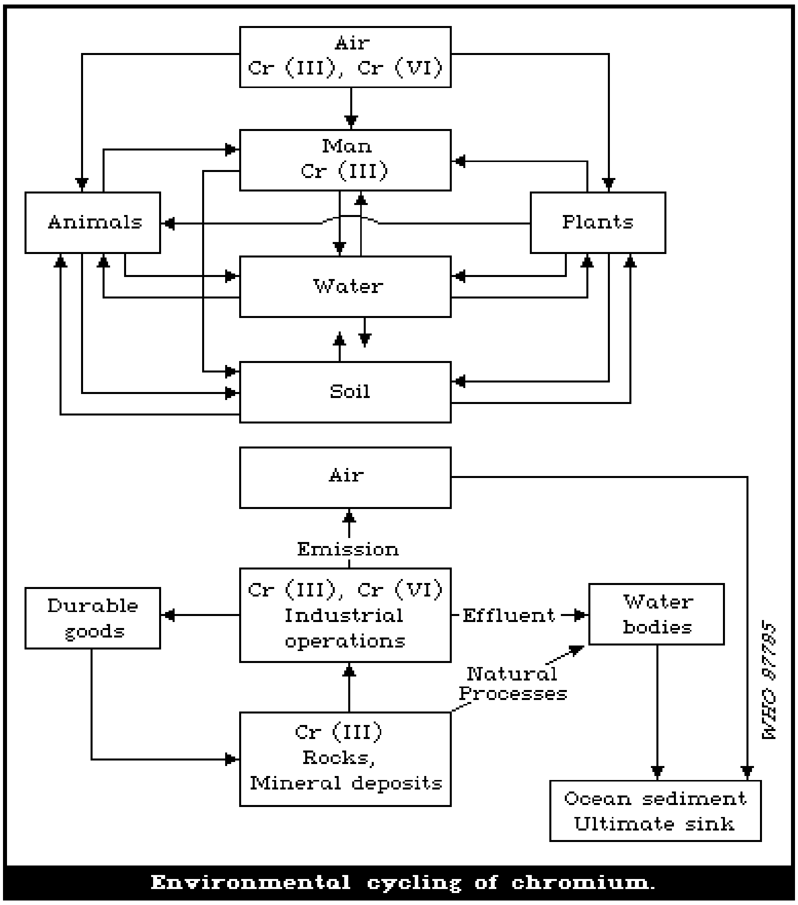
The table illustrates the fact that hexavalent chromium "settling in the soil or water is expected to be eventually reduced to trivalent chromium by organic matter"[13]. The

[10] Panos Zarogiannis, Risk & Policy analysts, *Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium, Final report prepared for Department for Environment, Food and Rural Affairs*, (2005) available from www.defra.gov.uk/environment/chemicals/pdf/hexavalent060203.pdf

[11] Extract from, International Programme on Chemical Safety, INCHEM, World Health Organisation, *Environmental Health Criteria 61, chromium*, 1988. available from http://www.inchem.org/documents/ehc/ehc/ehc61.htm

[12] Ibid.
[13] International Chromium Development Association, "Chromium and health a summary", available from: http://www.icdachromium.com/chromium-introduction.php

chromium industry association, the International Chromium Development Association, ICDA also indicates on its website that hexavalent chromium may persist in water as watersoluble complex anions (groups of bonded atoms negatively charged because they gained one or several electrons).



Source: International Programme on Chemical Safety, INCHEM

Figure 4 The environment cycle of chromium

To conclude, chromium is a chemical element with various oxidation states. Hexavalent chromium is not a single chemical substance but is the name given to chemicals compounds which contain an atom of chromium in one of its oxidation state.

In this context, the oxidation state is highly important as it determines the characteristics of an atom in a chemical compound. Whereas trivalent chromium is considered an essential micro-nutrient for the human body, hexavalent chromium compounds are known as chemicals causing cancer. Depending on its “surroundings”, a chromium atom can pass from one oxidation to another.

All these considerations are key to understand the risk assessment of hexavalent chromium and the difficulties that can arise when it comes to regulating the risks posed by hexavalent chromium.

1.2 Chemical risk and hexavalent chromium

Today, chromium is used in a wide range of applications for instance as pigments in photography and paints or as wood preservatives. What is the risk arising from the use of chromium and in particular hexavalent chromium? What is the risk associated with the use of hexavalent chromium in electrical and electronic equipments?

This section will address these two questions by providing some background information on the definition of the risk associated with chemicals.

1.2.1 Risk assessment methodologies[14]

Risk is a complex concept that is used in many sectors of society. In everyday language risk usually refers to "a situation involving exposure to danger"[15].

When it comes to risk emerging from chemicals substances, there are two main factors to consider. Risk is a combination of the hazard linked to the chemical substances and the exposure to such a substance.

In 1983, the National Research Council in the US defined a new approach for the assessment of risk to human health (HRA) in a report entitled "*Risk Assessment in the Federal Government: Managing the Process*".

The NRC aimed to propose a list of procedures to qualify and quantify chemical risks. The approach includes 4 main steps as follows:

- Hazard identification;
- Dose-response evaluation;
- Exposure assessment; and
- Risk characterisation

A similar approach has gradually been developed for the evaluation of ecological risks emerging from the use of chemicals.

---

[14] See Prof. Steenhout, *ENVI 042 Ecotoxicologie, DES Gestion de l'environnement*, (2005-2006) p10-11

[15] Compact Oxford English dictionary, « risk », available from http://www.askoxford.com/concise_oed/risk?view=uk

In 1992, the US Environmental Protection Agency proposed a 3-step process to assess chemical risk as follows:

- Problem formulation
- Analysis (characterization of exposure and ecological impact); and
- Risk characterisation

These frameworks for risk assessment and risk management are now widely used. The 1983 NRC definition has been broadened to include the characterization of hazardous ecological impacts emerging from environmental exposure to hazards caused by human activities.

The following table aims to illustrate a "risk assessment framework intended to facilitate integration of human health and ecological risks of toxic chemicals and other environmental stresses (from NRC, 1983 and USEPA, 1992).

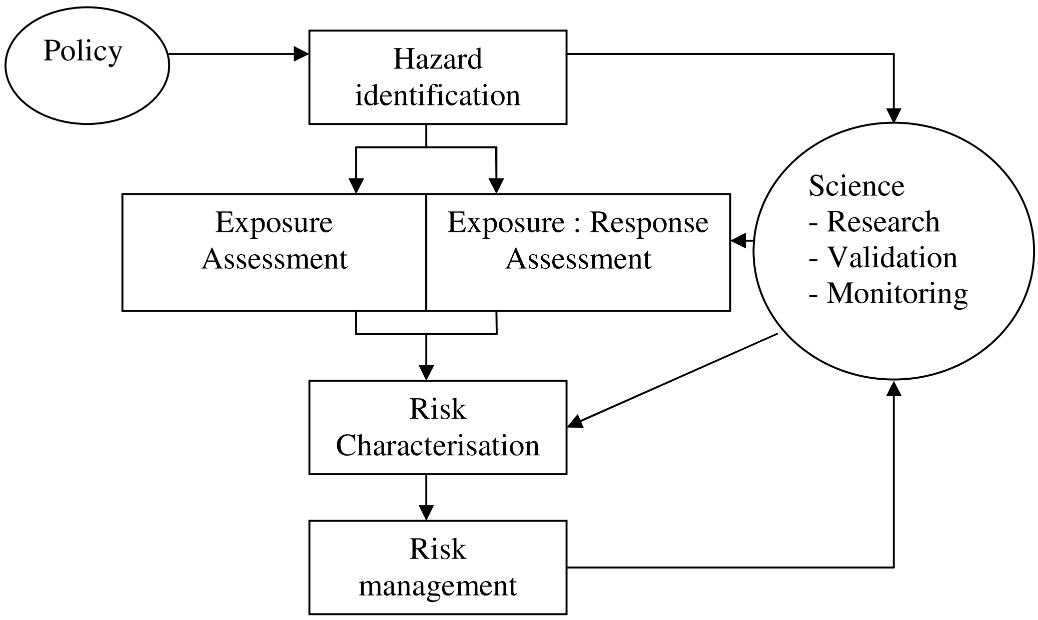


Figure 5 Risk assessment of chemicals

The framework designed in the U.S aimed mainly at separating the risk characterization from the risk management phase, in other words separating the so-called "scientific" assessment of risk from the policy process of risk management. "This issue is less relevant for Europe where there has always been a recognition of the blurred dividing line between assessment and policy"[16].

[16] Robyn Fairman et alii, *Environmental Risk Assessment, Approaches, Experiences and Information Sources,* European Environment Agency, Environmental Issue Report N°4, October

Risk assessment methodologies differ in the U.S and in Europe. In Europe, emphasis is put on the precautionary principle. As the European Environmental Agency describes it, “when faced with using data fraught with scientific uncertainty, two approaches are possible. Some people would choose to assume that substances or agents are harmless until proved (by science) to have harmful effects. Other would assume that agents are harmful until proved to be safe”[17].

The definition of risk assessment provided by the European Environment Agency in 1999 includes an additional element: the necessity to consider the whole lifecycle of a chemical[18]. “Risk assessment is the procedure in which the risks posed by inherent hazards are estimated either quantitatively or qualitatively. In the lifecycle of a chemical for instance, risk can arise during manufacture, distribution, in use or the disposal phase. Risk assessment of the chemical involves the identification of the inherent hazards at every stage and an estimation of the risks posed by these hazards. Risk is estimated by incorporating a measure of the likelihood of the hazard actually causing harm and a measure of the severity of harms in terms of consequences to people or the environment”.

The following sections will use the concepts of risk assessment to provide an overview of the risk associated with hexavalent chromium.

1.2.2 Physico-chemical properties of hexavalent chromium

As explained in section 1.1, hexavalent chromium is not a single “chemical substance” and many chemical compounds can contain an atom of chromium in its +6 oxidation state. This means that physico-chemical properties of hexavalent chromium compounds (such as weight, pressure, density, solubility) can differ.

However, some parameters such as chemical behaviour in the environment can be similar. For instance, in water, the solubility of hexavalent chromium compounds is important while trivalent chromium is less soluble. In soils and sediments, hexavalent chromium tends to be rapidly transformed into trivalent chromium. This process is

---

1999, p20 available from http://reports.eea.europa.eu/GH-07-97-595-EN-C2/en/part1-section1.pdf

[17] Robyn Fairman, op.cit., p19

[18] Robyn Fairman, op.cit., p18

favoured by anaerobic conditions and weak pH. Hexavalent chromium does not bioaccumulate in fish and its bio-availability to plants is limited.[19]

1.2.3 Hazard related to hexavalent chromium

To provide an overview of the toxicity of hexavalent chromium compounds, several aspects need to be considered including the routes of exposure including inhalation, ingestion, skin contact, as well as the time of exposure (acute/chronic toxicity).

It is important to bear in mind that similarly to physico-chemicals properties, the hazards related to specific hexavalent chromium compounds can differ both in terms of hazards caused to humans or to the environment

With regard to ingestion, the lethal dose of chromium trioxide for instance, has been estimated between 1 and 3 grammes per kilogramme for body weight. Chromates are far more toxic given that the lethal dose for human by ingestion has been estimated between 50 and 70 mg. For doses usually encountered in food, the stomach can reduce hexavalent chromium in trivalent chromium. In this context, only very high doses of chromium can saturate the reduction capacity of the stomach.

With regard to inhalation, hexavalent chromium can cause irritation of the respiratory tract and lead to ulceration and perforation of the nose mucus membrane. The No Observed Adverse Effect Level for occupational exposure has been estimated to 0, 001mg of hexavalent chromium per cubic meter.

According to the International Agency for Research on Cancer (IARC)[20] , there is sufficient evidence to demonstrate the carcinogenicity of hexavalent chromium for humans.

Epidemiological studies showed excess risks of lung cancer in case of chronic exposure. These studies also demonstrated that hexavalent chromium cause adverse effects to the skin, the respiratory tract and, to a lesser degree, the kidneys. Studies on stem cells provide evidence of the carcinogenicity of hexavalent chromium. Hexavalent chromium induced a variety of effects (including DNA damage, gene mutation, sister chromatid

---

[19] INERIS, *Fiche de données toxicologiques et environnementales des substances chimiques, chrome et ses dérivés,* Version N°2-4 février 2005, pp1-80 available from www.ineris.fr/index.php?module=doc&action=getFile&id=143

[20] International Agency for Research on Cancer, World Health Organisation, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Chromium, Nickel and Welding*, Volume 49, Last Updated 5 November 1997 available from http://monographs.iarc.fr/ENG/Monographs/vol49/volume49.pdf

exchange, chromosomal aberrations, cell transformation and dominant lethal mutation) in a number of targets, including animal cells in vivo and animal and human cells in vitro. These demonstrate that hexavalent chromium compounds are genotoxic.

In addition to its carcinogenic properties, hexavalent chromium is also a respiratory and a skin irritant. IARC reports that hexavalent chromium compounds may cause adverse effects to the skin, the respiratory tract and, to a lesser degree, the kidneys in human. "Once developed, chrome sensitivity becomes fairly persistent; in such cases, even contact with chromate-dyed textiles or wearing of chromate-tanned leather shoes can cause or exacerbate contact dermatitis."[21]

Hexavalent chromium can therefore be particularly toxic to humans if orally ingested, inhaled or in case of dermal contact. Since 1990, IARC considers hexavalent chromium compounds as carcinogens of group 1, for which there is sufficient evidence to demonstrate their carcinogenicity to humans. In the European classification, most chromium VI compounds were classified as Carcinogenic Mutagenic and Reprotoxic (CMR) category 1 and CMR category 2 in 1996 and 2004. The US EPA classified chromium VI compounds as group A, carcinogenic for humans by inhalation and group D non classifiable with regard to carcinogenicity for humans by ingestion[22].

In the environment, the Predicted No Effect Concentration (PNEC) reflects the quantitative link between dose (intensity of exposure to a substance) and the effect. The PNEC or Predicted No Effect Concentration takes into account the degree of uncertainty or extrapolation (between 10 and 10.000).

The table below provides the PNEC for hexavalent chromium in different compartments of the environment (water and soil). It also provides a comparison with lead and inorganic mercury. A comparison highlights that in water, the PNEC for hexavalent chromium is lower than lead but significantly higher than mercury. In soil, the PNEC for hexavalent chromium is closer to that or mercury than significantly higher to that of lead.

	Lead	Inorganic mercury	Hexavalent chromium
PNEC eau douce	5µg/L	0.24µg/L	4.1µg/L
PNEC eau salée	5.4µg/L		3.4 µg/L
PNEC sol	12mg/kg dry weight	27µg/kg dry weight	0.035mg/kg

Figure 6 Predicted No Effect Concentration of lead, inorganic mercury and hexavalent chromium in the environment

Source: INERIS

[21] Wikipedia, " hexavalent chromium"

[22] INERIS, *Fiche de données toxicologiques et environnementales des substances chimiques, chrome et ses dérivés*, Version N°2-4 février 2005, pp1-80.

1.2.4 Exposure to hexavalent chromium compounds

Chromium is produced through the mining of chromite ore (FeCr2O4). This mining takes place mainly in South Africa (half of the production) Kazakhstan, India and Turkey. Chromium is obtained by heating the ore in the presence of aluminium or silicon. According to the International Chromium Development Association, "there was an estimated 19 million tonnes of marketable chromite ore produced in 2005"[23].

Hexavalent chromium is present in many different compounds that have a variety of industrial applications. Major industrial uses of hexavalent chromium compounds include: chromate pigments in dyes, paints, inks, and ceramics; chromates added as anticorrosive agents to paints and other surface coatings; and chromic acid for metal plating to provide a decorative or protective coating. The below table provides an overview of chromium applications. [24]

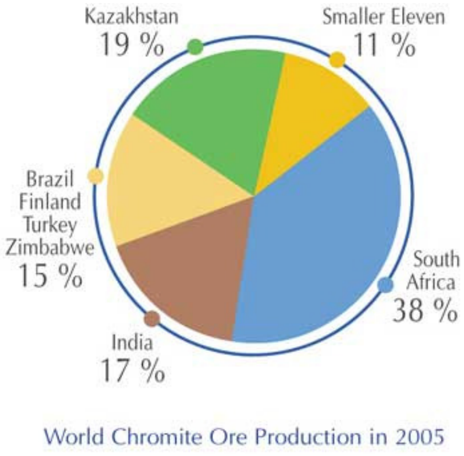
The various applications of hexavalent chromium are particularly interesting to bear in mind when it comes to understanding the justification for the ban of hexavalent chromium under the RoHS Directive. The International Chromium Development Association, ICDA mentions that "nearly 90% of chromium usage today goes into stainless steel and other speciality steels." Indeed, electrical and electronic products may not be the most prominent end uses of hexavalent chromium.

Another interesting point from the overview in the figure 8 below is the change of oxidation state during the processing of chromite from mining to the downstream uses

---

[23] International Chromium Development Association, "Chromium and health a summary" available from http://www.icdachromium.com/chromium-introduction.php

[24] Reproduced from Panos Zarogiannis, Risk & Policy analysts, *Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium, Final report prepared for Department for Environment, Food and Rural Affairs*, (2005)



Source: International Chromium Development Association ICDA
http://www.icdachromium.com/chromium-introduction.php
Figure 7 World production of chromium

Cr(VI) can also be formed when performing "hot work" such as welding on stainless steel, melting chromium metal, or heating refractory bricks in kilns. In these situations the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that converts the chromium to a hexavalent state.[25]

The principal sources of chromium emissions in the atmosphere are the chemical industry, the combustion of natural gaz, oil and coal. Wind transport of road dusts, cement kilns and downstream user of chromium are other sources of atmospheric emissions[26].

Exposure to hexavalent chromium components is often in the form aerosols or particulate matter. Environment exposures would most likely occur through exposure to hexavalent chromium dusts according to a report by the U.S. Environmental Protection Agency in 1998.

[25] Occupational Safety and Health Administration, U.S. department of Labor, " Small entity compliance guide for the Hexavalent chromium standards", 2006 available from www.osha.gov/Publications/OSHA_small_entity_comp.pdf

[26] INERIS, op.cit, p.6

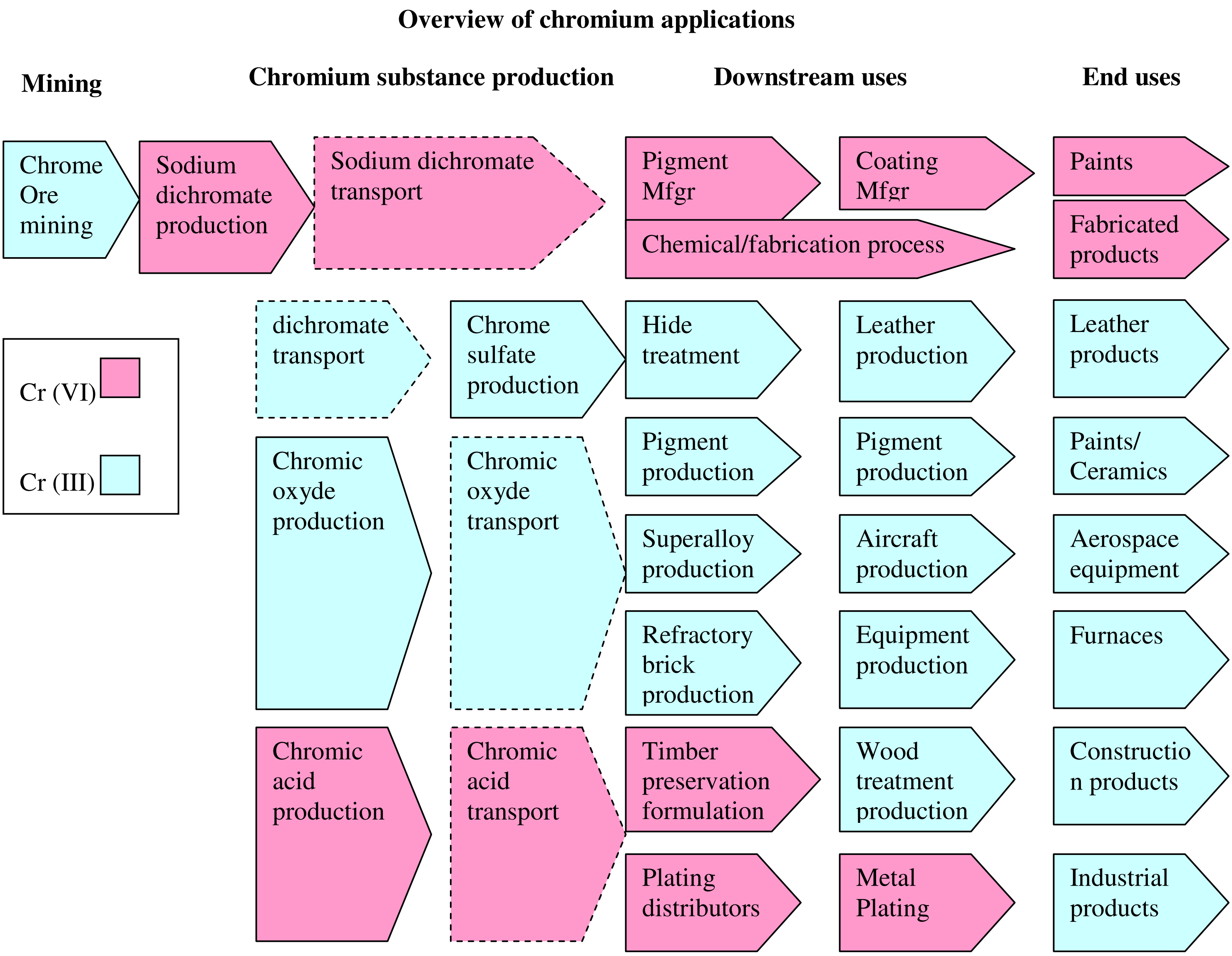


Figure 8 Overview of chromium applications

1.3 Risk emerging from EEE and WEEE

Hexavalent chromium is used very often in electrical and electronic equipment. As Ray Flankin from ROHSwell, an organisation aiming at helping business comply with WEEE and

ROHS, puts it " at first glance, most people can't think of any place it is used in electronics. In reality, it is as pervasive as lead (Pb)"[27].

As stated on ROHSwell , "the culprit is generally zinc chromate. This ubiquitous plating finish inhibits corrosion on many different parts commonly used in electronics products. It is readily identified by a yellowish color it imparts to plated metal parts. The plating process that applies the chromate produces Cr VI in sufficient quantity to greatly exceed the concentration limits set by all of the current green regulations." [28]

Given the main routes of exposure (emissions to the air and by inhalation), one can expect that the risk to humans emerging from the use by consumers of electrical and electronic equipment would be limited. Indeed, in electrical and electronic equipments, hexavalent chromium is mainly used as a surface treatment and anti-corrosive agent on metal used in electrical/electronic components and on screws. Therefore, during the phase of use by consumers, there would be limited if not non-existant emissions to the atmosphere limited risk of ingestion (perhaps apart from cases of accidental ingestion).

From the exposure data in the previous section, it seems that hexavalent chromium would pose a far greater risk in electronic and electrical equipment during the production phase. Occupational exposure would be largely at stake, especially in chemical processing, chrome plating and metal working industries

Another critical phase for the use of hexavalent chromium in electrical and electronic equipment is the end-of-life.

At the end of the product life-cycle, electrical and electronic equipment become waste that is mainly disposed of via landfill or incineration. It can also be recycled.

In landfills, hexavalent chromium seems to be converted to trivalent chromium. However, incineration can be particularly problematic since it could contribute to the release of hexavalent chromium emissions. Indeed, incineration of wastes containing chromium can result in releases to the atmosphere of hexavalent chromium, which can leach from the ash.

Studies on the topic[29] associate the possible release of hexavalent chromium from waste incinerator not only to the chromium content but also to the chlorine and the sulfur content.

---

[27] Ray Franklin, *Deleting Hexavalent Chromium from Electronics*, ROHSwell 18 February 2005, available from www.rohswell.com/News/Matl001.php

[28] Ibid.

[29] Kennedy Ian M. (Ed), *Formation and destruction of hexavalent chromium in a laboratory swirl flame incinerator, Combustion science and technology* , abstract available from http://cat.inist.fr/?aModele=afficheN&cpsidt=2500965

In addition, they suggest that hexavalent chromium can be formed in incinerators regardless of the valence of the chromium in the waste.

The European Environment Agency estimates that 840 tonnes of chromium is emitted to the atmosphere worldwide from incinerators[30]. However, this amount is still rather low campared to other sources of emissions. In 1990, emissions of hexavalent chromium resulting from incineration representated 4% of the total emissions of hexavalent chromium in EU 15[31].

Metal	Atmosphere emissions from waste incineration	
	1000 tonnes / year	As % of total emissions
Antimony	0.67	19.0
Arsenic	0.31	3.0
Cadmium	0.75	9.0
Chromium	0.84	2.0
Copper	1.58	4.0
Lead	2.37	20.7
Manganese	8.26	21.0
Mercury	1.16	32.0
Nickel	0.35	0.6
Selenium	0.11	11.0
Tin	0.81	15.0
Vanadium	1.15	1.0
Zinc	5.90	4.0

Figure 9 World-wide atmospheric emissions of trace metals from waste incineration
Source: European Environment Agency

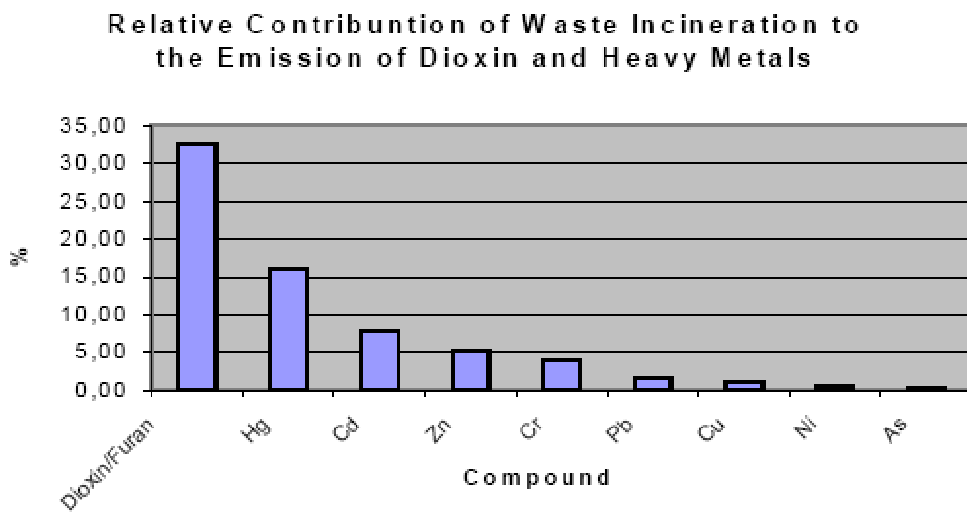


Figure 10 Relative contribution of waste incineration to total emissions in EU 15 in 1990
Source: European Environment Agency

---

[30] Jügen Schmid, at alii, Dangerous substances in waste, Technical Report n°38, European Environment Agency, February 2000, p 18 available from http://reports.eea.europa.eu/technical_report_no_38/en

[31] Ibid, p28

To conclude, it is important to highlight that the risk associated with the use of hexavalent chromium in electrical and electronic equipment comes mainly from the production phase and to a lesser extent to the end-of-life phase. Electrical and electronic equipment seems to represent only a minor aspect of the management of the chemical risk arising from hexavalent chromium.

1.4 Conclusion: very hazardous compounds

This first chapter provided some background information on hexavalent chromium.

Hexavalent chromium compounds are substances containing a chromium atom in its +6 oxidation state. Among the other oxidation state of chromium, the hexavalent state is the most hazardous one. Hexavalent chromium compounds are classified as know carcinogens to humans in most classification systems.

The main exposure route to hexavalent chromium is through emissions to the air. In soil and in water, hexavalent chromium tends to be reduced to trivalent chromium.

Hexavalent chromium is still widely used in industrial applications especially in the metal plating industry. According to the data from the chromium industry, electrical and electronic are not a major source of risk arising from hexavalent chromium.

In electronic and electrical equipments, hexavalent chromium is mainly used as an anti-corrosive agent on metallic components. The risk emerging from hexavalent chromium in relation to electrical and electronic equipment is not linked to the use of such equipments but arises from the processing and the end-of life stage.

These are key considerations to understand the starting point and the objectives of the RoHS Directive. These aspects will be examined in the next chapter.

2 Historical overview of EU risk management measures for hexavalent chromium

Chapter 1 provided information on hexavalent chromium. Hexavalent chromium compounds are hazardous chemicals that can cause serious threats to human health including cancer.

Given their hazardous properties recognized in the classification systems[32,] hexavalent chromium compounds were the object of regulatory requirements long before the RoHS directive was adopted in 2002. In the EU for instance, directive 76/769/EEC adopted in 1976 created a legal structure for the restrictions on the use of particularly hazardous substances (in particular, substances classified as Carcinogenic Mutagenic and Reprotoxic category 1 and 2).

Emissions of and exposure to hexavalent chromium are controlled by a wide range of EU-wide policy instruments. A report commissioned by the Department for Environment, Food and Rural Affairs (DEFRA) in the U.K., and finalised in October 2005, identifies no less than twelve pieces of EU legislation regulating directly or indirectly hexavalent chromium.

In addition, the report highlights that hexavalent chromium is also regulated at international level by the Baltic Environment Protection Commission (the Helsinki Commission) and the Oslo-Paris Convention (OSPAR).[33]

In this context, one may question the need for a new and specific EU regulatory instrument targeting electronic and electrical equipment. This question is all the more accurate given that, as illustrated in the first chapter, the main risk linked to hexavalent chromium in electrical and electronic equipment does not seem to arise from the use of such products by consumers.

This chapter provides an overview of the policy instruments addressing the risk from hexavalent chromium. It will particularly highlight those that could have been used by EU regulators for establishing restrictions for hexavalent chromium in EEE.

[32] See chapter 1.
[33] Panos Zarogiannis, Risk & Policy analysts, *Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium, Final report prepared for Department for Environment, Food and Rural Affairs*, (2005) pp 87-133 available from www.defra.gov.uk/environment/chemicals/pdf/hexavalent060203.pdf

This overview will provide useful preliminary information to understand the objectives and the specificity of RoHS.

The overview will cover the following field of regulation:

- Chemicals legislation;
- Soil protection;
- Water protection;
- Industrial emissions; and
- Waste.

2.1 Chemicals legislation and occupational safety

Prior to the adoption of the REACH regulation[34] in 2006, the corner stone of EU chemicals policy was Council Directive 67/548/EEC on the Classification, Packaging and Labelling of Dangerous substances. A similar directive was adopted in 1988 (Directive 88/379/EEC) to cover similar areas for 'preparations' described as a mixture of substances rather than substances. The existing system is going to be merged in the new REACH (Registration, evaluation and authorisation of chemicals) regulation that entered into force after the RoHS directive on the 1st of June 2007.

Directive 67/548/EEC created a system for standardizing classification, packaging and labelling of dangerous substances (both industrial chemicals and pesticides). Since its adoption, the directive has been amended nine times (9th Amendment: Directive 1999/33/EC) and adapted to technical progress twenty-eight times (28th ATP: Directive 2001/59/EC)[35]**.**

Hexavalent chromium compounds were included in the list of dangerous substances of Directive 67/548/EEC through adaptations to technical progress in 1996 and in 2004[36].

Directive 67/548/EEC included requirements for producers "to carry out an investigation to make themselves aware of the relevant and accessible data which exist concerning the

[34] Regulation (EC) No 1907/2006

[35] European Commission, *Consolidated Version of Directive 67/548/EEC*, available from http://ec.europa.eu/environment/dansub/main67_548/index_en.htm

[36] INERIS, *Fiche de données toxicologiques et environnementales des substances chimiques, chrome et ses dérivés*, Version N°2-4 février 2005, pp1-80.

properties of such substances. On the basis of this information, they shall package and provisionally label these substances"[37].

In addition to classification by producers, the Directive provided that Member State regulatory authorities would work together to produce harmonized classifications of substances of special concern. To date around 8000 substances have been classified in this way and added to Annex 1.

Another innovation of Directive 67/548/EEC was the introduction of the safety data sheets (SDS) system. Producers of substances and preparations that meet the criteria for classification as dangerous are also required to create a SDS containing information about the substance's properties. This SDS must be passed on to their customers. However, the directive did not include legal requirements for producers to perform any test. The SDS was based on available data.

The classification system introduced by Directive 64/548/EEC has been key to introducing further restrictions in consumer products.

Indeed, the 1967 Directive was soon complemented by Directive 76/769/EEC on the Restrictions on marketing and use of certain dangerous substances and preparations.

This directive adopted in 1976 created a reactive tool for Member States to impose restrictions when they had concerns about specific chemicals. Under this directive, chemicals with certain classifications, for example CMR category 1 and 2 are automatically restricted such that they cannot be sold to the public as substances or in preparations.

The restrictions are listed in Annex 1 of the Directive and this annex has been amended since a number of times.

Relevant amendments to Annex 1 of Directive 76/769/EEC for hexavalent chromium include:

- In 1997 chromium trioxide was included in annex 1 as a CMR 1.
- In 1999, chromium (VI) compounds were listed as CMR 2 with the exception of barium chromate and of compounds specified elsewhere in Annex I to Directive 67/548/EEC as category CMR 2.
- In 2003, the use of chromium was restricted in wood preservatives and in cement.[38]

[37] Lowell Center for Sustainable Production, "Chemicals Policy Initiative", available from http://www.chemicalspolicy.org/ExistingEUregulation.shtml

[38] European Commission, "consolidated text of Annex 1 of Directive 76/769/EEC" available from: http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/consolid_1976L0769_en.pdf

The Carcinogens Directive (Directive 90/394/EEC) is also relevant in the case of hexavalent chromium. This piece of legislation deals mainly with worker protection lays down an order of priority in obligations on employers to reduce the use of carcinogens at work.

The overriding obligation is to replace the carcinogen with a substance which is not dangerous or is less so. Where a safer alternative exists, the employer must substitute it, whatever the cost to the business. Where substitution proves "technically impossible", the employer must ensure that the carcinogen is manufactured or used in a closed system. If he cannot take this safety step, he must ensure that the workers' exposure is "reduced to as low a level as is technically possible". The Carcinogens Directive also provides for occupational exposure limit values to be established.[39]

To conclude, hexavalent chromium is covered by the EU policy framework on chemicals. This framework includes classification and labelling requirements as well as possible restrictions. It is therefore interesting to point out that EU regulators could have used Directive 76/769/EEC to impose restrictions on electrical and electronic equipment rather than a separate directive such as RoHS.

2.2 Water protection

Council Directive 76/464/EEC (Dangerous substance directive) on Pollution of the Aquatic Environment aimed at regulating the discharge of pollutants to inland surface waters, territorial waters, inland coastal waters and ground water.

The Directive introduces two lists of substances as follows:

- list I (the black list): the discharge of pollutants included on this list is to be eliminated; before a decision for their inclusion on the list is reached, substances are listed in a “candidate list I”.
- list II (the grey list): the discharge of pollutants included on this list is to be reduced; For these substances Member States are required to establish pollution reduction programmes including quality objectives for water (Water quality objectives WQO).

Chromium and its compounds are listed on the grey list, which means that the discharge of chromium in water is to be reduced by Member States.

Directive 76/464/EEC is currently being integrated in the new Water framework directive or Directive 2000/60/EC establishing a Framework for the Community Action in the field of Water Policy.

[39] European Trade Union Institute, ETUI-REHS, “Occupational cancers” available from http://hesa.etui-rehs.org/uk/dossiers/dossier.asp

The Annex X of the Water Framework Directive with the list of priority substances has replaced the "candidate list I". The pollution reduction programmes will still be in place until 2013.

On the 17th of July 2006, the Commission adopted a proposal for a new Directive to protect surface water from pollution (COM(2006)397 final). The Commission proposes to set limits on concentrations in surface waters of 41 dangerous chemical substances that pose a particular risk to animal and plant life in the aquatic environment and to human health. Chromium is not included in this proposal.[40] This proposal establishes environmental quality standards for the priority substances which Member States must achieve by 2015.

This proposal is still being considered by European legislators. The European Parliament has proposed to widen the scope of the priority substances without considering the inclusion of chromium during its first reading on 22 May 2007.

Chromium does presently not belong to the list of priority substances. As a result, there are no community-wide quality standards or emission limits. Member States are free to decide to set an EQS for chromium and its compounds.

However, it is not unlikely that chromium could be later considered for inclusion in the priority list of substances.

Another policy instrument in the field of water policy that contributes to the regulation of hexavalent chromium is Council Directive 91/271/EEC on Urban Waste Water Treatment . The Directive sets minimum treatment standards to be achieved according to a phased approach. The report on the implementation of the directive includes information on the chromium content of sludge. Therefore, this directive contributes to the monitoring of chromium including hexavalent chromium in the environment.

2.3 Soil protection

Council Directive 86/278/EEC on the Protection of the Environment and in particular of the Soil, when sewage sludge is used in agriculture regulates the use of sewage sludge in agriculture with a view to prevent their harmful impact on soil, vegetation, animals and human health. The directive lays down limit values for the concentration of heavy metals in soil (annex IA), in sludge (Annex IB) and for the maximum annual quantities of heavy metals that can be introduced in the soil (Annex IC).

[40] European Commission, "Priority substances under the Water Framework Directive", available from http://ec.europa.eu/environment/water/water-dangersub/pri_substances.htm

Chromium is included in annex IA and IB of the directive. However, no limitation is fixed at EU level. Concentration limits have been established at Member State level.

After several attempts to set EU-wide concentration limits for chromium in 1988 and 2000, the Commission has "decided to halt the work towards a possible revision of the Directive"[41].

2.4 Industrial emissions

Emissions of hexavalent chromium from industrial installations are regulated by Council Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC).

The objective of the IPPC Directive is to prevent or, when this is not possible, to reduce emissions to air, water and land from activities mentioned in Annex 1 of the Directive. All installations covered by the IPPC directive are required to obtain an authorization or permit from national authorities. They should apply the best available techniques (BAT) which are established by BAT Reference Documents (BREF). The deadline for existing installations to operate in accordance with the IPPC Directive is the 30th of October 2007.

The most relevant types of installations with regard to hexavalent chromium emissions include:

- Installations producing and processing metals
- Installations for surface treatment of metals and plastics materials
- Chemical installations producing basic inorganic chemicals
- Chemical installations producing plant health products and biocides
- Plants for the tanning of hides and skins above a certain capacity.
- Waste management installations.

Metals and their compounds, and therefore hexavalent chromium compounds, are included in Annex III of the Directive which comprises a list of the main pollutants to be taken into account for fixing emissions limit values. Total chromium is also included in the list of pollutants to be reported if a threshold value is exceeded.

To conclude, the IPPC Directive is an extremely useful instrument to address the risk arising from hexavalent chromium. It should contribute to reduce significantly the risk given that, as described in chapter 1, the main risk associated with hexavalent chromium originates from the processing and the end-of-life.

[41] Panos Zarogiannis, op.cit.,p 102.

2.5 Waste

Prior to the adoption of the RoHS Directive, Directive 2000/53/EC of the European Parliament and the Council on End-of-life vehicles include restricting provisions on hexavalent chromium (ELV directive).

The ELV Directive's approach is very similar to that of RoHS and its sister directive on Waste Eletrical and Electronic (WEEE)[42]. It lays down measures aiming at the prevention of waste from vehicles and at the reuse, recycling and other forms of recovery of ELVs and their components.

The use of hexavalent chromium is banned with only a limited number of exemptions. Article 4 (2) (a) requires Member States to ensure that material and components put on the market after 1 July 2003 do not contain hexavalent chromium other than in the cases contained in Annex II of the Directive.

Exemptions are of two types:

- Annex II included an exemption for the use of hexavalent chromium in corrosion preventing coatings. This exemption expired on the 1st of July 2007.
- A maximum concentration value up to 0.1% by weight and per homogenous material for hexavalent chromium is tolerated, provided that it is not intentionally introduced.

2.6 Conclusions: RoHS inspired by waste policy?

Before the adoption of the RoHS Directive, hexavalent chromium was already regulated by a wide-range of policy instruments at European level.

In particular, it is intriguing to observe that the EU already had a framework in place to establish restrictions on specific products with the Directive 76/769/EEC on the Restrictions on marketing and use of certain dangerous substances and preparations. This seems to question the need for a specific directive on electrical and electronic equipment.

In addition, the IPPC Directive seems to provide a solution for the main risk arising from the industrial use of hexavalent chromium.

How did the regulators come to consider a totally new instrument? The above overview of policy instruments already provides clues for answering this question, which will be the subject of the next chapter.

[42] Directive 2003/96/EC

Despite its title “restrictions on hazardous substances”, the approach of the RoHS Directive seems closer to the ELV Directive, a piece of EU legislation addressing the waste management of end-of-life vehicles than to chemicals legislations and restrictions. Indeed, similarly to the ELV directive, RoHS proposes a ban of hexavalent chromium for products put on the market after a chosen date. It also includes a list of temporary exemptions.

The next chapter will examine in more details the specificity of RoHS through a description of the elaboration process and of the concrete legal mechanisms at stake in the restrictions of hazardous substances in electrical and electronic equipment.

3 The Restriction on a Hazardous Substances (RoHS) Directive: the ban of hexavalent chromium in electronic and electrical appliances

Directive 2002/95/EC on the restriction of the use of certain hazardous substances (RoHS) published in the Official Journal of the European Community in February 2003 restricts the use of hexavalent chromium in electrical and electronic equipment starting on 1 July 2006. There is only one exemption, the cooling system of absorption refrigerators.

This chapter aims to underline the core objectives of the RoHS Directive and to provide a better understanding of the intentions of the regulators. A brief overview of the elaboration process of RoHS is particularly useful to understand the close link between RoHS and product and waste policy.

It will then provide a detailed analysis of the legal mechanisms of the directive covering the scope, the ban, the exemption and the adaptation to scientific progress.

3.1 The objectives of the RoHS directive

The RoHS Directive (2002/95/EC) was published in the Official Journal on the 13th of February 2003. However the elaboration of the directive is a process that took place over several years.

The purpose of this section is not to reflect on the European decision-making process but rather to present key milestones in the elaboration of the Directive that are useful to understand the intentions of the EU regulator.

The RoHS Directive was adopted according to the co-decision procedure. This procedure includes several steps as described by the following figure:

- the proposal by the European Commission, an Institution having the monopoly of initiative for community legislation
- the adoption by the Council of the European Union or Council of ministers representing the Member States and by the European Parliament.

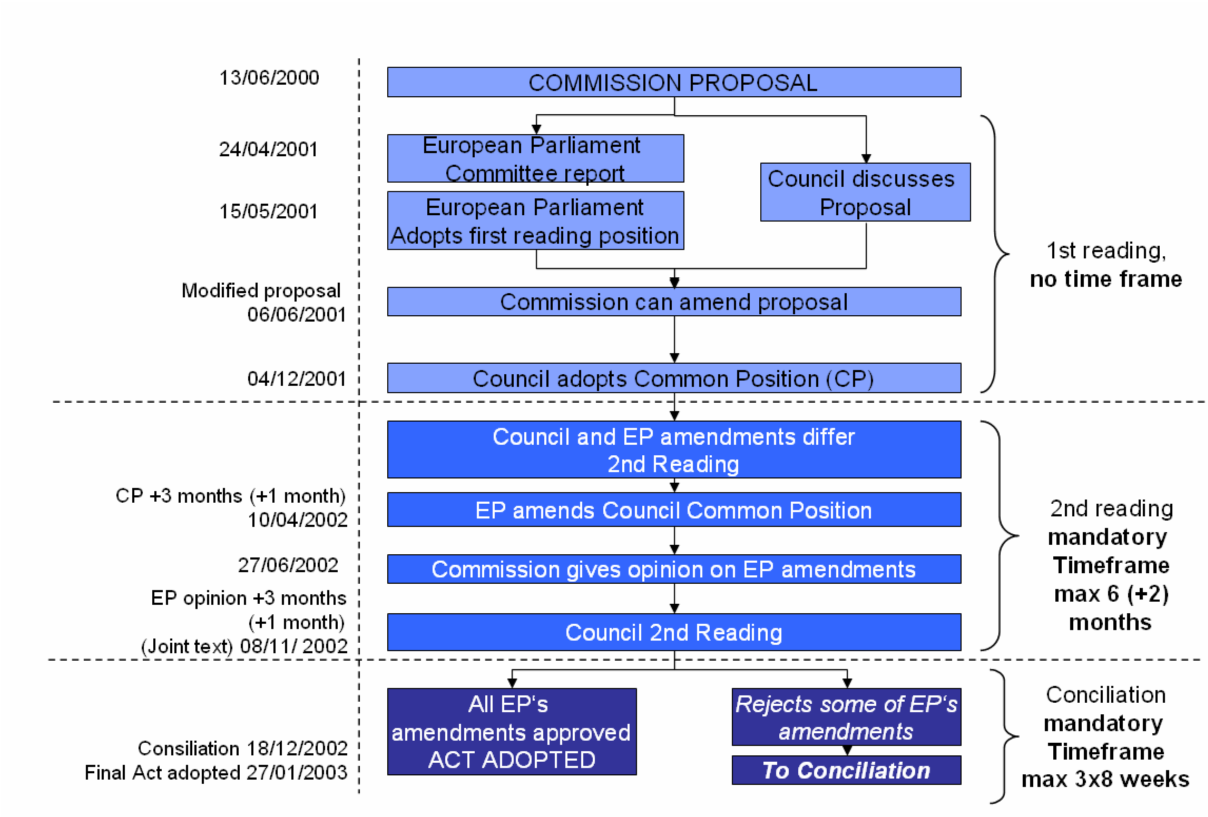


Figure 11 The codecision process and the RoHS Directive

The result of the adoption process is a complex multi-layered compromise. The text is first the outcome of a compromise between the European Parliament and the Council of European Union. In the European Parliament, the position reflects a compromise between the position of political groups and between diverging national interests. In the Council, it reflects the various positions of the Member States.

The following section will focus on the initial phases of the elaboration of the RoHS directive. This preliminary phase under the auspice of the European Commission is key to understanding the intention of the regulators.

3.1.1 A harmonizing directive

The Commission published its proposal on the 13th of June 2000. In its explanatory memorandum to the proposal, the European Commissions provides an overview of the history of the elaboration process including the consultation of the main stakeholders involved.

This already indicates that the rationale for the RoHS directive lay in waste legislation. The Directive on Waste Electrical and Electronic equipment (WEEE) and the RoHS directive are closely intertwined. This is illustrated by the fact that the European Commission presented the two proposals in a single document and that the explanatory memorandum is common to the two texts. The elaboration process of WEEE and RoHS is key to understanding this link between the two directives.

First discussions that led to the proposal for the RoHS Directive took place in the mid-1990s and originated from discussions on electronic waste. “In 1994 and 1995, representatives of Member States, all relevant economic operators and environmental NGOs participated in a Project Group which worked out an information and recommendation document on the management of WEEE”[43].

Further to this project group, all stakeholders were consulted on discussion papers published by the European Commission. In particular, in June 1999 a draft Proposal of the WEEE Directive was submitted to a business test panel as a pilot project. It concerned mainly Small and Medium Sized Enterprises (SMEs). The Draft proposal of the WEEE Directive included the restrictions of certain hazardous substances. WEEE and RoHS were originally conceived as parts of a unique directive and RoHS is therefore born from this initial scission of the WEEE Directive.

The reasons behind this initial split in two proposals can be found in the consultation process. One of the key requests of the industry was then that of a harmonized approach at European level to avoid the distortion of the Internal Market.

As a result, the Commission decided to use the internal market provisions of the Treaty (Article 95) establishing the European Community as a legal basis for the RoHS Directive. At the same time the legal basis for the WEEE directive is Article 175 on environment protection.

Article 95 differs from Article 175 in terms of the objectives and the policies. However, more importantly, Article 95 makes it more difficult for Member States to maintain or develop national legislation that includes stricter requirements than in the finalised directive. Conversely, under Article 175, Member States would have had greater scope to adopt stricter measures.

As such, the RoHS Directive can be interpreted as a harmonizing directive. This is partly what the European Commission touches upon when illustrating the need for the RoHS Directive with the fact that “the Netherlands, Denmark, Sweden, Austria, Belgium and Italy

---

[43] European Commision, *Proposal for a directive of the European Parliament and the Council on waste electrical and electronic equipment; Proposal for a directive of the European Parliament and the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment*, COM (2000) 347 final, Brussel, 13 June 2000, (Explanatory memorandum) p.26

have already presented legislation on this subject. Finland and Germany are expected to do so soon"[44].

The harmonization potential of RoHS is however not fully optimized given that RoHS has been proposed as a European Community directive rather than a regulation. While regulations apply directly to the whole internal market after their publication in the official journal, directives need to be transposed into national law by the Member States offering them flexibility as to the legal instruments to reach the objectives of the directive.

The necessity to transpose the RoHS Directive in national law entails additional delays for industry to obtain legal certainty. Even the clearly delimited scope of RoHS was subject to legal controversies (inclusion or exclusion of Deca-BDE for instance, or the interpretation of "put on the market"[45]), which led to additional difficulties as highlighted in chapter 4. Nevertheless, the clearly delimited timeline for implementation (1st of July 2006), can be considered as sufficiently precise for stakeholders, and industry in particular, to rely on it.

As such, the RoHS Directive clearly demonstrate the harmonizing objective of EU regulators even if Member States would entitled to enforce stricter restrictions in national law. "A state-level substance restriction on electronics would therefore most probably be acceptable in the European Communicy – unless the harmonizing RoHS Directive is viewed as preempting all state-level substance restrictions on electronics across the board, and this limiting the allowable substance restrictions to those set on the six harmonized ban"[46].

The European Commission wanted to combine two elements with its double proposal: a harmonized approach for the product aspect of the legislation and flexibility for the establishment of collection and treatment systems. This explains the use of two legal basis and ultimately why WEEE and RoHS remain two separate pieces of legislation despite a close link on matter and scope. RoHS's primary stated objective is "to harmonise national measures on the restriction of the use of certain hazardous substances in electrical and electronic equipement".[47]

A strong link between the two directives was maintained throughout the decision-making process starting from the publication of the Commission's proposal for WEEE and RoHS in a unique document.

---

[44] European Commission, RoHS Explanatory memorandum p.4
[45] See section 3.2
[46] Harri Kalimo, *E-cycling : linking trade and environmental law in the EC and the US* (Hotei Publishing, 2006) p237
[47] European Commission, RoHS Explanatory memorandum p.5.

3.1.2 Between waste and product policy

As the previous section highlighted, the origin of RoHS is to be found in waste legislation. This would explain why the directive addressed a substance such as hexavalent chromium without touching upon the issue of the risk arising from the use of this substance in consumer products.

In such a context, products requirements can be understood as the extension of the prevention of waste. Waste prevention can be understood in quantitative or qualitative terms. The explanatory memorandum of the European Commission clearly states that "because of their hazardous content, electrical and electronic equipment cause major environment problems during the waste management phase if not properly pre-treated"[48]. Figure 12 reflects the rationale for considering product restrictions and substitution of hazardous substances as means of waste prevention.

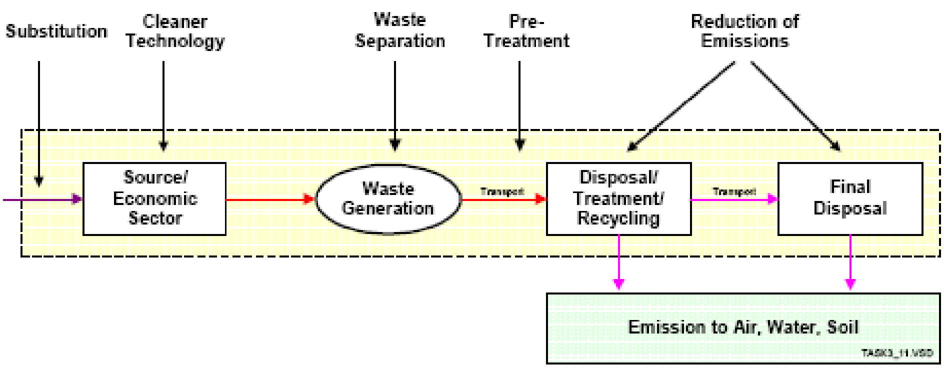


Figure 12 Life-cycle considerations on dangerous substances for waste prevention
Source: European Environment Agency[49]

In the waste hierarchy of management options, enshrined in the EU's Waste Framework Directive since 1991[50], waste prevention is considered the most preferable waste management option. Since 1989, the European Community's strategy on waste relies on the waste hierarchy which prioritises the prevention and reduction of waste, then its reuse and recycling and lastly the optimization of its final disposal. The explanatory memorandum of the RoHS directive clearly reflects the implementation of the hierarchy: "end-of-pipe technology could not be considered as the only method to avoid emissions from waste management operations"[51].

[48] European Commission, RoHS Explanatory memorandum p. 4
[49] Jügen Schmid at alii, Dangerous substances in waste, Technical Report n°38, European Environment Agency, February 2000, p 6 available from http://reports.eea.europa.eu/technical_report_no_38/en
[50] Directive 91/156/EEC
[51] European Commission, RoHS Explanatory memorandum p.8

As a result, it is not surprising that the type of restrictions imposed by RoHS can be compared to former waste directives. As explained by the European Commission, "the proposal follows the principles of existing Community waste legislation, which already included restrictions on the marketing of hazardous substances"[52]. Examples of similar approaches to the RoHS directive can be found in Directive 94/62/EC on packaging and packaging waste, Directive 91/157/EEC on batteries and accumulators or Directive 2000/53/EC on End-of-life vehicles. As demonstrated above[53], the ELV directive also includes restrictions on hexavalent chromium.

However, RoHS cannot be reduced to a piece of waste legislation. As many commentators suggested, the originality of RoHS lay on the extent of its impact on products. As Aaron McLoughlin points out, RoHS marks "a major step by the European Community in regulating the environmental impact of products."[54]

The WEEE already contains a "potentially far-reaching provision on product design"[55]. Article 4 of the directive invites Member State to encourage the design and production of electrical and electronic equipment which takes into account and facilitate dismantling and recovery, in particular the reuse and recycling of waste electrical and electronic equipment. However, the RoHS Directive goes a step further by imposing a ban on certain hazardous substances, thereby obliging the industry to substitute the hazardous substances.

This represents a clear rupture with the voluntary and "soft law" approach advocated by the European Commission on product related policies. According to Harri Kalimo, the RoHS directive is a good example of a legislator setting "purposefully future environmental standards at levels that are known to surpass the capabilities of today's technologies, relying on technological innovation during the regulated transition period"[56].

3.1.3 The justification for restricting the use of hexavalent chromium under RoHS

The justification of the European Commission for proposing to ban hexavalent chromium from electrical and electronic equipment results from a waste prevention approach that was extended to product requirements. However, it is interesting to understand the reasons behind the selection of the hazardous substances that would be banned. Why hexavalent chromium and not other substances?

---

[52] European Commission, RoHS Explanatory memorandum p.12
[53] See chapter 2, section 2.1.5
[54] Aaron McLoughlin, "What is in a Name? Regulation of Electrical and Electronic Products", European Environmental Law Review, October 2005, p252
[55] Aaron Mc Loughlin, op.cit, p257
[56] Harri Kalimo, op. cit., p204

The risk arising from the substances covered by RoHS are well documented in the proposal. However, this is less the case for hexavalent chromium especially when it comes to the potential exposure: “as regards possible exposure, chromium VI contained in waste can easily leach from landfills which are not appropriately sealed. During incineration of chromium VI contaminated wastes the metal evaporates through fly ash. Chromium VI in the fly ash is easily soluble. There is agreement among scientists that wastes containing chromium should not be incinerated”[57].

The Commission argues that the strategy of substituting substances is based on the most current scientific knowledge, taking into account the specific problems caused by these substances in the waste stream. However it admits that “less information is available from exposure from chromium (VI) compared to the targeted heavy metals (lead, cadmium, mercury).”[58]

It seems that scrutiny over hexavalent chromium primarily originates from the metallic condition of chromium. The 2000 report from the European Environment Agency[59] includes chromium in the list of highly toxic heavy metals causing problems at the stage of incineration.

With regard to hexavalent chromium, it can be argued that the decision to ban its use in electrical and electronic equipment results from a precautionary approach. “A precautionary approach would be to do as much as possible to reduce the emission of the agent potentially causing a serious environmental threat before science has proved or disproved causation”[60]. Indeed, the Commission admits that despite lack of data on chromium exposure “the hazard profile of chromium VI raises even more concerns than those related to lead, cadmium and mercury. It is, therefore suggested to adopt for chromium (VI) the same risk reduction approach as for the other targeted substances”[61].

According to the European Commission’s Communication on the precautionary principle, this principle covers “those specific circumstances where scientific evidence is insufficient, inconclusive or uncertain and there are indications through preliminary objective scientific evaluation that there are reasonable grounds for concern that the potentially dangerous

---

[57] European Commission, RoHS explanatory memorandum, p 14
[58] European Commission, RoHS explanatory memorandum, p 46
[59] Jügen Schmid at alii, op.cit., p.18
[60] Robyn Fairman, op.cit, p19
As opposed to the precautionary approach, “an approach based on risk would be to do as much as is necessary to achieve “acceptabl” risk based on the results of the risk assessment”

[61] European Commission, RoHS explanatory memorandum p 46.

effects on the environment, human, animal, or plant health may be inconsistent with the chosen level of protection"[62].

As presented in the first chapter, if the environmental and public health objective is to reduce the risk posed by hexavalent chromium in waste electronic equipment, a ban of that substance would be plausible.

Analysing the necessity of the RoHS ban on lead, Harri Kalimo highlights that "a counter-argument could downplay the relative risk that lead poses in waste electronics in comparison with other sources lead in the society. Furthermore the necessity review would also need to take into account the materials with which lead would be replaced. If the replacements of lead are equally hazardous, or create similar risk to the environment and human health, the necessity of a lead ban could be questioned"[63].

The same analysis transposed to hexavalent chromium could also be used to question the necessity of the ban of this substance. For instance, it is interesting to point out that the regulator did not choose to restrict the use of chromium trivalent as well. As explained in chapter 1, the oxidation state of chromium can be modified under certain conditions. In an incinerator, for instance, it is plausible that emissions of hexavalent chromium can originate from not only waste containing hexavalent chromium, but also waste containing chromium in another oxidation state (trivalent chromium for instance). In addition, trivalent chromium is often considered as a substitute for hexavalent chromium. As a result, the outcome of a restriction on hexavalent chromium alone could have limited effects in terms of managing the risk arising from hexavalent chromium in electrical and electronic equipment.

However, there are additional elements that can be used to justify the ban of hexavalent chromium. One of them is the requirement of recycling and re-use of electrical and electronic equipment in the WEEE Directive. The high toxicity of waste could hamper the reuse and recycling of WEEE. In the case of hexavalent chromium, this aspect is not well documented in the explanatory memorandum of the directive.

Another element would be the reduction of occupational exposure to toxic chemicals in the waste treatment sector. This issue takes all this importance when the recycling is carried out in third countries with lower occupational safety standards. For instance, recent studies in Guiyu[64], a major centre for WEEE recycling in China, have demonstrated a high level of pollution by toxic substances from the WEEE.

[62] European Commission, "Communication from the Commission on the precautionary principle" COM (2000) 1, Brussels, 2 February 2000, p10 available from http://ec.europa.eu/dgs/health_consumer/library/pub/pub07_en.pdf

[63] Harri Kalimo, op.cit, p234

[64] Agnès Ginestet, « Chine : le traitement des DEEE, source de pollution », in *Le Journal de L'Environnement*, 25 July 2007

3.2 Legal obligations: producer responsibility, substitution principle, ban and exemptions

As becomes evident in chapter 4, legal certainty is key to facilitate the seamless implementation of the RoHS Directive. Despite the clarity and conciseness of RoHS provisions, the interpretation of the Directive lead to several legal controversies. This section aims to provide a brief overview of the legal issues arising from RoHS' implementation.

3.2.1 The scope of RoHS

This section will address both the scope of the directive (categories of equipment covered by the Directive) and the scope of the ban (the substances covered by the RoHS restrictions).

With regard to the equipment covered, Article 2 (1) of the RoHS Directive refers to the scope of the WEEE directive and states that "the Directive shall apply to electrical and electronic equipment falling under the categories 1, 2, 3, 4, 5, 6, 7 and 10 set out in Annex IA to Directive n°2002/96/EC (WEEE) and to electric light bulbs and luminaries in households".

As a result, in addition to electric light bulbs and luminaries in households, the RoHS Directive applies to the following categories of electrical and electronic equipment quoted in Annex IA of the WEEE Directive:

- large and small household appliances;
- IT and telecommunications equipment;
- consumer equipment;
- lighting equipment;
- electrical and electronic tools (with the exception of large-scale stationary industrial tools);
- toys, leisure and sports equipment;
- automatic dispensers.
- light bulbs

As such, the RoHS Directive seems to cover the same scope as the WEEE Directive except for medical devices and monitoring and control instruments. It also applies to electric light bulbs and luminaires in households.

However, some specific exemptions provided by the WEEE directive are not necessarily replicated for the RoHS Directive. As highlighted by Aaron McLoughlin[65], the RoHS directive potentially cover some defense equipment are they are not explicitly exempted from the scope as it is the case in the WEEE Directive. This could create legal uncertainties for the industries providing equipment to the defense sector.

When it comes to the substances covered by the ban, the legal provisions are also far from straightforward. The directive clearly states “lead, mercury, cadmium, hexavalent chromium, PBB or PBDE” in Article 4.1.

However, legal controversies arose about the interpretation of the ban in the case of a specific substance, i.e. Deca-BDE. The Commission had to clarify its interpretation of the provisions in informal letters to the industry. According to Aaron McLoughlin, the controversy spread to the Commission’s own services. “It has been reported that the Commission Services were in two minds on whether Deca-BDE was banned, issuing contradictory interpretations. It was reported in the specialist environmental press that the Commission Services gave their opinion that Deca-BDE was not banned, to the surprise of Parliamentarians who worked on the RoHS Directive. Less than a month later the confusion was clarified as the Commission agreed that Deca-BDE is indeed banned.”

3.2.2 The ban and the exemption procedure

As for the scope of the RoHS Directive, the legal provisions imposing the restrictions of substances in EEE are not as straightforward as they may seem in the first place.

Admittedly, Article 4 (1) clearly states “that from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, PBB or PBDE”.

However, three issues arose from RoHS provisions on restrictions as follows:
- the term “put on the market”
- the methodology for tolerance levels in materials and components
- the deadline of the ban

“Put on the market”

One key element to understand the extent of the ROHS ban is the term “put on the market”.The interpretation of this mere expression led to a legal controversy.

[65] Aaron Mc Loughlin, op.cit, p 255

With a wide interpretation of "put on the market", the regulator could understand that no EEE containing the banned substances could be sold at all from 1 July 2006. According to Aaron McLoughlin, "this is a credible view because Member States with existing laws on restricted substances maintain the bans on sale of EEE containing restricted substances until 1 July 2006, and then adopt the Community standards."[66]

In fact, as Harri Kalimo explains "any sale or resale between any of the parties involved in the logistics of electrical and electronic equipment from the producer to the end-users could have been considered as an event of "putting EEE on the market".

However, this is not the interpretation that was retained by the Commission and the member States. They adopted an interpretation closer to that of the expression, "place on the market", that was suggested by the European Commission in the Guide to the implementation of directives based on the New approach.

In the guide, "placing on the market is defined as follows: "A product is placed on the Community market when it is made available for the first time. This is considered to take place when a product is transferred from the stage of manufacture with the intention of distribution or use on the Community market.' […]Thus, a transfer of a product is considered to have taken place, for instance, in the circumstances of sale, loan, hire, leasing and gift."[67]

The guide also defines a number of cases when a product is not considered "placed on the market for instance transfer for further measures such as assembling, or packaging or when a product is in transit, in a warehouse, or in manufacturer's stocks.

According to Harri Kalimo, the application of the new approach to the RoHS Directive seems mutually beneficial to the environment and the internal market. First, it is consistent with the waste hierarchy which gives priority to the prevention of waste. According to Kalimo, a far-reaching interpretation of "put on the market" would risk creating a mountain of waste consisting of unused products. In addition, the application of the new approach facilitates the compliance of the producers and manufacturers of EEE, who are not in a position to control the whole distribution channels.[68]

Methodology for tolerance levels in materials and components

The ban of the RoHS directive is not as stringent as it may seem. In addition to an annex to the Directive listing a limited number of applications that were exempted from the ban, EU regulators introduced tolerance levels. As it was argued that it is not always possible to completely abandon the banned substances, a tolerance level was established at 0.1% for

[66] A. Mc Loughlin, op. cit., p261
[67]Ibid
[68] Harri Kalimo, op. cit., p281-282

lead, mercury, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), and a tolerance level of 0.01% for cadmium.

In addition, Article 5 (1) (b) of the Directive provides that "materials and components can be exempted from the ban if their elimination or substitution via design changes or materials and components which do not require any of the materials or substances referred to therein is technically or scientifically impracticable, or where the negative environmental, health and/or consumer safety impacts caused by substitution outweigh the environmental, health and/or consumer safety benefits".

Industry argued that these provisions were a major source of legal uncertainty. As Harri Kalimo highlights, "the way in which the directive determines the substance ban seems slightly imprecise, as it regulates just the presence of the substances in "specific materials and components" of EEE"[69]This could lead to inconsistencies in the interpretation of "materials and components" with considerable financial implications for the industry. "Because the determination of the concentration levels of substances is a task of great technical detail, it would appear advisable that the constitutional method of regulatory harmonization should be combined with the expertise of, e.g., the global standardization organizations as far as the precise limits are concerned"[70].

The RoHS deadline

Admittedly, the RoHS deadline was clear and concise enough not to be discussed on legal grounds. However, the electronic industry argued that the deadline established by RoHS, did not rely on any prior feasibility assessment. It was rather perceived as a political compromise between the two co-legislators (the Council and the Parliament) without necessarily bearing in mind the preparations needed for the implementation of the Directive. The Commission had initially proposed the 1st of July 2008.

3.2.3 Adaptation to Scientific and Technical progress, review process

The RoHS Directive has not been designed as a static regulation but rather as a continually evolving one. The idea is that RoHS would oblige manufacturers to substitute hazardous substances with less hazardous alternatives. However, flexibility is needed where safer alternatives do not exist. The EU regulators therefore introduced a process to adapt to the unknown and to the scientific and technical progress, mainly by way of providing for regular review of the annex of exemptions to the RoHS Directive.

[69] Harri Kalimo, op. cit., p245
[70] Ibid.

The review of RoHS exemptions: comitology process

"RoHS recognises that the regulators and co-legislators, Parliament and Council, did not, or could not, provide for a permanent list of banned or exempted uses of the hazardous substances and allows for additional items to be added or removed from the exemption list, or both."[71]

This is all the more important given that many producers did not have the necessary mechanisms in place to know which hazardous substances they used in their products (see chapter 4) before the legislation was agreed. As a result, only after RoHS implementation started could they be in a position to assess whether safer alternatives existed. As Aaron McLoughlin explains "only upon reflection did some producers realise, or at least claim to realise, that there was no substitute available for the use of the hazardous substance. In light of representations to Member States, Member States and some producers submitted requests for additional exemptions according to Art. 5(1)(b) RoHS."

It was foreseen in the Directive that the list of the 10 exemptions initially foreseen would be reviewed regularly via a so-called comitology procedure in the light of scientific and technical progress. This was both for the purpose of removing existing exemptions (Article 5 (1)c) or adding new ones (Article 5 (1) b).

Article 5 (1) c clearly indicates that exemptions are granted only on a temporary basis since it obliges regulators to carry out "a review of each exemption in the Annex at least every fours years or four years after an item is added to the list"[72]

The comitology procedure is a procedure by which Member States delegate some executive powers to the European Commission. At the time of the adoption of the RoHS procedure, Council Decision 1999/468 on procedures for the exercise of implementing powers conferred on the Commission provided a framework for the use of comitology. There are three types of committees working according to different procedures and having various levels of legislative control over the Commission: advisory committees, management committees and regulatory committees.

Article 7 of the RoHS Directive establishes a Committee for the Adaptation to Sciencititific and Technical Progress of EC-Legislation on Waste (TAC). Its members are the European Commission and Member States. Observers are made up of the EEA Member States, the European Environment Agency, and Accession States. The TAC is a so-called regulatory affairs Committee.

---

[71] Aaron Mc Loughlin, op.cit., p263
[72] *Directive 2002/95 of the European Parliament and the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment*, Official Journal of the European Union, 13 February 2003, L 37, pp19-23 (RoHS Directive)

With a regulatory committee, the Commission can adopt implementing measures only if it obtains the approval of the committee (voting by qualified majority). In the absence of this approval, the proposed measure is referred back to the Council which takes a decision by qualified majority. However, if the Council does not take a decision, the Commission can adopt the measure provided that the Council does not object by a qualified majority. This procedure is used for measures relating to protection of the health or safety of persons, animals and plants and measures amending non-essential provisions of the basic legislative instruments.[73]

RoHS also provides for a clear framework for the review and possible addition of new exemptions. Article 4(2) provides for number of applications that are exempted from the restrictions and are detailed in the Annex. The conditions under which new exemptions can be granted are described in Article 5 (1) b. Exemption can only be granted if substitution is:

- technically impracticable; or
- scientifically impracticable; or
- the negative environmental, health and/or consumer safety impacts caused by substitution are likely to outweigh the environmental, health and/ or consumer safety benefits outweigh the human and environmental benefits of the substitution."

In practice, the comitology process leaves it to the discretion of the European Commission "to initiate consideration of the issue as it has the sole right to make a Proposal for a Draft Decision."[74] For the review process, the Commission has usually started requesting the input from the industry by receiving exemption requests. Then the Commission usually commissioned the technical expertise of an external consultant to determine whether there are substitutes available to the hazardous substances. After this preliminary phase, the Commission launches a stakeholder consultation on the potential exemptions.

Since the adoption of the RoHS Directive, the European Commission organised seven of these stakeholder consultations with a view to adapt the annex of the RoHS Directive.

It is interesting to point out that the comitology framework has been later revised amid claims of the European Parliament that the Commission went beyond its mandate (including in the case of implementing the RoHS Directive[75]). The European Parliament even launched a legal complaint against the Commission before the Court of Justice (C-14/06).

[73] Euractiv, "Comitology", available from http://www.euractiv.com/en/opinion/comitology/article-117454

[74] Aaron Mc Loughlin, op.cit., p263

[75] See two European Parliament's resolution adopted in 2005 B6-0218/2005 and B6-0392/2005

In 2006, an amendment was made to the 1999 Decision to introduce a new regulatory procedure with scrutiny for acts adopted under the co-decision procedure. It aims to give to the European Parliament an opportunity to oppose and block proposals in three cases:

- if the proposal exceeds the implementing powers given by the primary legislation;
- if it is incompatible with the aim or the content of the primary instrument;
- if it is in conflict with the subsidiarity or proportionality principle.

In the case of RoHS, the European Parliament had claimed that the Commission had gone beyond its powers by exempting Deca-BDE from the RoHS substance ban.

The review of the scope (adding new substances or new range of products) through the review of the directive

Article 6 of the RoHS Directive also provides for a more thorough review of the RoHS directive which would provide for the possibility to adapt the list of substances of Article 4(1) "on the basis of scientific facts and taking the precautionary principle". In addition, the EU legislators insisted that "particular attention shall be paid during the review to the impact on the environment and on human health of other hazardous substances and materials used in electrical and electronic equipment."[76]

In the context, the EU legislators invite the Commission to examine the feasibility of replacing such substances and materials and to present proposals to the European Parliament and to the Council in order to extend the scope of Article 4".

In addition to the task of proposing new substances to be added to RoHS, the Commission is also supposed to consider extending the scope of RoHS to medical device and monitoring and control instruments, the so-called categories 8 and 9 covered by the WEEE Directive.

To this end, the Commission has recently launched an information gathering exercise that was closed on 22 May 2007. It intends to present proposal in the course of 2008. Before coming forward with proposals for revision of the Directive, the Commission will consult stakeholders on the options being considered. This public consultation is planned for 2008.

In the review process, the Commission highlights that no specific substances are presently under consideration. [77]

[76] RoHS Directive, article 6
[77] European Commission, " The review of Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment: invitation for comments on topics and for information supply", available from http://ec.europa.eu/environment/waste/weee/pdf/review_2002_95_ec_directive.pdf

3.3 Conclusions: between waste prevention and product policy, a precautionary approach

The RoHS directive clearly has its roots in waste legislation as it was initially conceived as part of the WEEE directive. However, the RoHS directive can also be considered as a major shift from waste to "product policy" concerns.

As such, RoHS was followed by a series of European measures in the field of product policy such as the Integrated Product Policy initiative or the European Directive on the eco-design of energy using products. However, RoHS's strong regulatory approach with the ban of hazardous substances seems at odds with the later soft law approach taken by the European Commission on product policy.

Perhaps, this singularity can be explained in the context of the growing scrutiny of national legislators over electrical and electronic equipment. RoHS was felt necessary as a means of harmonizing national measures that were already taken at national level and to avoid a disruption of the internal market. As a result, the legal basis for adopting the RoHS directive lies on internal market provisions of the Treaty establishing the European Community (Article 95).

In the context, the choice of a ban of hexavalent chromium compounds seems to relate more to the "proximity" with other heavy metals that were going to fall under the ban, i.e. its metallic characteristic. The analysis of the Commission's justification for including hexavalent chromium in the scope of the directive seemed to indicate that chromium was added to the list on the basis of a precautionary approach.

The RoHS Directive was conceived as an evolving piece of legislation with the possibility to adapt to the scientific progress. Several exemptions to the RoHS ban were granted in a so-called comitology process in addition to the initial list.

In addition, several informal clarifications on diverging legal interpretations were necessary after the adoption of the RoHS Directive. The next chapter will analyse how the legal obligations created by the RoHS Directive were concretely put into practice.

4 Management of the RoHS implementation in the supply chain of EEE

In its explanatory memorandum to the RoHS Directive proposal, the Commission seem to consider that the implementation of the RoHS directive would not cause significant problems to the industry given that "a number of manufacturers have already phased out lead, mercury, cadmium, hexavalent chromium and halogenated flame retardants in various applications. This suggests that the costs of doing so are quite limited"[78].

In practice, the impact of substance restrictions in the supply chain of electrical and electronic equipment can be far-reaching. As Harri Kalimo explains the substitution of the RoHS substances by less hazardous substances represents "a considerable effort, when one considers the wide-ranging occurrence of the material[s] in electronic devices."[79]

This chapter intends to highlight how the RoHS restrictions were implemented in the electronic sector as well as the problems encountered. In particular, it will focus on the issue of managing the supply chain.

The first section will provide background information on how the electronic sector is organised, and how supply chain management has become a key component of global companies' strategy.

Then, the chapter will examine the concrete issues posed by the RoHS Directive in a world of modular production, when every function of the supply chain is generally outsourced to different companies.

[78] Explanatory memorandum, p.23
[79] Harri Kalimo, op. cit., p230

4.1 Supply chain management in the electronic sector

4.1.1 Definition of supply chain and supply chain management

A supply chain can be defined as "a coordinated system of organisations, people, activities, information and resources involved in moving a product or service, physically or virtually from the producer to supplier to customer".[80]

Supply chains include a succession of activities ranging from the extraction of raw material, the production (which can be broke down into several links such as component construction, assembly), the storage and final delivery to the consumer.

The management of the supply chain is particularly important for a company to fulfil customer demands through the most efficient use of resources, including the management of distribution capacity and of inventories.

Such a type of management has become increasingly core to business capacities with changing business models. As Suzanne Berger[81] explains, over the past twenty years business models have evolved in the modularisation of productions that she compares to an alignment of legos.

The table below illustrates the succession of tasks or functions linked to the manufacturing of any products ranging from expensive designer clothes, cars or computers.

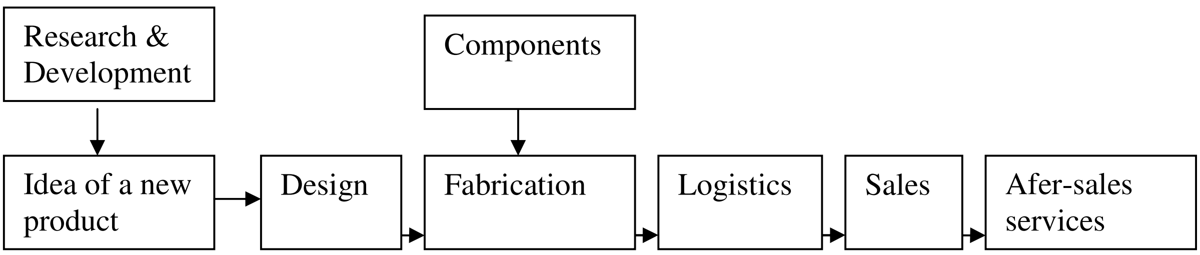


Figure 13 The production process as a lego game

When a company like IBM was producing a computer twenty years ago, nearly all the functions were taking place within the company. Most of the components (chips, keyboard,

---

[80] Wikipedia "supply chain" available from http://en.wikipedia.org/wiki/Supply_chain

[81] Suzanne Berger, *Made in Monde, Les nouvelles frontières de l'économie mondiale*, (Editions du Seuil : Paris 2006 pour la traduction française) p 85

mouse) were manufactured in IBM plants and a few others would come from American suppliers.

With what she calls the “rupture” of the 1980s and the mid-1990s, the production process has become increasingly fragmented. The big brands have outsourced the main production tasks step by step. Throughout the process, property links have been replaced by contractual bonds between independent companies.

The so-called rupture took place in the 1980s when many big American companies, with a strong tradition of vertical integration, looked into adopting the Japanese model of production “just in time” or “lean production”.

While American companies relied on a pyramidal managerial authority to coordinate activities, the Japanese had adopted a much “flatter” organisation, with less hierarchy degrees. This contributed to an enhanced communication between all employees in the workplace. The company relied on this network of informal communication, on dedicated employees and trust relationships with suppliers.

Japanese firms had developed the concept of lean production that allows them to produce a wide range of products quickly and at a reasonable price without cumbersome stocks or multiple suppliers to manage. Lessons from the Japanese success indicated that a strong integration of design, manufacturing and marketing was essential to improve results.

However, the main rupture really took off during the mid 1990s with the spread of new information and communication technologies. The digital revolution allowed for a simple and rapid coordination of the production process, even when different phases were taking place in independent companies around the world. In electronics, for instance, the modularisation of production really took off in the 1990s with new software allowing digital data and instructions to be passed on to suppliers.

Modularity also reduces the number of persons involved at the interface between different phases of the production process. This new model of production favours innovation allowing new combinations between the different functions of the production process.

For instance, it took less than a year for Apple’s successful iPod to move from a concept to a product. The main reason for this is that iPod relied on components already made by other manufacturers and outsourced most of the services. The elegant design of iPod was partially outsourced. iPod uses a Toshiba hard-drive, a Nidec disk reader, a ARM processor, a Texas Instruments card, a Cypress USB interface and a Sharp memory flash. The final assembly is made by Inventec, a Taiwanese contractual manufacturer. The costs of all components and services bought by Apple represents close to half of the sales price of an iPod.[82]

The shift to fragmented production process was fostered by the increase of the price of capital on the one hand and the will to move away from labour intensive activities. Outsourcing was seen as a way to relieve companies from the burden of investment and from overproduction risk.

Modular production and the fragmentation of the production process went hand in hand with the globalisation of production and the delocalisation of manufactures in developing countries especially Asia.

Nowadays, supply chains have become global "super-networks" (see Figure 14) and have contributed to the emergence of a new type of competition on the global market. Competition is no longer company versus company, but rather takes on a supply chain versus a supply chain form. Supply chain management becomes all the more strategic to a company's success.

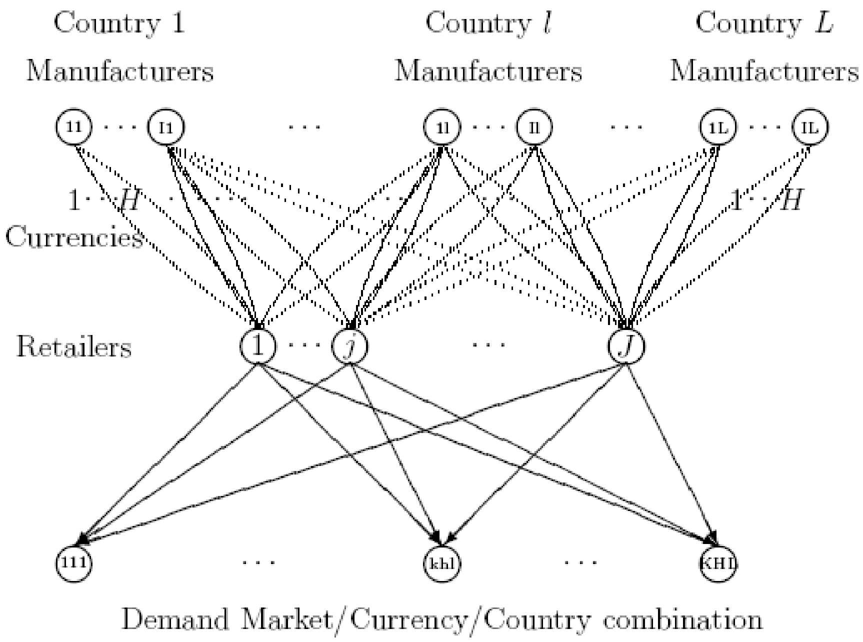


Figure 14 The Structure of the Global supply chain network
Source: Anna Nagurney, Jose Cruz, and Dmytro Matsypura
Dynamics of Global Supply Chain Supernetworks, November 2002

[82] Suzanne Berger, op. cit., p.100.

4.1.2 Organisation of the supply chain in the electronic sector

The electronic sector is highly fragmented. Besides major global brand firms, the sector comprises a wide range of companies carrying out outsourced functions of the production process. Different labels are given to these main contractors companies of the supply chain such as:

- Original Equipment Manufacturers (OEM)
- Original Design Manufacturers (ODM)
- Electronic Contract Manufacturers (ECM) or Contract Manufacturers (CM)
- Electronic Manufacturing Services (EMS)

The variety of labels reflects that of the functions that are now outsourced by brand firms. Useful definitions will be found in Figure 15.

The global trend is towards an increasing number of activities being outsourced to Taiwanese or Chinese ECM. These are usually SMEs that concentrate their production in Taïwan or China. Whereas they were mainly seen as component manufacturing plants a few years ago, ECM are increasingly developing to offer a wider range of services. This is especially the case of Taiwanese ECM facing the competition of Chinese companies. By gaining expertise as EMS offering to design, test, manufacture, distribute and provide return/repair services for electronic component, they wish to move a way for a competition with the Chinese merely based on price.[83]

Contractors are very unlikely to be able to build a brand's name in the electronic sector. Brand firms are fiercely preventing their manufacturers from becoming their competitors. For instance, when Acer, the biggest Taïwanese manufacturer of electronic products launched its own PC brand, it lost most of its OEM activity and in particular its contractual partnership with IBM.[84]

Actors in the electronic supply chain: useful definitions

"**Original equipment manufacturer, or OEM**, is a term that refers to a situation in which one company purchases a manufactured product from another company and resells the product as its own, usually as a part of a larger product it sells. OEM is the company that originally manufactured the product".[85] The term Value Added Reseller or VAR can be used to describe the reseller. It is important to point out that there is confusion in the use of the term OEM as it may also be used to refer to "VAR" or brand firms.

[83] Suzanne Berger, op. cit., p222
[84] Ibid p224
[85] Wikipedia, "original equipment manufacturer" available from http://en.wikipedia.org/wiki/Original_equipment_manufacturer

An **original design manufacturer (ODM)** is a company which manufactures a product which ultimately will be branded by another firm for sale. Such companies allow the brand firm to produce (either as a supplement or solely) without having to engage in the organization or running of a factory. ODMs have grown in size in recent years and many are now sufficient in size to handle production for multiple clients, often providing a large portion of overall production. A primary attribute of this business model is that the ODM owns and/or designs in-house the products that are branded by the buying firm. This is in contrast to a contract manufacturer (CM).

A **contract manufacturer ("CM")** is a firm that manufactures components or products for another "hiring" firm. Many industries utilize this process, especially the aerospace, defense, computer, semiconductor, energy, medical, personal care, and automotive fields. Some types of contract manufacturing include CNC machining, complex assembly, aluminium die casting, grinding, broaching, gears, and forging.
In a contract manufacturing business model, the hiring firm - typically an OEM - approaches the contract manufacturer with a design or formula. The contract manufacturer will quote the parts based on processes, labour, tooling, and material costs. Typically an OEM will request quotes from multiple CMs. After the bidding process is complete, the hiring firm will select a source, and then, for the agreed-upon price, the CM acts as the hiring firm's factory, producing and shipping units of the design on behalf of the hiring firm.

Electronic Contract Manufacturing (ECM) is a term used for companies that offer contracts for electronic assembly for another company. For instance, instead of attempting to manufacture complex circuit boards themselves OEM companies often outsource their manufacturing operations to ECM companies. In effect Contract manufacturing providers do not post their brand name on any product, and both design and the brand name belongs to the OEM.

As ECMs grew larger, many of them developed into EMS (Electronic Manufacturing Service) companies to offer a broader spectrum of services in addition to manufacturing. Today the trend continues even further, with many EMS becoming what is caller Original Design Manufacturers (ODM), offering complete electronic products for companies such as Wal-Mart, skipping the OEMs all-together.

Electronic manufacturing services (EMS) is term used for companies that design, test, manufacture, distribute and provide return/repair services for electronic component and assemblies for original equipment manufacturers (OEMs).
The business model for the EMS industry is to specialize in large economies of scale in manufacturing, raw materials procurement and pooling together resources, industrial design expertises as well as create added value services such as warranty and repairs. This frees up the customer who does not need to manufacture and keep huge inventories of products.

In recent years, EMS players have shifted production to low-cost geographies; embraced non-traditional industries including consumer electronics, industrial, medical and instrumentation; and added substantial vertical capabilities, stretching from design and ODM through system assembly, test, delivery and logistics, warranty and repair, network services, software and silicon design, and customer service.

Figure 15 Actors in the electronic supply chain: useful definitions

In such a fragmented supply chain, the strategy of major global firms and the choice of the supply chain functions are closely intertwined.

When Suzanne Berger and her team at the Massachussets Institute of Technology interviewed the CEOs, Supply Chain and R&D Directors in more than 500 companies in Asia, Europe and America, they discovered that the choice of production functions to be retained in a company was a highly strategic element. Their research highlighted that major brand firms such as IBM, Sony or Dell have adopted significantly different strategies.

On the 7^{th} of December 2004, IBM announced the sales of its PC division to the Chinese PC manufacturer Lenovo. At the time Samuel J. Palmisano, the CEO explained that companies in the IT sector had only two choices, investing massively in R&D and providing innovation to other companies, or differentiating themselves with low prices, high production volumes and enormous economies of scale. IBM had chosen the first solution and will concentrate on top range services and materials. This was also the choice made by Philips selling its flat screen division to TPV Vision, a Taiwanese OEM.

This does not mean that the PC market is no longer fructuous for big brands. Contrary to IBM, main direct IBM competitors in the field of PCs, Sony and Dell, are not considering leaving this market. Dell, for instance, specialised in distribution and logistics and focuses on its main strength, namely marketing and distribution. Dell allows its client to “conceptualise” its own computer, buy it on the internet and have it delivered in a few days. Dell invests less than 1% of its turnover in R&D.

Sony adopted a different strategy and maintained its tradition of pioneer by inventing “key products” in various sectors. Indeed, the company has an impressive record of building its success on key products that have revolutionised the daily life of consumers all over the world. In 1950, Sony invented VCRs, transistor radio in 1955, colour TV Trinitron in 1969, walkman in 1979, the CD player in 1982, the video recorder in 1983, the digital camera in 1988. Not surprisingly, Sony spends 6.4% of its turnover in R&D.

However, Sony does not wish to outsource as much as Dell. Sony’s directors explain that outsourcing can also slow down the flow of information in the supply chain and that contractual manufacturers are not able to evolve rapidly enough for Sony’s products with a life-cycle included between three and six months. Sony is currently using OEM and ODM to manufacture some PlayStations and low range Vaio computers. However, the firm is building its own factories in China to avoid using outsourcing. Another issue at stake is the necessity to avoid risks of leaking intellectual properties[86].

Sony like Toshiba argued that their firms were in a better position to benefit from competitive advantage of having access to new components designed by their own firms if they retained their own PC activities. This is also the reasoning of most Japanese firms such Matsushita (Panasonic), NEC, Sharp and Hitachi who have decided to keep producing finished products and some components.[87]

The South Korean firm Samsung who became the third computing company after IBM and HP has also chosen to retain the vertical integrated pattern.

Major computing companies	
Vertically integrated manufacturers	Apple · HP · IBM · NEC · Sun
Conglomerates	Hitachi · LG Electronics · Matsushita · NCR · Philips · Samsung Electronics · Siemens · Sony · Toshiba · Thomson
Software	Adobe · CA · Electronic Arts · Intuit · McAfee · Microsoft · Nintendo · Novell · Oracle · Red Hat · SAP · Symantec
Dot-com/web services	Amazon · AOL · eBay · Google · Microsoft · Yahoo!
Computer hardware	Acer · ASUS · Dell · Fujitsu Siemens · Gateway · Lenovo · Quanta
Computer Network/Telecommunications	Alcatel-Lucent · Avaya · Cisco · Ericsson · Huawei · Juniper · Nokia Siemens Networks · Nortel · ZTE
Computer Storage	EMC · Maxtor · NetApp · Seagate · Western Digital
Cellular Network	Motorola · Ericsson · Nokia · Palm · RIM · Qualcomm
Semiconductors	AMD · Broadcom · Elipda · Fairchild Semiconductor · Freescale · Hynix · Infineon · Intel · Micron · National · NVIDIA · NXP · Qimonda · Renesas · Rohm · STMicroelectronics · Sharp · TI · TSMC · VIA
Electronics Manufacturing Services	Celestica · Elcoteq · Flextronics · Foxconn · Jabil · Kimball Electronics · Plexus · Quanta Computers · Sanmina-SCI · SMTC Corporation · Solectron · Ultraflex International

Figure 16 Examples of major companies in the electronic sector

Source: Wikipedia, article on electronic component

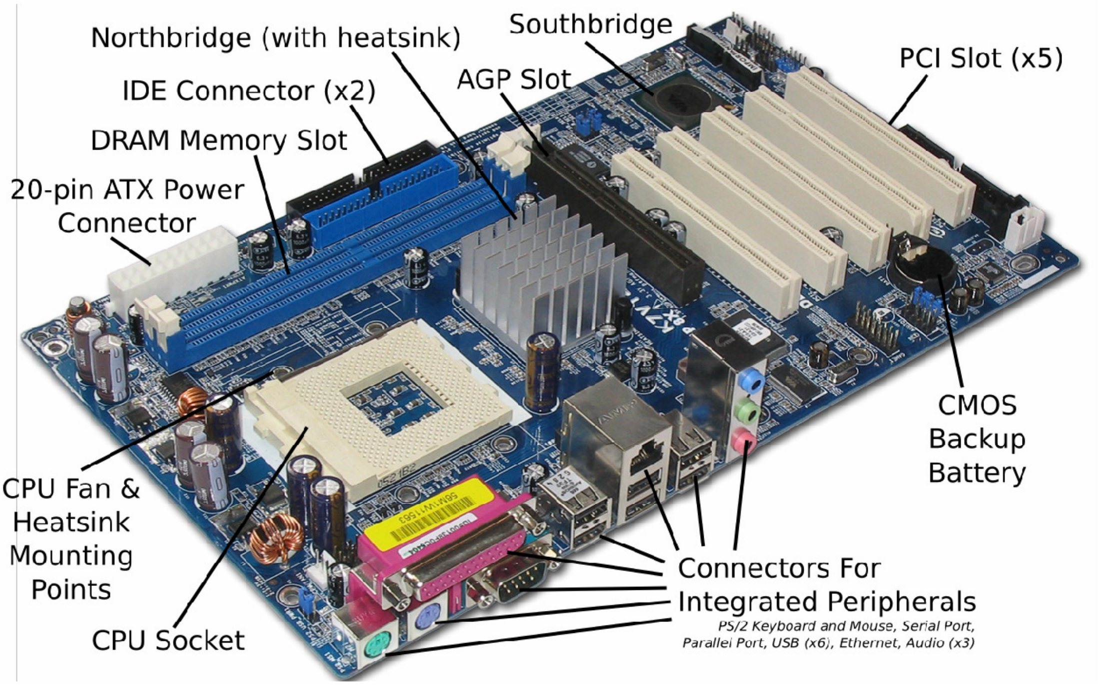
The organisation of the supply chain has become increasingly complex since the mid-1990s and the modularisation of the production process. In the electronic sectors, major brand firms have been adopting various strategies for the organisation of their supply chain. However, most of them are outsourcing a significant part of the production process.

Another element of the complexity of the electronic supply chain is the large number of components used in electronic equipment and the miniaturisation of equipment.

---

[86] Suzanne Berger, op.cit., p183- 197
[87] Suzanne Berger, op.cit, p207

The picture of a mere PC motherboard illustrates the high number of electronic components contained in a consumer product.



.

Figure 17 Example of the complexity of a computer's motherboard
Source: Wikipedia[88]

Each component is identified by a code with a view to facilitate the functioning of the component market.

With the complexity of both electronic products and their supply chain, one can already sense the magnitude of the impact of a substance ban in the electronic sector.

The following section will look in more details how the organisation of the supply chain becomes paramount to an industry's compliance with the RoHS Directive.

4.2 The RoHS substance ban: a challenge for the electronic sector

[88] Wikipedia "The 2004 K7VT4A Pro motherboard by ASRock. The chipset on this board consists of northbridge and southbridge chips" available from http://en.wikipedia.org/wiki/Image:Quick_overview_of_pc_hardware.jpg#file

As explained in chapter 3, RoHS introduces a ban on certain substances including hexavalent chromium for EEE "put on the market" after the 1st of July 2006. As such, the companies targeted by the RoHS ban are the major brand firms who commercialise electronic products under their brand name.

However, one perceives immediately the difficulties arising from the implementation of RoHS for the electronic sector with a fragmented supply chain. The purpose of this section is to examine what were the impacts of the RoHS directive on the supply chain and on the relationship between major brand firms and their suppliers.

If electronic components are now manufactured by various contracted manufacturers for an original equipment manufacturer (OEM) selling it to a brand firm, it is still the brand's reputation and liability that can be undermined in case of non compliance with the RoHS Directive.

4.2.1 The vulnerability of brand firms and their liability under RoHS

The RoHS directive has placed the electronic sector under the spotlight. The IT industry had remained largely unregulated prior to the adoption of the WEEE and RoHS directive, at least at EU level.

One of the main IT producers interviewed in April 2007 explained that this was precisely the novelty of the RoHS Directive. While in the past, substance restrictions were common to a wide range of sectors, the RoHS directive clearly targeted EEE. If IT companies had regarded rather lightly their obligations under general restrictions of chemical legislation, they could not ignore the restrictions applying specifically to their sector. The main argument around the careful scrutiny on compliance with the RoHS ban was the increased likelihood of being caught for non-compliance.

The RoHS directive clearly relates to products "put on the market"[89]. This means that brand firms in the electronic sector are more likely to be liable for any issue of compliance with the RoHS directive than their contract manufacturers, even though non-compliance would arise from the production processes of the contract manufacturers.

This largely explain why one of the first demand of brand firms to their contractors preparing for the implementation of the RoHS directive have been the requirement of declaration or certificate of conformity. With such certificates and declarations, the brand firms could prevent the risk from bearing the legal and financial liability for non compliance.

[89] See chapter 3

However, with their high brand values, the brand firms are more likely to face problems in case of non-compliance. This would include commercial problems. As illustrated by Figure 18 on the Sony "cadmium crisis" in 2001, "environmental missteps can create public relations nightmares, destroy markets and careers, and knock billions off the value of a company"[90]. In this particular crisis, Sony's losses have been estimated at 130 million dollars.

"**Sony's very expensive Christmas**

"In the week before Christmas 2001, the Sony Corporation faced a nightmare. The Dutch government was blocking Sony's entire European shipment of PlayStation game systems. More than 1.3 million boxes were sitting in a warehouse instead of flying off store shelves.
Was this a trade war or embargo against violent video games? Sony executives probably wished it were something that easy to fix.

So why was Sony at risk of missing the critical holiday rush? Because a small, but legally unacceptable, amount of the toxic element cadmium was found in the cables of the game control. Sony rushed in replacements to swap out the tainted wires. It also tried to track down the source of the problem – an eighteen month search that included inspecting over 6.000 factories and resulted in a new supplier management system. The total cost of this "little" environmental problem: over $ 130 million."[91]

Figure 18 Sony's expensive Christmas

Furthermore, brand firms could also be hit by reputational damage. Given that the main business model in the IT sector is now organised around the value of the brand's name to commercialise products manufactured by OEM and certified manufacturers, preserving a brand's name and reputation is key to success.

With an increased scrutiny of regulators and civil society stakeholders since the adoption of RoHS, major brand firm have become particularly vulnerable to threats to their brand's values and image especially in relation to environmental performance or the use of toxic chemicals.

Daniel Esty and Andrew Winston has proposed a list of criteria for companies that are the most vulnerable to what they call the "green wave" or the "unavoidable new array of environmentally driven issues" industry groups are faced with in every sector.

Among this list of criteria of vulnerability[92], five criteria could apply to the brand firms of the electronic sector as follows:

---

[90] Daniel C.Esty & Andrew S. Winston, *Green to gold, how smart companies use environmental strategy to innovate, create value and build competitive advantage*, Yale Universtity Press, 2006,p.10

[91] Daniel C.Esty & Andrew S. Winston, op.cit., p1
[92] Ibid, p20

- High brand exposure. This is the case for IT companies with substantial goodwill and intangible values, given their track record of contributing to innovation and societal benefits;
- Current exposure to regulations. This is clearly the case for the electronic sector with the WEEE and RoHS directive, but also more recent regulation of energy using products at EU level.
- Increasing potential for regulations. A revamp of the EU integrated product policy [93]or further scrutiny under the new REACH regulation on chemicals. The authors of the list themselves clearly refer to electronics producers.
- Competitive market for talent. The electronic sector can see their primary assets walk out the door if they are displeased with the company's values.
- Established environmental reputation. Here the author that the firms with problematic histories should expect "extra scrutiny" while companies with good track record will benefit from more "leeway and goodwill in the market place".

Because of the intangible value of their brand name and reputation, major electronic brand firms are therefore more vulnerable to pressure from regulators and civil society to comply with environmental standards.

Evidence of this increased scrutiny on electronic brand firms can be found in the regular ranking organised by Greenpeace as part as their campaign on greening electronics. As part of their campaign "High-tech: highly toxic", Greenpeace publishes every three months a "Guide to Greener electronics" with the performance of major brand firms of the electronic sector (see below ranking published in June 2007).

Brands are rated according to the two main demands by the environmental NGO that the companies "clean up their products by eliminating hazardous substances and takeback and recycle their products responsibly once they become obsolete".

Major electronic firms carefully monitor the evolution of the Greenpeace ranking. During the interview process carried out for this research on the RoHS Directive, most representatives of the IT companies interviewed mentioned this initiative by Greenpeace in April 2007. They expressed concern about the validity of the ranking's methodology, based on the information published on companies' web sites.

As an example of the methodology issue, they particularly quoted the example of Lenovo, the Chinese PC manufacturer, who jumped from the lowest rank in August 2006 to the best performance in March 2007, before Nokia, the regular leader of the Green guide, who had partnered with Greenpeace on several occasions[94].

---

[93] ENDS daily article on revamping product policy
[94] For instance, Nokia products were praised by Greenpeace in their campaign against toxic chemicals (see the "substitute with style" brochure).

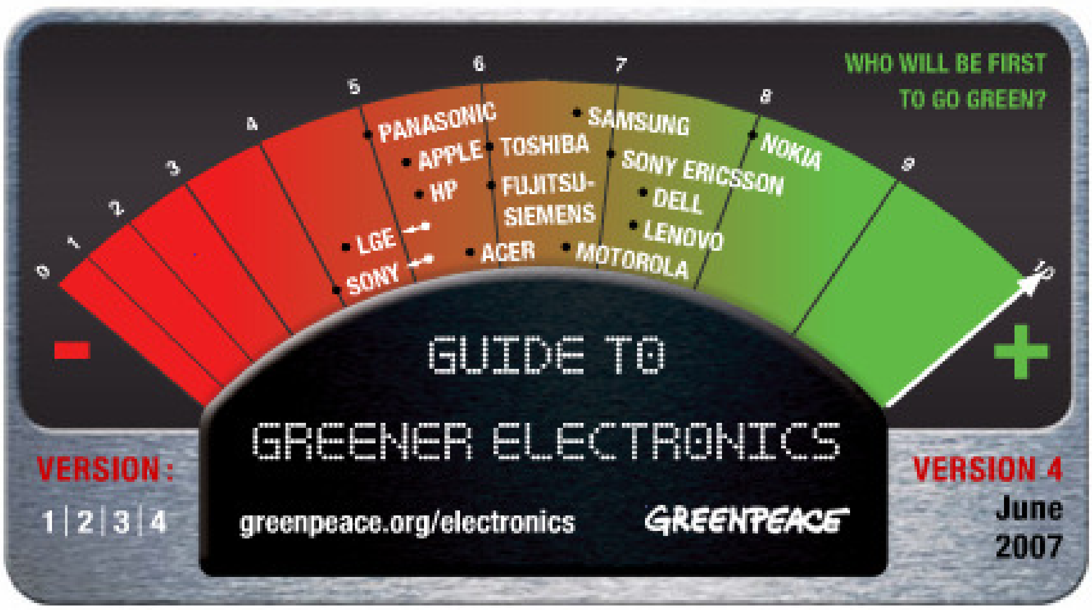


Figure 19 Greenpeace ranking of electronic brand firms in June 2007

RANK	JUNE '07	MARCH '07	DECEMBER '06	AUGUST '06
1	Nokia ↑	Lenovo ↑	Nokia ↔	Nokia
2	Dell ↑	Nokia ↓	Dell ↔	Dell
2	Lenovo ↓	Sony Ericsson ↑	Fujitsu-Siemens ↑	HP
4	Sony Ericsson ↓	Dell ↓	Motorola ↑	Sony Ericsson
5	Samsung ↔	Samsung ↑	Sony Ericsson ↓	Samsung
6	Motorola ↔	Motorola ↓	HP ↓	Sony
7	Toshiba ↑	Fujitsu-Siemens ↓	Acer ↑	LGE
8	Fujitsu-Siemens ↓	HP ↓	Lenovo ↑	Panasonic
9	Acer ↔	Acer ↓	Sony ↓	Toshiba
10	Apple ↑	Toshiba ↑	Panasonic ↓	Fujitsu-Siemens
11	HP ↓	Sony ↓	LGE ↓	Apple
12	Panasonic ↑	LGE ↓	Samsung ↓	Acer
13	LGE ↓	Panasonic ↓	Toshiba ↓	Motorola
14	Sony ↓	Apple ↔	Apple ↓	Lenovo

Figure 20 Greenpeace: comparison of ranking in the electronic sector between August 2006 and June 2007

Source : Greenpeace[95]

[95] Greenpeace "Toxic electronics", available from http://www.greenpeace.org/international/campaigns/toxics/electronics/how-the-companies-line-up

Out of the six companies interviewed in April 2007, only one company was particularly reluctant to engage with Greenpeace. According to the interviewee, the company's low ranking was not justified by its top range environmental performance. Rather, the explanation was in the company's policy of discretion when it comes to communicating around environment performance.

Another example of a campaign targeting the IT industry is the report on the mobile phone industry by the group Somo[96]. Among some of the critical issues facing the mobile phone industry, Somo emphasises the use of toxic chemicals in the production process and the lack of protection of workers.

The campaigns by Greenpeace and Somo illustrate well the enhanced scrutiny on the IT sector since the adoption of the RoHS Directive and moving towards the implementation of the REACH regulation on chemicals.

The vulnerability of brand firms to reputational damage is particularly important to bear in mind to understand their interest in favour of a successful implementation of the RoHS Directive. Non-compliance with the RoHS directive, although largely depending on the performance of Taiwanese and Chinese contract manufacturers, could badly impact brand firms in the electronic sector.

4.2.2 A challenge throughout the electronic sector

The implementation of the RoHS directive and the preparation for the RoHS ban on 1st July 2006 has been a real challenge throughout the electronic sector. This high amount of specialized IT press articles dedicated to this subject and the flourishing of consultancy services dedicated to RoHS implementation illustrate the magnitude of this challenge.

On a blog dedicated to the implementation of RoHS, an expert describes the impact of the legislation throughout the supply chain: "At first glance, it would seem that the Restriction on the Use of Hazardous Substances (RoHS) law mainly affects OEMs whose brand name is listed on the equipment. However, the law is having a huge impact on electronics manufacturing services (EMS) providers who build systems for OEMs. EMS providers must work with suppliers to make sure their parts are RoHS compliant. Key for all suppliers is materials declarations. Equipment manufacturers will have to provide documentation that

---

[96] Joseph Wilde & Esther de Haan, *Sneak preview, the High cost of calling, critical issue in the mobile phone industry,* SOMO, Center for research on Multinational corporations, November 2006

show none of the listed hazardous substances are in any parts or materials used in equipment. Most OEMs and EMS companies are building databases of suppliers, parts and materials content."[97]

A specialised consultancy providing assistance for RoHS implementation highlights the same challenge as follows: "Supporting the substance bans as defined by the European Union's Restriction of Hazardous Substances (RoHS) directive is a problem that impacts all levels of the electronics supply chain—from raw material and component manufacturers, to the original equipment manufacturers (OEMs)." [98]

Given the modularity of the supply chain, operators at the beginning of the supply chain such as contract manufacturers will play a major role. The brand firms "are ultimately responsible for ensuring compliance of their products and have to answer to the regulatory bodies on all compliance issues. Since most [brand firms] in the electronics industry outsource manufacturing of their products, the Electronics Manufacturing Services (EMS) provider or contract manufacturer plays a vital role in ensuring that the products are manufactured to compliance standards."[99]

Actors up the supply chain such as EMS or ODM are thus likely to face tougher challenges than the brand firms given that they must support multiple customer requirements and manage the collection and validation of data from thousands of suppliers.

To conclude, it is important to realise "how complicated it is for today's networked Original equipment manufacturer-type electronics producers to implement a substance ban. The company whose brand appears on the final end-user product typically manages an intricate interface of hundreds of specialized component and material suppliers and subsuppliers around the globe. The bans and other substance requirements need to be communicated at the lowest levels of the supply chain."[100]

4.3 Organising the RoHS substance ban: concrete questions

If companies adopted different detailed strategies when it comes to RoHS implementation, interviews with representatives of the IT sector reveal that the shift to a RoHS compliant supply chain followed a number of steps as follows:

---

[97] Steve Hemmed, "RoHS Impacts EMS industry" in *RoHS Case Study and References* available from http://www.rohs101.com/2005/10/27/rohs-impacts-ems-industry/

[98] E2open, "Case Study Eco-compliance, EMS/ODM company", available from http://www.e2open.com/dynassets/protected/en/E2open_Eco-Compliance_case_study.pdf

[99] Ibid

[100] Harri Kalimo, op.cit., p233

- Understanding legal obligations and raising awareness at the right level of the company
- Listing components including banned substances and analysing the substitution possibilities (substance or process substitution)
- Material declaration and communication of information along the supply chain
- Auditing suppliers
- Management of the stock and production flow for a seamless implementation of the RoHS deadline.

Each of these steps will now be examined in more details.

4.3.1 Understanding the legal requirement and raising awareness of the challenge

This may seem like an obvious first step for the implementation of the Directive. However, it has not been as straightforward a process as one may have expected.

This is mainly due to the uncertainties of the legal text[101] on certain key aspects such as the scope of the ban. This has not facilitated the transposition of the RoHS directive by EU Member States.

One of the key issues for the industry has been the diverging interpretation of the provision "put on the market". "The electronics industry representatives understood that the initial position of the European Commission was, surprisingly, in favour of a wide interpretation: any sale ore resale between any of the parties involved in the logistics of electrical or electronic equipment from the producers to the end-users could have been considered as an event of putting EEE on the market".[102]

However, as highlighted by Harri Kalimo, this would have been ill-advised from the perspective of the environment protection and the internal market. It would risk creating a mountain of waste consisting of unused products. "The Commission later unofficially clarified that it subscribed to the viewpoint that "putting on the market referred to the initial action of making a product available for the first time on the Community market, with a view to distribution or use in the Community"[103].

This interpretation problem caused significant waste of resources with increased difficulties managing warehouses. This created issues of legal certainty for IT operators who had the

[101] See chapter 3
[102] Harri Kalimo, op.cit., p280
[103] Ibid, p282

impression of being confronted to changing set of rules despite the tight deadlines imposed by the RoHS ban. “Adhering to the EU Commission’s changing rules and regulation has been a burden, but not from what you might expect,” said Markus Terho, director of environmental affairs at Nokia. “Technological implementation has been straightforward; the burden has been, and still is, that the legal requirements keep changing. We would have liked the requirements frozen, giving us a year to implement them. Instead, the changes are frequent [and] sudden changes by the Commission are not transparent.”[104]

With changing interpretation of legal requirements, IT companies have also been confronted to another challenge, that of communication and awareness raising. This challenge has been both internal and external.

Within the IT sector, the organisation of RoHS implementation varied from one company to another. For instance, Hewlett Packard (HP) designated a project manager on RoHS compliance while Dell implemented a strategy without such a compliance leader. Given the significance of the effort to realise to meet RoHS compliance deadline, the communication aspect has been a key factor for the implementation. Recognising the magnitude of the task and dedicating the right amount of resource to the challenge require the buy in of very high hierarchy level in the company.

4.3.2 Listing components including banned substances and finding substitutes – the example of hexavalent chromium in Tyco Electronics products

The major step for the preparation of the implementation process is the listing of components that include banned substances. This can turn out to be a time-consuming exercise as reported in Electronic business.

“It's hard not to get a little panicky over Europe's impending Restriction of Hazardous Substances (RoHS). Consider the scope: The world's largest catalog distributor of electronic components, NewarkInOne, stocks more than 165,000 parts that commonly contain the banned materials. The distributor's database maintains specs, data sheets, inventory and price information on four million devices. "Our estimate is that 70 percent of the parts we

[104] John F. Mason, “Life with RoHS: How is the directive doing in Europe today?”, in *Electronic News*, 27 March 2007 available from www.edn.com/article/CA6427406.html?partner=enews

stock will be affected by RoHS," says NewarkInOne's president, Paul Tallentire. He expects an even bigger impact on the four million devices in the database.[105]

Nevertheless this step of the process is key to evaluate the need for substitution solutions.

Tyco Electronics is a US based provider of engineered electronic components and claims to be the "world's largest manufacturer of passive and electronic components"[106]. Preparing for RoHS implementation, Tyco Electronics particularly looked at how they were using hexavalent chromium.

They identified that the main uses of hexavalent chromium were:

- in conversion coatings used for enhanced corrosion protection as well as for appearance
- in adhesion film for organic coatings

They concluded that a series of products and components were affected such as die cast products, shells, fasteners and electrical chassis.

[105] Barbara Jorgensen, "The "greening" of the supply chain: Suppliers, distributors and customers struggle with RoHS compliance", in *Electronic Business*, 1 June 2005 available from www.edn.com/article/CA603501.html

[106] John R. Penica, and Robert D. Hilty, "Chromate and Cadmium:Use and Alternatives" , RoHS support center, Tyco Electronics, available from www.tycoelectronics.com/customersupport/rohssupportcenter/pdf/tyco_hex_chrome_and_cad_overview.pdf

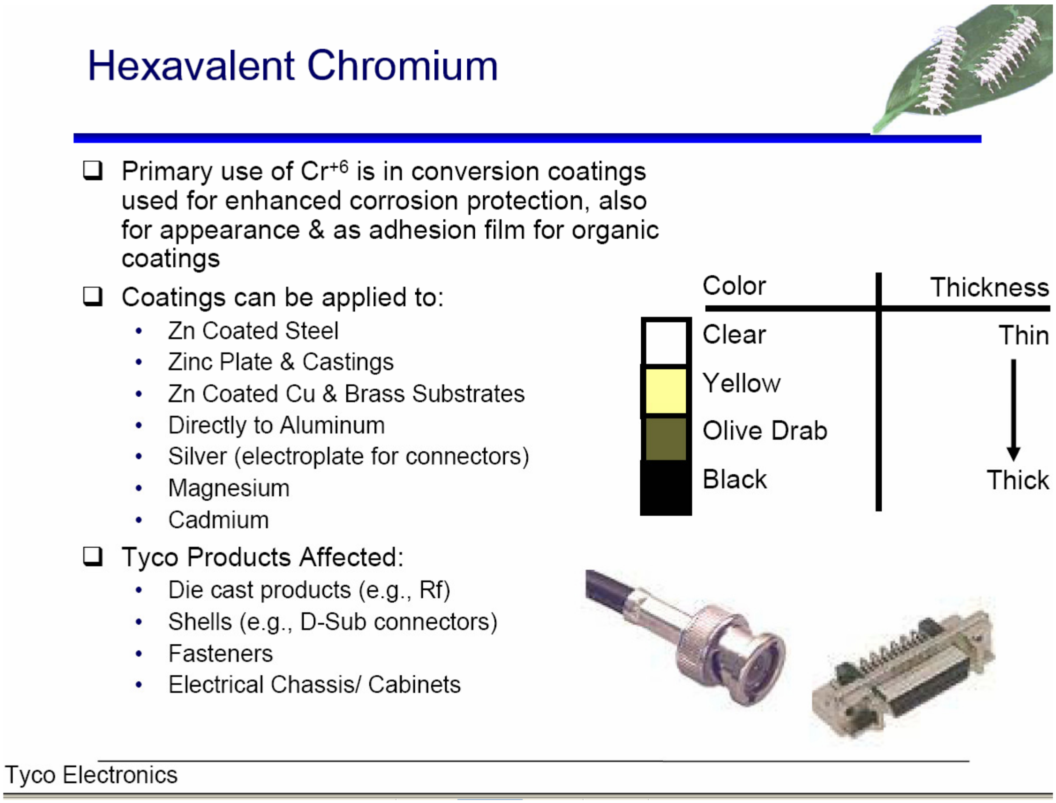


Figure 21 Tyco Electronics' products affected by the ban on hexavalent chromium
Source: John Penica, Robert Hilty, Tyco Electronics

Then they looked at possible alternatives and concluded that there was no universal replacement for hexavalent chromium and that alternatives would need to be considered on a case by case basis. They chose to carry out some testing on trivalent chromium, on resin coatings and permanganates as chromium free coatings.

The first step to the consideration of alternatives is the listing of the attributes of hexavalent chromium. This provides technical information why hexavalent chromium is used in specific applications. Tyco Electronics defined the following attributes for hexavalent chromium:

- "Prevents oxide formation of barrier plate/ inhibits corrosion through formation of passive surface boundary layer
- Conductive: Predictable surface resistance/ continuity characteristics
- Satisfactory substrate for paint applications (e.g. Mil-Aero)
- Predictable "Run-In" and "Break Away" torque values (Threaded hardware – automotive applications)
- Sacrificial relative to Zn & Cd substrates. Re-passivates exposed base metal, becomes soluble in presence of moisture
- Can be modified: Olive drab or black color options

- Process drying temperatures should not exceed 140 deg. F as thermal decomposition is likely above this point due to dehydration and microcracking, thus self regeneration will not occur.[107]

As a result the alternatives to hexavalent chromium should demonstrate similar characteristics. According to Tyco Electronics, alternatives to chromium should thus have the following desirable attributes:

- "Should be easily applied using existing metal finishing equipment and have low capital installation costs
- Abrasion resistant
- Should exhibit predictable torque characteristics
- Suitable base for organics/ paints
- Conductive
- Exhibit suitable film stability over time
- Cost effective"

It is particularly interesting to point out that the lower toxicity of alternatives to hexavalent chromium is not considered as a main criterion in the search for alternatives.
The conclusion of the presentation is that trivalent chromium is likely to offer more efficient solutions as an alternative to hexavalent chromium. The use of chrome-free alternative coatings would require multi-step systems to achieve similar results to hexavalent or trivalent chromium. The applied costs would therefore be higher than for trivalent chromium.

According to representatives of the electronic sector interviewed in April 2007, hexavalent chromium has not caused major problems in terms of finding suitable alternatives in view of the RoHS directive ban. It has been replaced by trivalent chromium in many electronic components. This substitution has had a direct visible effect in the case of hexavalent chromium. Former components with an iridescent yellow/ bronze colour have been replaced by iridescent light blue or dark blue, hexavalent chromium free parts.

However, this substitution of hexavalent chromium by trivalent chromium was not successful in all cases. One issue highlighted during the interview was the difference in electromagnetic compatibilities of hexavalent chromium and trivalent chromium. If the electronic sector did not seem to have concerns over the use of trivalent chromium, this was not necessarily the case of the so-called "white goods" industry. Because of the different electromagnetic compatibilities, the use of trivalent chromium would cause difficulties with regulations on magnetic fields.

[107] John Penica, Robert Hilty, op.cit.

4.3.3 Material declaration – producing and transmitting information in the supply chain

4.3.3.1 Material declaration – a communication tool in the supply chain

One of the first measures brand firms requested as a way to limit their legal liability in case of non compliance is certification from their supplier that their equipment was compliant with the RoHS Directive.

As a result, the supply chain has started to be inundated with requests for material declarations after the adoption of the RoHS Directive. As Todd Brady from Intel points out "requests for material information have exploded'[108]. In 2004, such requests had doubled compared to their 1999 levels. In the first half of 2004 alone, Intel had received 1200 requests.

Managing these requests soon became a challenge in the supply chain. As Tyco electronics explains, "due to the lack of clarity in the RoHS legislation and the absence of industry standards, many companies have developed their own definitions and requirements for RoHS compliance and reporting"[109].

Given the complexity and the miniaturisation of electronic equipment, gathering material information is not an easy task. As an industry expert explains, "you can not have an integrated circuit without some lead, which is still allowed. Each component has from two to 20 materials, and in the device you need to determine how many, such as lead, cadmium or chromium, have been used. In a mobile phone we have from 50 to 350 components. So we are talking about thousands of components which makes it very difficult -- if not impossible -- to test them all. We know some small companies make products that do not comply, but the regulators can not test them all." [110]

---

[108] Todd Brady, "Material Declaration: EIA, EICTA, JGPSSI Update", *Presentation at NEMI RoHS/Lead-Free Summit*, 19 October 2004, available from http://thor.inemi.org/webdownload/newsroom/Presentations/15.pdf

[109] Tyco Electronics, *Tyco Electonics Material Declaration Strategy*, November 2005, available from http://www.tycoelectronics.com/aboutus/environmentalinitiatives/pdf/TERoHSComplianceMaterial%20DeclPosition_112005.pdf

[110] Barbara Jorgensen, op.cit

4.3.3.2 Harmonisation efforts at global level on material declaration, test and sampling methods

To address these issues, companies from the electronic sector worked together to develop a "joint industry guide" to material declaration. Discussions started as early as 2001 and gathered industry representative bodies in Europe (EICTA), Japan (JGPSSI) and the US (EIA and JEDEC). After three years of consultation, the Joint Industry Guide on Material Composition Declaration for Electronic Products (JIG-101)[111] was published in April 2005.

Annex A of the guide lists the materials and substances whose disclosure is currently mandated by legislation (JIG Level A). Annex B lists the materials and substances that trigger hazardous waste management requirements or pose significant environmental, health or safety concerns (JIG Level B). Annex C lists the required and optional data fields to be used in material composition declaration. Annex E cites the laws and regulations which apply to Level A materials and substances. It also lists common examples of products using Level A or Level B materials and substances. Annex F provides CAS numbers for chemical elements and their compounds (where known). They are grouped by category. CAS refers to the Chemical Abstracts System developed by the American Chemical Society.[112]

However, the use of this Joint Industry Guide was far from being considered satisfactory.[113] Many companies found that the wide scope of the Joint Industry Guide went too far beyond the RoHS substances.

In November 2005, when designing its strategy for material declaration, Tyco electronics, an electronic component manufacturer, mentioned that "many customers are requesting Material Declarations (a document that discloses the ppm levels of substances in a product) to "verify" RoHS compliance (as noted this is NOT required by legislation). Some customers are requesting Material Declarations of only the six RoHS restricted substances. Some customers are requesting disclosure far beyond RoHS banned substances – list may be similar to that proposed by the Joint Industry Guide. A limited number of customers are requesting 100% material disclosure. This level of information is typically not available as it is considered proprietary by many suppliers."

---

[111] An example of material declaration according to JIG can be found at http://www.pc.ibm.com/ww/lenovo/procurement/Guidelines/Lenovo_Supplier_Material_Declaration_IPC-1752-1_V1_1.pdf

[112] RSJ Technical Consulting, "What is JIG", available from http://www.rsjtechnical.com/WhatisJIG.htm

[113] Nathalie Cliquot, Interview with Electronic Sector representatives, 16 and 17 April 2007.

The impact of this lack of harmonization is important on the management of the supply chain. It has also created new business needs. For instance, some companies offer product lifecyle management and enterprise content management. The type of problems experienced in the supply chain is complex. PTC, one of the companies offering such services explains “suppliers are being inundated with hundreds of reengineering and information requests from their customers, each in different formats and with different requirements. The redesign of products could create chaos in numbering and tracking parts. Part selection, bill-of-materials (BOM) analysis, workflow approval and reporting will take on new urgency. Tracking of configurations, inventory, suppliers, raw materials and more will have new legal implications.”[114]

For many industry experts, this lack of harmonisation turned into a logistical nightmare. “To date, there is no standard way of distinguishing a part that contains lead, for example, from one that does not. There's no standard way of declaring which substances a component does—or does not—contain, although standardization efforts are underway. And there are few provisions for warehousing the number of devices that will be required as the electronics industry transitions toward materials that are more environmentally friendly while still manufacturing noncompliant products. "[115]

Interviews with industry experts in April 2007 revealed that the lack of harmonized standards for material composition has been one of the main challenges of the RoHS directive. The problem is more fundamental than communication tools along the supply chain as it touches upon the issue of test methods and sampling methods. According to industry experts interviewed in May, depending on the test and on the sampling method, the results of a test can sensibly differ in China and in Belgium. Given that the RoHS directive establishes a low level of concentration permitted for the banned substances (0.1, this variations can widely affect the compliance of a product.

In addition to the lack of standards for test methods, the lack of a definition for what is considered “homogenous material” is critical to the industry. The industry was hopeful that these issues could be addressed at global level within the TC111 initiative.

The TC111 initiative is taking place under the aegis of the International Electrotechnical Commission (IEC), the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies. In March 2005, a first

[114] Chad Hawkinson, “Roadmap to environmental regulatory compliance :Ballooning regulatory environment encourages strategic approach”, 19 September 2005 available from http://www.greensupplyline.com/showArticle.jhtml?printableArticle=true&articleId=170704689

[115] ibid

conference was organized in Milan, and then followed by a series of conferences in Spain (June 2005), in Cape Town (October 2005).

The initiative was then divided in several working groups. The first working group (WG1) is dedicated to Material Declaration (RoHS compliant) in which the US members are taking the lead. The second working group deals with design for environment and relates to the Energy-using products directive. The third working group (WG3) also deals with RoHS compliance and addresses the issue of Test Method for Hazardous Substances or controlled substance analysis method. In WG3, Germany is taking the lead. In addition to these working groups, France was taking the lead on the establishment of an overall framework for RoHS compliance.[116]

This standardization is still on-going long after the RoHS deadline of 1 July 2006. In April 2007, industry experts explained that the standardization process had not yet succeeded in the case of hexavalent chromium because of high error margins. A new proposal was to be submitted in July 2007.

The challenge of globally harmonized standards is sometimes downplayed by NGOs highlighting that well-know instruments to determine the levels of materials such as XRF analyzers are already available[117].

However, the length and scope of the standardization process epitomizes the challenge for the electronic sector as well as the efforts the industry has put into the RoHS implementation process.

---

[116] Atsushi Tajima, "TC111 Status of Material Declaration WG andChemical Substances in Products Framework PT62476", available from http://www.iec.ch/about/rc/iec-aprc/cent_event/pres_pdf/tajima.pdf

[117] Nathalie Cliquot, Interview with NGO representatives, May 2007

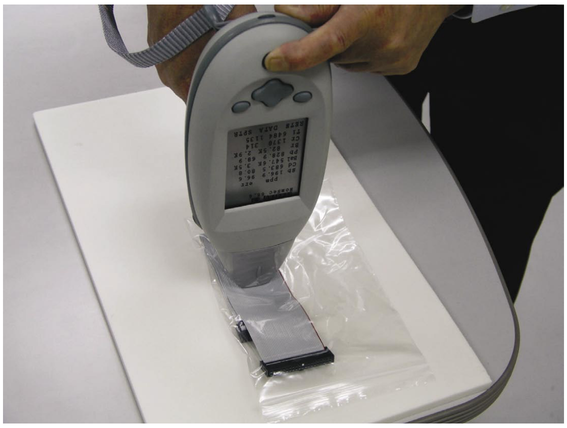


Figure 22 Component analysis carried out with a handheld XRF analyzer
Source: Niton[118]

4.3.3.3 Specific product codes for RoHS compliant components – confusion on the market

From the issues quoted above, the codification of RoHS compliant components has been widely reported as a critical question for the whole industry. When companies place an order for components, they use product codes. Preparing for RoHS implementation, some companies have chosen to identify their RoHS compliant component with completely new numbers.

On the contrary, some component manufacturers have been reluctant to changing the product code. For instance, at Philips Semiconductors, the "policy has been to keep the same part numbers for RoHS compliant products". This is to enable an easy, seamless transition to the RoHS products. According to the specialised press, "Suppliers resist changing part numbers, because it's time-consuming and complex. Any change to a part's form, fit or function has to be circulated to customers and the rest of the supply chain; data sheets and specs have to be rewritten and OEMs may have to tweak their product designs. As long as a RoHS-compliant part is backward/forward-compatible, suppliers say, there's no reason to rename the part."[119]

Some of the communication tools used by industry to trade components such as the electronic data interchange (EDI) were not designed to take into account the implementation

[118] http://www.niton.com/documents/literature/DueDiligenceforRoHS.pdf
[119] Barbara Jorgensen, op.cit.

of RoHS. For instance, “There currently is no data field on an EDI purchase order for compliant versus noncompliant components”[120].

The lack of information can seriously impact industries including those not covered by the RoHS ban. Without a change of product code and adequate information, a company using non-RoHS compliant can end up with RoHS compliant parts with slightly different characteristics. This also increases risks of dysfunctioning equipment.

For instance, “The lead-free solders EMS companies use to attach components to a printed circuit board usually melt at higher temperatures than solders containing lead. These higher temperatures may cause problems in components that can't tolerate the higher heat or cause defects in the lead that attaches the component to the board.”[121]

Given this problems of communication in the supply chain, some brand firms had to enhance their dialogue with their suppliers. “To meet RoHS requirements, HP started working with suppliers in early 2003 and has maintained ongoing communications. For example, in July 2005, HP held a forum in China with regional suppliers to review and discuss HP’s social and environmental responsibility (SER) and RoHS requirements.”[122]

4.3.4 Auditing schemes for suppliers

If certificates of RoHS compliance granted by supplier are a useful means of communication in the supply chain, they are far from being enough to guaranty the conformity of products. As a UK agency assisting companies to comply with RoHS highlights, “purely relying on certificates or other documentation without assessing their validity is unlikely to be considered as adequate if a business has refused or failed to take a reasonable precaution”[123].

When the RoHS Directive was adopted, brand firms were well aware of the potential costs of non compliance. The Sony cadmium crisis in 2001 was quoted by many representatives of the electronic sector as a useful example to quantify the potential costs of non-compliance.

---

[120] Ibid
[121] Ibid
[122] Hewlett Packard, “HP Global citizenship, Environment, Product Design”, available from http://h41111.www4.hp.com/globalcitizenship/uk/en/environment/productdesign/materialuse.html

[123] National weight and measures laboratory, “RoHS, due diligence” available from http://www.rohs.gov.uk/content.aspx?id=7

This has allowed the buy-in of the appropriate hierarchical level in the companies to address the challenge of RoHS compliance. As highlighted by one of the interviewee, the electronic sector also had to comply with chemicals restrictions in the past. However, the chances of being caught for non-compliance were so narrow that compliance was not regarded as a priority. With the Sony crisis and the scrutiny on the electronic sector, the stake of RoHS compliance was perceived as very high.

With the challenge of RoHS compliance, companies at all level of the supply chain had to enhance their dialogue with their suppliers. This could entail the establishment of comprehensive auditing schemes for suppliers.

As recommended by a UK agency assisting companies for the implementation of RoHS, "What constitutes reasonable action depends on your business. It is recommended that all the activities of the business which may cause a breach of RoHS should be identified, controlled and checked by a system of working, for example;

- supplier reliability and selection of raw materials and components
- goods in control and quarantine
- production processes and contamination
- evidence and documentation
- stores control and mixing compliant and non-compliant materials and components, labelling
- staff training and experience "[124].

Not surprisingly, Sony was quoted by most interviewees as the firm who had developed the most comprehensive internal auditing scheme. Most brand firms had to develop a materials tracking system. HP mentions that its suppliers have responded to HP's requirements by providing RoHS-compliant components, improving incoming inspection processes and improving their supplier quality management processes. In the few cases where restricted substances have been discovered in products, suppliers have quickly determined how this occurred and have implemented process improvements to correct the problem."[125]

At the time of the adoption of the RoHS Directive, suppliers auditing scheme are not new systems. The issue of guarantying good practices throughout the supply chain had been experienced in particular through Corporate Social Responsibility (CSR) codes of conducts.

---

[124] National weight and mesures laboratory,op.cit.

[125] Hewlett Packard, "HPglobal citizenship, Environment, Product design" available from http://h41111.www4.hp.com/globalcitizenship/uk/en/environment/productdesign/materialuse.html

“A large number of especially multinational corporations have introduced Codes of Conduct, a set of written principles, guidelines or standards, which are intended to improve the company’s social and environmental performance. Realising that CSR issues arise throughout the supply chain (see below figure) and that companies are increasingly held responsible for the conditions under which their products are being produced, these codes often go well beyond the boundaries of the individual organisation and include social and environmental requirements for suppliers”[126].

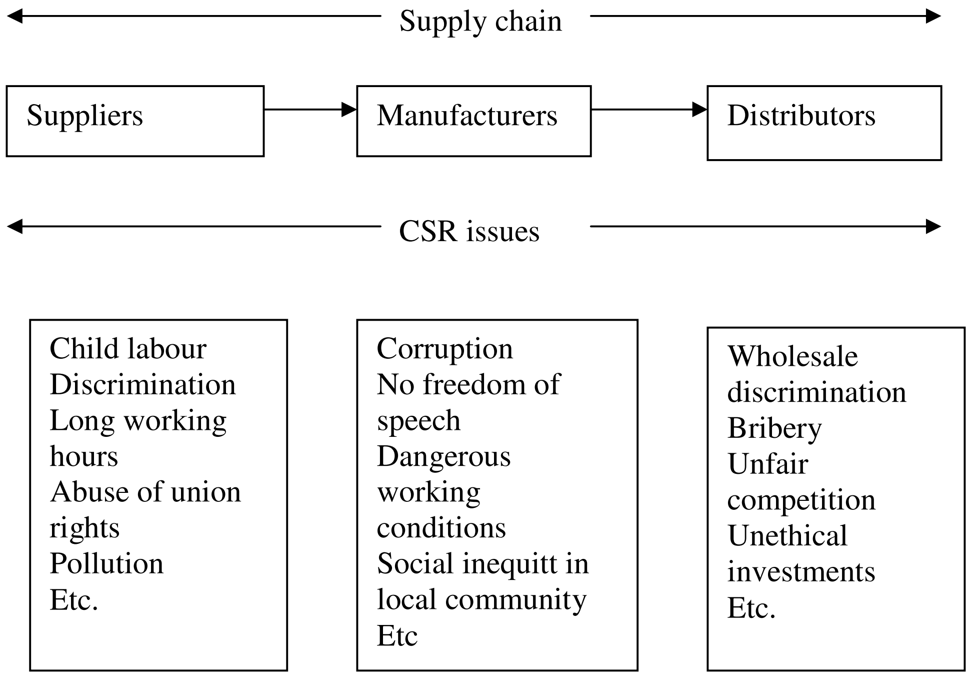


Figure 23 Examples of CSR issues in supply chain (Neergaard and Pedersen 2005)

4.3.5 Managing the stock, the product flow and the RoHS deadline

The RoHS Directive is fixing a clear deadline for the phasing out of hazardous substances covered by the directive: the 1st of July 2006. As a result, the process of establishing supply chain communication and supplier’s auditing scheme also needs to take into account the timeframe.

The switch to RoHS compliant products entails the substitution of the RoHS substances in components but could also imply a switch to new processes. Therefore, the timeline for implementing these changes can widely vary from one component to another. In addition, it

[126] Esben Rahbeck-Pedersen and Mette Andersen, “Safeguarding corporate social responsibility (CSR) in global supply chains : how codes of conduct are managed in buyer-supplier relationships”, in *Journal of Public Affairs*, August- November 2006, p229

does not facilitate the estimations with regards to the time necessary to operate the switch to RoHS compliant products.

With the complexity of supply chains in the electronic sector, time management has become a key to RoHS implementation. It was feared that several segments of the supply chain would miss the deadline.

For instance, the specialised press reported in October 2005 that some OEMs and brand firms were forced to "ask component suppliers to slow down the progression to RoHS compliance" with significant impact on the supply chain. "The delay puts a drag on the entire process, in some cases delaying compliance for suppliers and in other cases forcing them to develop and manage dual product lines of compliant and non-compliant parts." [127]

As Stephen Marlow from Toshiba America Electronic Components explains "It's up to our customers when we can move. We announced in September [2005] that we would convert all of our manufacturing to RoHS-compliant by the end of the year, but some of our customers are not ready."[128]

As illustrated by the Sony cadmium crisis, the consequences of missing the RoHS deadline could be very costly. Experts of the electronic sectors pointed out that "if entire segments miss the deadline, industry insiders say it's almost certain to create a legal mess that will take years to sort out. The first taste of that was when Sony shipped Playstations into Europe with non-compliant power supplies a couple years ago. An entire shipment never made it into the European market, affecting everyone within Sony's supply chain. Executives say that RoHS will multiply that type of effect by several orders of magnitude." [129]

The RoHS Directive was designed to address these difficulties with the possibility to provide flexibility on some applications and uses. This is precisely the justification for introducing a list of exemptions to be reviewed regularly.

However, the timeline set for the implementation of the Directive did not leave many opportunities to leverage the exemption procedure. Some industry expert analysed that the flexibility offered by RoHS with the exemptions process "made it difficult for to develop complete company transition plans" [130]. Because of the adoption process foreseen for exemptions, request for further exemptions under RoHS could not be adopted by the European regulators before the July 2006 deadline. As highlighted in the sector, "feedback from an industry teleconference in April 2005 indicated that the approval process for

---

[127] Ed Sperling "RoHS: Supply chain not yet ready", in *Electronic News*, 27 October 2005 available from www.electronicsweekly.com/Articles/2005/10/27/36743/rohs+supply+chain+not+yet+ready.htm

[128] Ibid

[129] Ibid

[130] Guy Martindale and H.R. Chai, "RoHS Implementation: An OEM and EMS Case Study", in *Circuits Assembly*, 1 January 2006 available from http://circuitsassembly.com/cms/content/view/2579/95/

exclusions would take longer than the time pending before the July 2006 compliance date."[131]

Indeed, the first additional exemptions granted by the TAC were published in September 2006 after the July 2006 deadline. For hexavalent chromium, only one additional exemption was requested for hexavalent chromium in passivating coatings.

According to the interviews carried out in May, many of the exemptions were requested not on the basis of the lack of alternatives but as a way to ensure a longer transition deadline. As a result, according many industry representatives, exemptions granted by RoHS are now considered obsolete.

Beyond the issue of meeting the deadline, the problem is also for manufacturers to estimate the quantity of non-RoHS compliant components that would be needed until the July 2006 deadline. If estimations turn out to be too low to respond to the demand, this can cause significant disruptions in the supply chain with economic losses. On the contrary, "one problem the manufacturers face is being left with non-compliant product they cannot use after the July deadline"[132].

4.4 An impact beyond the scope of the RoHS directive and the European market

Given the cost of maintaining list two manufacturing lines, one for RoHS compliant products and non RoHS compliant products, there are strong incentives to manufacture only RoHS compliant parts. As indicated by the specialised press "RoHS bans the use of lead and five other substances from being used in equipment sold in Europe. Many suppliers have ceased making parts with lead and the other substances, effectively obsoleting the components." [133]

This can create tensions in the supply chain as buyers of components for non RoHS product are not made aware of this switch in the whole supply chain. "Rather than issuing an end-of-life (EOL) notice for the parts informing buyers the leaded versions are no longer made,

[131] Guy Martindale and H.R. Chai, op.cit

[132] Richard Wilson, "RoHS: Is the supply chain ready?", in Electronics Weekly, 20 March 2006 available from
http://www.electronicsweekly.com/Articles/2006/03/20/37921/rohs+is+the+supply+chain+ready.htm

[133] James Carbone, "RoHS means more electronic component obsolescence", in *Purchasing,* 14 December 2006, available from www.purchasing.com/article/CA6397126.html

many suppliers issue product change notices (PCN).However, without an EOL notice, buyers may not be aware a noncompliant part will no longer be available. Many OEMs still use noncompliant parts, including defense, aerospace and medical companies, which are exempt from RoHS." [134]

As a result, the price of non-RoHS compliant has risen due to tighter supply of non-compliant parts. "In fact, there is a tighter supply of RoHS-compliant parts as manufacturers have not produced enough to meet demand, according to independent distributors. But, there are reports of tighter supply of noncompliant parts also."[135]

Therefore the impact of RoHS goes far beyond the products covered by the directive. It also impacts products for which an exemption has been granted; other sectors such as defense, aerospace or medical applications and also broader markets than just the European market.

As Aaron McLoughlin points out, even if some products have been granted an exemption, RoHS will create a major shift away from the banned substance, which will raise the costs of those industries still relying on non-compliant products. "For example, whilst there are exemptions for the use of leaded solder in chips, the chip manufacturer industry will shift away from lead. Leaded solder chips costs will rise significantly and will force even those who have been provided with an exemption to use leaded solder60 to move away from its use. In an industry that is dependent on large volumes for low prices, bespoke part manufacturing is a legal but not economic option. [136]

Similarly, RoHS impacts sectors not originally covered by the directive. "Though aeronautic is considered 'out of scope' of the RoHS ruling, it is affected anyway because our supply chain has to transition from lead-based to lead-free alternatives," Bruno Costes, Airbus' head of industrial coordination, said, noting that the company has been tracking the RoHS directive since its preparation, providing responses and aerospace information to the Commission and European aerospace associations."[137]

As a result, there is increasing economic incentives for companies to switch to RoHS compliant components when designing products. "This has put the design engineer into a precarious position as component selections are being made. Those who fail to understand

[134] James Carbone, op.cit,
[135] James Carbone, "Supply of RoHS parts tightens", in Purchasing, 13 July 2006 available from www.purchasing.com/article/CA6350544.html
[136] Aaron Mc Loughlin, op.cit, p257
[137] John Mason, " How is Europe tackling RoHS Legislation", in Electronic News, 27 March 2007, available from http://www.electronicsweekly.com/Articles/2007/03/27/41054/how+is+europe+tackling+rohs+legislation.htm

the longer-term supply chain implications of RoHS risk being caught with component price increases and an increased potential for component obsolescence."[138]

Furthermore, because of its impact on global supply chain, RoHS has impacted other markets rather than just the European market. According to the specialized press "the actual amount of RoHS-compliant products moving through the supply chain in the Americas is greater than 50% and growing."

In China, "RoHS is very much on the agenda"[139]. However, most companies working towards RoHS compliance in China are doing so rather within a defensive strategy, reacting to the pressure of their customers in global supply chains. "There does not seem to be any attention (and even acknowledgement) that the directive actually is to be periodically updated, both in respect to the exceptions, but also concerning an extension of restricted substances. Many [Chinese companies] are applying a rather ad-hoc approach in their compliance work, where they look at each different task separately as they experience the requirements from customers"[140].

4.5 Conclusions: RoHS, a "wake-up call" for the electronic sector

Since the 1980s, the electronic sector has evolved considerably with the modification of production methods and the "modularisation" of production. As a result, an increasing number of production tasks are being outsourced to different companies, located around the globe. This tendency was accelerated during the 1990s with the use of new technologies of information and communication.

While supply chains are becoming increasingly complex and component manufacturers are moving to Taiwan and now to China, brand firms still remain in the eyes of the public (and the law) the manufacturers of electronic equipment.

Given the complexity of global supply chains in the electronic sector, the implementation of the RoHS directive has required a titanic effort from the industry to put in place supply chain communication tools and certification mechanisms with material declarations. This has, in

---

138 Steven Schultz, "RoHS implementation: a summary, Engineers must understand long-term supply chain implications" available from http://avnet.com

[139] Tyge Kjaer et alii, "Are the European directives WEEE, RoHS and EuP fostering Cleaner Production among the Chinese industry?" available from www.vito.be/erscp2005/documents/papers/PAPER050.PDF

[140] Ibid, p3

turn, fostered the need for global standards and the standardisation process under way will greatly facilitate the task of RoHS compliance.

The lack of a harmonised definition for homogenous materials, the lack of a harmonised format for material declaration in the supply chain, the problem of similar product codes for RoHS compliant and non-compliant products, the management of the RoHS deadline have been only just a few of the challenges to overcome.

These issues have greatly complicated the task assigned by the RoHS Directive to substitute some hazardous substances by less hazardous alternatives. In addition to the cost of listing all components affected by the RoHS restriction and finding viable alternatives, the re-organisation of the supply chain, the establishment of auditing scheme of suppliers must also be taken into account.

In view of these efforts, the costs involved by the implementation of the RoHS Directive seem far from “limited” as originally thought by the EU regulators. The consequences of the RoHS Directive have been exponential.

However, industry experts argue that the costs of the RoHS Directive were worth it. Griffin Teggeman, manager of Freescale’s Environmentally Preferred Product Program explains: “we’ve been asked if RoHS has been a burden, costly or worthwhile. Unfortunately, the answer is all of the above. Technology required for the initial implementation was costly, as was product qualifications, compliance process development and staffing. The on-going information collection, certification and delivery process is an industry burden; it uses resources that might otherwise develop new products or solve new problems. Yet, if RoHS can effectively reduce the hazardous substances in the environment, it will be worthwhile”[141].

As Paul Tallentire, president of NewarkInOne, an Electronic component distributor, puts it “This is only the beginning […] The challenge for the electronics industry is not just compliance with RoHS: It's also about managing the environmental impact of our products”[142].

[141] Barbara Jorgensen, op.cit.
[142] Ibid

5 Conclusion

Largely untouched by environmental regulations prior to the adoption of the RoHS Directive in 2003, the electronic sector has had to face since then a series of EU environmental laws with the substances restrictions imposed by RoHS and waste take-back obligations required by the WEEE Directive, the adoption of the EU's directive on eco-design of energy using products[143] and more recently the REACH regulation on chemicals.

By imposing new environmental requirements on products, EU regulators have fostered reflections on the environmental impacts of electronics and have highlighted the need to take environmental concerns into account in the management of global supply chain networks.

This has become all the more important as the electronic sector has experienced a significant shift in the organisation of production in the last twenty years. The increasing complexity and miniaturization of electronic devices went hand in hand with the globalization of supply chain networks, moving from vertically integrated companies to a myriad of independent producers in charge of specific functions in the supply chain.

In this context, if RoHS can be considered as a breakthrough in the EU's product policy, its philosophy is to be found largely in waste legislation. As this case study on hexavalent chromium in electrical and electronic equipment highlighted the main objective of the regulator remained that of waste prevention through the substitution of hazardous substances.

Indeed, as illustrated by the first chapters, the health and environmental risks associated with the use of hexavalent chromium compounds in electrical and electronic equipment relate more to the manufacturing and the end-of-life phases rather than consumer use. Indeed, hexavalent chromium compounds were identified, on the basis of a precautionary approach, with other heavy metals as problematic during the incineration of municipal waste.

Were these product requirements met by companies and their global supply chain? Was hexavalent chromium successfully phased out of electronics?

At the end of the day, it is difficult to say whether the hopes and expectations of EU regulators have been dashed in China and Taiwan by the complexity of the global supply chain of electronic products.

[143] Directive 2005/32/EC on the Eco-design of Energy Using Products

All companies interviewed claimed to have met the 1st of July 2006 deadline. However, it is hardly surprising that company representatives would admit otherwise given the legal and financial liability of their company in case of non compliance as well as the potential reputational damage.

There has been no case of non-compliance detected but this could be due to the lack of inspections on behalf of Member States. In March 2006, Greenpeace[144] carried out the testing of laptop computers bought in Europe from five popular brands. It clearly revealed that, just four months before the RoHS deadline, major brands from the electronic industry were not yet ready for the entry into force of the RoHS ban.

The enforcement of the Directive by Member States authorities has been identified as a critical issue. Industry representatives rightly highlight that there will be no incentive for companies to comply with the Directive in the long run if the Member States do not put in place the necessary inspections and controls of electrical and electronic equipment. These can be costly components at a time when Member States are facing budgetary constraints.

However, despite the difficulties in assessing its outcome, the RoHS Directive can be considered as an essential "wake-up call" for the electronic sector. In certain cases, RoHS has encouraged and fostered broader reflections on the environmental impact of electronics.

Lessons drawn from RoHS implementation may be precious for the implementation of future product policy or the new chemicals regulation.

There are fundamental differences between the restrictions imposed by RoHS and the new REACH regulation that entered into force on the 1st of June 2007 with its authorisation system to continue use of substances of very high concern. As an industry expert rightly pointed out "RoHS was about knowing that certain substances were not found in your product; REACH is about knowing what substances are found in your product"[145]. However, the difficulties overcome during the RoHS implementation process such as the means to enhance dialogue along the supply chain and the standardisation of material declaration could facilitate the industry's adaptation to future challenges.

From the regulators' perspective, RoHS has allowed the EU to take the lead in setting product standards and driving product design. The RoHS Directive was copied in South

---

[144] Kevin Bridgen and David Santillo, *Toxic Chemicals in Computers exposed, determining the presence of hazardous substances in five brands of laptop computer,* Greenpeace, September 2006 available from
http://www.greenpeace.org/raw/content/international/press/reports/toxic-chemicals-in-computers.pdf

[145] Interview with industry expert, April 2007

Korea, China and California. In March 2007, a Commission's official summarises the difficulties and the success of the directive: "in a nutshell, because of the many stakeholders involved from different sectors and continents, some of them may have wished that the implementation of the RoHS directive had been smoother and easier to adhere to", adding that companies are coping very well. "They are finally understanding the importance of the changes required and trying to go along with them. The new rules have been broadly accepted and their relevance recognized. An important indicator is also that some of our major trading partners are adopting RoHS-like legislation."[146]

While RoHS can be considered as a successful "wake-up call" for the electronic sector, the future of the directive currently hangs in the balance with the review under way. Commission's officials already indicated a will to "remove any unnecessary administrative burdens or costs that are revealed"[147]. Other rumours see the RoHS Directive merged into REACH's restrictions. The year 2008 will be crucial to determine whether RoHS will be enlarged to a wider scale including more devices and more substances or if, in the eyes of regulators, it has already served its purpose, paving the way for new product and chemicals policies.

---

[146] John Mason, "How is Europe tackling RoHS Legislation", in Electronic News, 27 March 2007, available from http://www.electronicsweekly.com/Articles/2007/03/27/41054/how+is+europe+tackling+rohs+legislation.htm

[147] Ibid.

Bibliography

Berger, Suzanne, *Made in Monde, les nouvelles frontières de l'économie mondiale*, (Editions du Seuil, Paris, 2006)

Berkamp, Lucas and Bunge, Josefina, *EU Product-Related Standards Drive Product Design and Manufacture in Multinational Enterprise*, in Spotlight on international business opportunities, Hunton & Williams, May 2003

Brady, Todd "Material Declaration: EIA, EICTA, JGPSSI Update", *Presentation at NEMI RoHS/Lead-Free Summit*, 19 October 2004, available from http://thor.inemi.org/webdownload/newsroom/Presentations/15.pdf

Bridgen, Kevin and Santillo, David, *Toxic Chemicals in Computers exposed, determining the presence of hazardous substances in five brands of laptop computer,* Greenpeace, September 2006 available from http://www.greenpeace.org/raw/content/international/press/reports/toxic-chemicals-in-computers.pdf

Carbone, James, "RoHS means more electronic component obsolescence", in *Purchasing,* 14 December 2006, available from www.purchasing.com/article/CA6397126.html

Carbone, James, "Supply of RoHS parts tightens", in *Purchasing*, 13 July 2006 available from www.purchasing.com/article/CA6350544.html

Compact Oxford English dictionary, « risk », available from http://www.askoxford.com/concise_oed/risk?view=uk

Directive 2002/95 of the European Parliament and the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, Official Journal of the European Union, 13 February 2003, L 37, pp19-23

E2open, "Case Study Eco-compliance, EMS/ODM company", available from http://www.e2open.com/dynassets/protected/en/E2open_Eco-Compliance_case_study.pdf

Ellenbecker Michael, et al., *Alternatives for significant uses of hexavalent chromium in Massachusetts*, Encyclopedia of Earth, 9 May 2007

Esben Rahbeck-Pedersen and Mette Andersen, "Safeguarding corporate social responsibility (CSR) in global supply chains : how codes of conduct are managed in buyer-supplier relationships", in *Journal of Public Affairs*, August- November 2006, p229

Esty, Daniel C. and Winston, Andrew S. *Green to gold, how smart companies use environmental strategy to innovate, create value and build competitive advantage*, Yale Universtity Press, 2006,

Euractiv, "Comitology", available from http://www.euractiv.com/en/opinion/comitology/article-117454

European Chemicals Bureau, Classification and Labelling databases and IUCLID database available from the following web sites:
http://ecb.jrc.it/esis/index.php?PGM=ein&DEPUIS=autre
http://ecb.jrc.it/IUCLID-DataSheets/7440473.pdf
http://ecb.jrc.it/classification-labelling/search-classlab/

European Commission, *Communication from the Commission on the precautionary principle*, COM (2000) 1, Brussels, 2 February 2000, available from http://ec.europa.eu/dgs/health_consumer/library/pub/pub07_en.pdf

European Commission, *Consolidated text of Annex 1 of Directive 76/769/EEC* available from: http://ec.europa.eu/enterprise/chemicals/legislation/markrestr/consolid_1976L0769_en.pdf

European Commission, *Consolidated Version of Directive 67/548/EEC*, available from http://ec.europa.eu/environment/dansub/main67_548/index_en.htm

European Commission, *Priority substances under the Water Framework Directive*, available from http://ec.europa.eu/environment/water/waterdangersub/pri_substances.htm

European Commision, *Proposal for a directive of the European Parliament and the Council on waste electrical and electronic equipment; Proposal for a directive of the European Parliament and the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment*, COM (2000) 347 final, Brussel, 13 June 2000,

European Commission, *The review of Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment: invitation for comments on topics and for information supply*, available from http://ec.europa.eu/environment/waste/weee/pdf/review_2002_95_ec_directive.pdf

European Trade Union Institute, ETUI-REHS, "Occupational cancers" available from http://hesa.etui-rehs.org/uk/dossiers/dossier.asp

Fairman, Robyn et alii, *Environmental Risk Assessment, Approaches, Experiences and Information Sources,* European Environment Agency, Environmental Issue Report N°4, October 1999, available from http://reports.eea.europa.eu/GH-07-97-595-EN-C2/en/part1-section1.pdf

Franklin, Ray*, Deleting Hexavalent Chromium from Electronics*, ROHSwell 18 February 2005, available from www.rohswell.com/News/Matl001.php

Agnès Ginestet, « Chine : le traitement des DEEE, source de pollution », in *Le Journal de L'Environnement*, 25 July 2007

Greenpeace "Toxic electronics", available from http://www.greenpeace.org/international/campaigns/toxics/electronics/how-the-companies-line-up

Harremoës, Poul (ed), *Late lessons from early warnings: the precautionary principle 1896-2000*, Environmental Issue Report n°22, European Environment Agency, 2001, available from http://reports.eea.europa.eu/environmental_issue_report_2001_22/en/Issue_Report_No_22.pdf

Hawkinson, Chad, *Roadmap to environmental regulatory compliance :Ballooning regulatory environment encourages strategic approach*, 19 September 2005 available from http://www.greensupplyline.com/showArticle.jhtml?printableArticle=true&articleId=170704689

Hemmed, Steve, "RoHS Impacts EMS industry" in *RoHS Case Study and References* available from http://www.rohs101.com/2005/10/27/rohs-impacts-ems-industry/

Hewlett Packard, "HP Global citizenship, Environment, Product Design", available from http://h41111.www4.hp.com/globalcitizenship/uk/en/environment/productdesign/materialuse.html

INERIS, *Fiche de données toxicologiques et environnementales des substances chimiques, chrome et ses dérivés,* Version N°2-4 février 2005, pp1-80 available from www.ineris.fr/index.php?module=doc&action=getFile&id=143

International Agency for Research on Cancer, World Health Organisation, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Chromium, Nickel and Welding*, Volume 49, Last Updated 5 November 1997 available from http://monographs.iarc.fr/ENG/Monographs/vol49/volume49.pdf

International Chromium Development Association, "*Chromium and health a summary*", available from: http://www.icdachromium.com/chromium-introduction.php

International Programme on Chemical Safety, INCHEM, World Health Organisation, *Environmental Health Criteria 61, chromium*, 1988. available from http://www.inchem.org/documents/ehc/ehc/ehc61.htm

Jensen, Pablo *Des atomes dans mon café crème, la physique peut-elle tout expliquer?,* (Editions du Seuil, Paris 2001)

Jorgensen, Barbara, "The "greening" of the supply chain: Suppliers, distributors and customers struggle with RoHS compliance", in Electronic Business, 1 June 2005 available from www.edn.com/article/CA603501.html

Kalimo, Harri, *E-cycling: linking trade and environmental law in the EC and the US* (Hotei Publishing, 2006) 757p

Kennedy, Ian M. (Ed), *Formation and destruction of hexavalent chromium in a laboratory swirl flame incinerator, Combustion science and technology*, abstract available from http://cat.inist.fr/?aModele=afficheN&cpsidt=2500965

Kjaer, Tyge et alii, "Are the European directives WEEE, RoHS and EuP fostering Cleaner Production among the Chinese industry?" available from www.vito.be/erscp2005/documents/papers/PAPER050.PDF

Lowell Center for Sustainable Production, "Chemicals Policy Initiative", available from http://www.chemicalspolicy.org/ExistingEUregulation.shtml

Martindale, Guy and Chai, H.R. "RoHS Implementation: An OEM and EMS Case Study", in *Circuits Assembly*, 1 January 2006 available from http://circuitsassembly.com/cms/content/view/2579/95/

Mason, John "How is Europe tackling RoHS Legislation", in Electronic News, 27 March 2007, available from http://www.electronicsweekly.com/Articles/2007/03/27/41054/how+is+europe+tackling+rohs+legislation.htm

Mason, John F., "Life with RoHS: How is the directive doing in Europe today?", in *Electronic News*, 27 March 2007 available from www.edn.com/article/CA6427406.html?partner=enews

McLoughlin, Aaron "What is in a Name? Regulation of Electrical and Electronic Products", *European Environmental Law Review*, October 2005

Nagurney, Anna et al., *Dynamics of Global Supply Chain Supernetworks*, November 2002

National weight and measures laboratory, "RoHS, due diligence" available from http://www.rohs.gov.uk/content.aspx?id=7

Occupational Safety and Health Administration, U.S. department of Labor, " Small entity compliance guide for the Hexavalent chromium standards", 2006 available from www.osha.gov/Publications/OSHA_small_entity_comp.pdf

Penica, John R. and Hilty, Robert D. , "Chromate and Cadmium:Use and Alternatives" , RoHS support center, Tyco Electronics, available from www.tycoelectronics.com/customersupport/rohssupportcenter/pdf/tyco_hex_chrome_and_cad_overview.pdf

Pressman, Jeffrey L. and Wildavsky, Aaron, *Implementation: How Great Expectations in Washington are Dashed in Oakland; Or Why it's Amazing that Federal Programs Work At All, This Being the Saga of the Economic Development Administration as Told by Two Sympathetic Observers Who Seek to build Morals on a Foundation of Ruined Hopes,* (University of California Press, Berkeley, 1973)

RSJ Technical Consulting, "What is JIG", available from http://www.rsjtechnical.com/WhatisJIG.htm

Schultz, Steven, "RoHS implementation: a summary, Engineers must understand long-term supply chain implications" available from http://avnet.com

Schmid, Jügen at alii, *Dangerous substances in waste*, Technical Report n°38, European Environment Agency, February 2000, available from http://reports.eea.europa.eu/technical_report_no_38/en

Sperling, Ed, "RoHS: Supply chain not yet ready", in Electronic News, 27 October 2005 available from www.electronicsweekly.com/Articles/2005/10/27/36743/rohs+supply+chain+not+yet+ready.htm

Steenhout, *ENVI 042 Ecotoxicologie, DES Gestion de l'environnement*, (2005-2006) p10-11

Tajima, Atsushi, "TC111 Status of Material Declaration WG andChemical Substances in Products Framework PT62476", available from http://www.iec.ch/about/rc/iec-aprc/cent_event/pres_pdf/tajima.pdf

Tyco Electronics, *Tyco Electonics Material Declaration Strategy*, November 2005, available from
http://www.tycoelectronics.com/aboutus/environmentalinitiatives/pdf/TERoHSComplianceMaterial%20DeclPosition_112005.pdf

Wikipedia, “electron configuration” available from
http://en.wikipedia.org/wiki/Electron_configuration

Wikipedia, “electron shell” available from http://en.wikipedia.org/wiki/Electron_shell

Wikipedia “Hexavalent chromium” available from
http://en.wikipedia.org/wiki/Hexavalent_chromium

Wikipedia “periodic table”, available from
http://en.wikipedia.org/wiki/Periodic_Table#Standard_periodic_table

Wikipedia, “original equipment manufacturer” available from
http://en.wikipedia.org/wiki/Original_equipment_manufacturer

Wikipedia, “oxidation state” available from http://en.wikipedia.org/wiki/Oxidation_state

Wikipedia “supply chain” available from http://en.wikipedia.org/wiki/Supply_chain

Wilde, Joseph and de Haan, Esther, *Sneak preview, the High cost of calling, critical issue in the mobile phone industry*, SOMO, Center for research on Multinational corporations, November 2006

Wilson, Richard, “RoHS: Is the supply chain ready?”, in Electronics Weekly, 20 March 2006 available from
http://www.electronicsweekly.com/Articles/2006/03/20/37921/rohs+is+the+supply+chain+ready.htm

Zarogiannis, Panos, Risk & Policy analysts, *Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium, Final report prepared for Department for Environment, Food and Rural Affairs*, (2005) available from
www.defra.gov.uk/environment/chemicals/pdf/hexavalent060203.pdf