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SUBSTITUTION FOR HAZARDOUS CHEMICALS ON AN INTERNATIONAL LEVEL—THE APPROACH OF THE EUROPEAN PROJECT "SUBSPORT"

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ABSTRACT

The systematic description and promotion of substitution options and processes is an underdeveloped and often missing element in chemical management and chemical policy discussions. This article describes major barriers and drivers for substitution, and concludes that more specific information can be an essential instrument to overcome those barriers. It also explains the development and features of a large information tool under development called SUBSPORT, an abbreviation for Substitution Support Portal. SUBSPORT is a three-year European project which aims at providing authorities, industry, and stakeholders with information on alternatives for the effective substitution of hazardous chemicals. It will help companies meet the substitution requirements expressed in national, European Union, and international legislation. SUBSPORT will make information available in four languages.

Keywords: substitution, hazardous chemicals, support portal

Substitution is a preferred risk reduction strategy in environmental policy and in workers' health and safety legislation. Replacing harmful substances and

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processes with less harmful ones or with nonchemical alternatives is widely acknowledged as a very effective strategy to reduce, minimize, or even eliminate risks. Additionally, substitution of dangerous chemicals with less dangerous ones is recognized as an optimal way to overcome the difficulties of complex chemicals regulations.

The Substitution Support Portal or SUBSPORT, is an information tool planned and initiated by a group of university, nonprofit, for-profit, and government institutions that provide substitution support and guidance: Kooperationsstelle Hamburg IFE (Germany), ISTAS (Spain), Chemsec (Sweden and international), and Grontmij (Denmark) with the support of the Lowell Center for Sustainable Production (United States). The idea behind this three-year project was to compile practical experiences in the promotion and support of substitution and to join efforts in the creation of a portal to help companies, governments, workers, and consumers overcome challenges to substitution, as well as providing practical information that would cover as many sectors and hazardous chemical applications as possible.

DEFINING SUBSTITUTION

An understanding of the SUBSPORT Project and its objectives requires a broad understanding of the concept of substitution and the ways in which its key factors have been defined. The term "substitution" is used in legal documents, but without precise definition in its practical and political sense. The perceptions of different stakeholders vary widely, especially regarding the issue of whether substitution should be a "fundamental principle," a "duty to both manufacturers and users," a "preferred risk reduction strategy," or "just another tool for managing the same level of risk."

Some examples of definitions by different stakeholders illustrate this inconsistency. The European Chemical Industry Association (CEFIC) regards substitution as "the replacement of one substance by another with the aim of achieving a lower level of risk" [1]. CEFIC's focus is on controlling risk and not on reducing the intrinsic hazards of a substance. According to this notion, substitution is not a preferred risk reduction strategy but only one strategy of equal standing among many others, such as technical and organizational solutions, including the personal protection of exposed individuals. Chemical enterprises follow this conceptual approach. For example, the chemical company BASF states on its website that "substitution is one option among others of controlling human health and environmental risks. BASF applies substitution as part of its product stewardship policy and Responsible Care® commitment" [2].

The views of the international advocacy group Greenpeace on substitution are significantly different from those of the chemical industry and are much more focused on eliminating hazards and on systematic replacement of all hazardous chemicals. The organization notes: “The Principle of Substitution states that hazardous chemicals should be systematically substituted by less hazardous alternatives or preferably alternatives for which no hazards can be identified” [3]. This statement indicates that this nongovernmental organization’s (NGOs) trust in risk reduction measures other than replacement of hazardous chemicals is low; its political goal is elimination of hazards at the source by the transition to safer alternatives.

It is noteworthy that most political and legal definitions of substitution combine aspects of both hazard elimination and risk reduction. The European Parliament defines the substitution principle as: “the promotion of safer practices and substances,” that is, both the handling (“practices” that achieve risk reduction) and the hazards caused by the intrinsic properties of a substance (“substances”) shall be reduced [4]. A similar approach is used in the Swedish Environmental Code, which defines substitution as the replacement of hazardous substances. It states that:

> Persons who pursue an activity or take a measure, or intend to do so, shall avoid using or selling chemical products or biotechnical organisms that may involve risks to human health or the environment if products or organisms that are assumed to be less dangerous can be used instead [5].

Over time, the terms “hazard” and “risk” have been replaced by the more neutral term “concern” in legal and scientific definitions of substitution. Charlie Auer, former director of the U.S. Environmental Protection Agency’s Office of Pollution Prevention and Toxics, offered this formulation in 2006: “Informed substitution is the considered transition from a chemical of particular concern to safer chemicals or non-chemical alternatives” [6].

Meanwhile, significant European chemical legislation like the Registration, Evaluation and Authorization of Chemicals (REACH) also uses the term “concern” and leaves open the interpretation of whether the “concern” should be reduced by risk reduction or hazard elimination measures (substitution). Preamble 12 of the REACH legislation expresses it this way: “An important objective of the new system to be established by this Regulation is to encourage and in certain cases to ensure that substances of high concern are eventually replaced by less dangerous substances or technologies where suitable economically and technically viable alternatives are available” [7].

Finally, some scientists have added to this definition that the process of substitution needs to achieve a functional equivalent for the replaced substance. In 2003 Joachim Lohse and Lothar Lissner defined substitution as “the replacement or reduction of hazardous substances in products and processes by less hazardous or non-hazardous substances, or by achieving an equivalent functionality via technological or organisational measures” [8].

SUBSPORT considers substitution as a primary measure to reduce risks arising from the use of dangerous chemicals in products and processes. Substitution can support risk reduction for the environment, workers, consumers, and public health. Substitution can be accomplished by the use of an alternative, less hazardous substance as well as through changes to technologies that eliminate the need for hazardous chemicals. We do not consider the reduction of exposures to dangerous substances—for example, by means of protective or containment measures like extraction or waste water treatment plants—to be substitution.

Despite the various definitions and the different levels of support for the concept among stakeholders, there is a common understanding that substitution can be used to reduce chemical concerns through the replacement of hazardous chemicals or through technology change. However, there are still barriers to the effective implementation of the concept. The key question is therefore how to integrate the concept into chemicals management frameworks and make it operational for chemical manufacturers and users. First, we examine how substitution is treated in legal frameworks.

SUBSTITUTION IN CHEMICALS REGULATION FRAMEWORKS

Substitution requirements are common in international, European, and national chemicals legislation [9]. Selected international and European legislation illustrates the variety of approaches toward substitution. At the international level, several agreements on chemicals include substitution requirements. The Stockholm Convention on Persistent Organic Pollutants (POPs) aims at eliminating and phasing out the most hazardous POPs to protect human health and the environment from the impacts of these chemicals. To do so, it establishes the requirement to use substitute or modified materials, products, and processes to prevent the formation and release of POPs. The Persistent Organic Pollutants Review Committee (POPRC) is in charge of reviewing chemicals proposed to be included in this Convention. The POPRC must carry out risk management evaluations of substances, which includes an evaluation of alternatives [10].

The Rotterdam Convention specifies reduction targets for volatile organic chemical (VOC) emissions from stationary and mobile sources and suggests measures to be applied, including substitution of hazardous substances by other chemicals or by different technologies. Some examples of specific sectors and products where substitution may be considered are presented, but examples of substitution are not provided [11]. By requiring the phase-out and elimination of specified ozone depleting substances, the Montreal Protocol stimulated the search for substitute substances and technologies. All parties have to describe their strategies and plans to comply with the provisions, targets, and schedules of the Protocol, while collaborating in finding safer alternatives and making them generally available [12].

The Strategic Approach to International Chemicals Management (SAICM), a United Nations policy framework to promote chemical safety around the world, includes among its objectives: "To promote and support the development and implementation of, and further innovation in, environmentally sound and safer alternatives, including cleaner production, informed substitution of chemicals of particular concern and non-chemical alternatives" [13].

Many pieces of European legislation have promoted substitution of chemicals for environmental and worker protection. For example, an important goal of REACH is to encourage and, whenever possible, to ensure that substances of very high concern are eventually replaced by less dangerous substances or technologies if economically and technically viable alternatives exist [7, Article 60]. In the occupational safety and health area, the EU Chemical Agents Directive and the EU Carcinogens and Mutagens Directive establish substitution as the preferred option to prevent risks caused by chemical agents at workplaces. Also several pieces of environmental legislation include substitution requirements, such as the Biocide Directive [14] and the VOC Directive [15]. For example, the VOC Directive considers substitution the first option in preventing VOC emissions, and special attention is paid to the substitution of carcinogens, mutagens, and chemicals toxic to reproduction when used separately or in preparations. Other technical measures to reduce emissions should be taken only "where appropriate substitutes are not available."

In many European legal texts, a hierarchy of control and risk reduction measures is outlined, with substitution as the most effective and radical measure at the top of this hierarchy, followed by technical and organizational measures, and ending with a more or less passive protection of the target media against chemicals, be it the protection of water, soil, air, wildlife, or human beings. Typical wording in such legislative texts is "Substitution shall by preference be undertaken" in the EU Chemical Agents Directive [16] or "The employer shall reduce the use of a carcinogen or mutagen at the place of work, in particular by replacing it, in so far as is technically possible . . ." in the EU Carcinogens and Mutagens Directive [17].

Unfortunately, this legal preference does not include a detailed definition of how substitution should be practically implemented, compared to other legally acceptable solutions, such as personal protective equipment. As a result legislators have left it to regulatory authorities, companies, and other stakeholders to implement one of the legal options; and stakeholders are rarely obliged to justify their decision for solutions at lower levels of the prevention hierarchy—that is, technical solutions like encapsulation or as a last resort, personal protective equipment. Substitution is therefore a legal preference but in fact is not implemented on a broad scale.

Meanwhile, some legislators have recognized this approach of leaving the choice of risk reduction measures up to implementing bodies as unsatisfactory and ineffective. As a result, more detailed regulations (related to specific sectors or chemicals) have been introduced. The legislative approach to substitution has shifted to include requirements for the assessment of alternatives, in a prescriptive way (as a technical rule to be followed, or as guidance), for example in the REACH guidance for substitution of substances of very high concern or in the German TRGS 600 (Technical Rule for Hazardous Substances) regulatory framework for substitution (see Table 1). Under REACH, for example, all applicants for authorisation should provide an analysis of alternatives considering their risks and the technical and economic feasibility of substitution [7, Article 60]. An example of how TRGS has been used is a comparison of a standard brake cleaning process in auto repair workshops with three alternative solutions that use less hazardous substances. Several health and safety and environmental risks as well as technical criteria, organizational requirements, and costs are described for all the processes of brake cleaning—the conventional one and the three alternatives. Such detailed descriptions for alternatives assessment offer both companies and authorities guidance on how to assess substitution and how to compare advantages and disadvantages of alternatives to a conventionally used chemical. Experience has shown that legal mandates for substitution alone may not lead to substitution actions in practice without technical and research support, particularly when other risk reduction options are legally acceptable.

SUBSTITUTION IN PRACTICE

Legal requirements are undoubtedly the first step in promoting chemical substitution. Replacing harmful substances and processes with less harmful ones or with nonchemical alternatives is seen from the perspective of legislation as one of the most effective strategies of risk reduction—a reduction of risk at the source. Substitution is also seen as a critical means to overcome limits of pollution controls and command and control regulations. However, the concept of substitution seems to have had a limited impact on chemicals management, particularly in the workplace. Substitution is often considered by enterprises as a complex risk reduction strategy with unpredictable costs and consequences (see box) [18–21].

Substitution is carried out in companies in various manners—according to a Dutch study—from sporadic substitution activities (a substitute is well promoted and easily available on the market) to a more systematic approach of identifying and implementing substitutes [22]. Although legislative requirements are recognized by companies as a key driver for substitution, other factors contribute as well, such as vendors' knowledge, management's commitment, supply chain requirements, costs of worker protection and environmental protection, and pressure from the public or from workers, among others.

For example, for small and medium-sized enterprises, with very limited chemical information, assistance provided by vendors is an important driver.

Facade Cleaning

Facade cleaning is one of the sectors using highly toxic and dangerous chemicals manually in an open process. The decision about the techniques and chemicals used is mainly taken by the cleaning companies, based on their experience and skills, and in some the use of chemicals is regulated by standards for restoration. The cleaning tasks are different at every construction site and sometimes even within one facade. Cleaning companies prefer a strong and "one-for-all" product in order to ensure the success of their operations.

There are two main alternatives to conventional cleaners, which are based on acids, strong alkalines, chlorinated solvents, and aromatic solvents. Chemical substitutes are, for example, dibasic esters and similar chemicals with high effectiveness but slow mode of operation. The second and more common route is to switch to mechanical treatment with pressurized or heated water. Water-based high-pressure cleaners operate at a pressure of 70 to 200 bars, with machines using between 5 and 25 liters of water per minute. Both cold-water high-pressure cleaners and hot-water high-pressure cleaners are used, and for special purposes detergents are injected at around 1 to 5 percent.

The major advantage of both alternatives clearly is the reduction of chemical hazards for the environment and the workers. These advantages have to be balanced against the disadvantages: the use of less aggressive chemicals reduces the speed of the working process, full compliance with common regulations or standards for restoration might not be achieved, and the experience of workers with these new technologies is not as great as with conventional chemicals. Pressurized or heated water has other disadvantages: accident risks for workers (contact with high-pressure water and/or hot water), the generation of considerable amounts of wastewater, costs of energy for hot-water cleaning, threat of freezing, and premature decay or oxidation of masonry.

However, only specialised suppliers (e.g., of disinfectants) have the knowledge to provide their customers with safer products. This substitution process led by suppliers is a common model in supplier-client arrangements for smaller manufacturers, where users have limited information on chemicals.

Substitution led by users can be found where large companies—large in respect to their sector-specific market power—develop a policy of substitution and compel their suppliers to eliminate or reduce certain hazardous chemicals. A typical situation can be found in the auto industry and the large electric appliances industry, where suppliers are forced by their customers to apply "black," "grey," and "white" lists of chemicals with subsequent requirements for substitution and reduction. Restricted substances lists are a common way large firms are requiring substitution in their supply chains in response to both

Table 1. Tools and Databases on Substitution, Either Standalone or as Part of Chemical Management Tools

Tool or database	Description
BASTA (Sweden) http://www.bastaonline.se/	BASTA is a database of the Swedish construction industry to accelerate the phasing out of hazardous construction products.
CatSub (Denmark) http://www.catsub.dk/	This website is a catalogue of examples of substitution of hazardous chemicals—case stories describing successful substitutions with less hazardous chemicals. The case stories primarily come from companies, occupational health services, and the Danish Working Environment Authority.
CHEMSEC-SIN List (Sweden) http://www.chemsec.org/list	The aim of the SIN (substitute it now) List is to ensure that the REACH Authorisation procedure is an effective tool to fast-track the most hazardous substances for substitution and to facilitate toxic use reduction by businesses and other actors.
Cleaner Solutions Database (United States) http://www.cleanersolutions.org/	This online tool for solvent substitution in surface cleaning was created by the Surface Solution Laboratory (SSL) at the Massachusetts Toxics Use Reduction Institute (TURI). It links performance evaluation to specific testing parameters and environmental assessments based on the testing performed at the lab.
CLEANTOOL (German) http://www.cleantool.org	CLEANTOOL is a Europe-wide interactive database for parts cleaning, metal surface cleaning, and component cleaning and degreasing, based on real processes in numerous European companies.
COSHH Essentials (United Kingdom) http://www.coshh-essentials.org.uk	This method was developed by the UK Health and Safety Executive (HSE) to help firms comply with UK and European regulations on hazardous chemicals in the workplace. The method is used to determine the appropriate control measures for a given task. It can be used to compare alternatives by determining hazard levels for different substances and products.
EMKG (easy-to-use workplace control scheme for hazardous substances) (Germany) http://www.baua.de/en/Topics-from-A-to-Z/Hazardous-Substances/workplace-control-scheme.pdf	EMKG, developed by the Federal Institute for Occupational Safety and Health (BAuA) provides advice on controlling the use of chemicals.

Table 1. (Cont'd.)

Tool or database	Description
EU-OSHA Dangerous substances website (European Union) http://osha/europa.eu/en/topics/ds	This website provides background information and case studies, including substitution cases.
GISBAU/GISCHEM/GISMET (Germany) www.gisbau.de www.gischem.de www.gismet.de	GISBAU/GISCHEM/GISMET provide interactive access to occupational safety and health data and instructions for more than 30,000 chemical products and preparations when a chemical product consists of only one substance like hydrochloric acid.
IFCS Substitution and Alternatives Case Studies, Examples and Tools) (International) http://www.who.int/ifcs/documents/standingcommittee/substituti7on/en/index.html	This website, developed by a working group of the Intergovernmental Forum on Chemical Safety, provides a set of case studies, examples, and links to tools on chemical substitution and alternatives assessment.
IMDS (International Material Data System) (International) http://www.mdsystem.com/index.jsp	The IMDS is a material data system of the automobile industry. All chemical materials used for car manufacture are archived and maintained. In this way it is possible to meet the obligations placed on car manufacturers, and thus on their suppliers, by national and international standards, laws, and regulations.
KEMIguiden (Sweden) http://www.prevent.se/kemiguiden/	KEMIguiden is a Swedish interactive support tool for small and medium-sized enterprises to facilitate an easy achievement of compliance with legislation.
PAN Pesticides Database– Alternatives to Pesticides (International) http://www.pesticideinfo.org/Alternatives.html	This page provides links to organizations that provide information on nontoxic or least toxic approaches to pest management.
PPGEMS (United States) http://www.turi.org/library/other_online_resources/web_links_at_p2gems__1	This database of the Toxics Use Reduction Institute provides links to websites offering information about technologies, emerging technologies, or technology change tools that support pollution prevention.
RiseTox (Spain) http://www.istas.net/risctox/index.asp	ISTAS has developed several online tools to help safety representatives prevent chemical risks, including a database on hazardous properties of 100,000 substances (RiscTox), a database on alternatives for substitution (Alternativas), and a tool to assess and compare alternatives.

Table 1. (Cont'd.)

Tool or database	Description
Stoffenmanager (Netherlands) https://www.stoffenmanager.nl/default.aspx	Stoffenmanager is an interactive support tool for Dutch small- and medium-sized enterprises, to facilitate easy achievement of compliance with chemical legislation.
SUBSPORT (European Union) http://www.subsport.eu	SUBSPORT is a publicly available internet portal that constitutes a source of information on alternative substances and technologies, and of tools and guidance for substance evaluation and substitution management. The portal's main goal is to support companies in fulfilling substitution requirements deriving from agreements and legislation. A first version is expected for 2012 in four languages.
Substitution-cmr (France) http://www.substitution-cmr.fr/	A tool for all professional actors in the area of substitution, Substitution-cmr, created by the French Agency for Environmental and Occupational Health Safety (ANSES) is especially designed to replace category 1 and 2 carcinogens, mutagens, and reproductive toxicants (CMRs).
Technical Rule for Hazardous Substances 600 (TRGS) (Germany) http://www.baua.de/nn_78960/en/Topics-from-A-to-Z/Hazardous-Substances/TRGS/TRGS-600.html?_nnn=true	The German Hazardous Substances Ordinance (GefStoffV) states that the employer has the duty to determine, test, and decide on substitution and to document it. TRGS 600 includes a framework for deciding on substitution that considers criteria for assessing technical suitability and health and physicochemical risks of alternatives.

legal demands and market demands. Other common ways include positive lists of preferred substances, requiring eco-labelled products, and including environmental criteria in green procurement.

A number of large companies across sectors have instituted chemicals management/safer chemicals programs that require information on chemical content of products and substitution of high-concern chemicals. These companies—in a variety of sectors, such as the electronics, manufacturing and consumer products industries—include ABB, Boots, Marks & Spencer, EUREAU, Scania, IKEA, Skanska, Heidelberger, Bosch Siemens, H&M, NCC, and Volvo Technologies.

In addition, large companies that cooperate with many other companies and the public sector on a regular basis (e.g., construction companies) have developed strategic approaches to avoid hazardous substances. The reasons for this are, on one hand, to protect their workers, and on the other, to avoid additional costs for compliance with extensive health and safety and environmental protection requirements and safe disposal.

Many large companies are driven to substitution in order to avoid incidents or public criticism that might affect their reputations. Companies producing consumer goods (e.g., sportswear and shoes, furniture, clothes) seem to be highly vulnerable to such attention and have introduced strict rules to eliminate or reduce hazardous chemicals.

The pressure of safety representatives and trade unions has also forced some companies to substitute hazardous substances that cause occupational health problems. Several examples can be found in Spain, where the intervention of health and safety representatives from the trade union Comisiones Obreras forced companies to substitute for carcinogens, reproductive toxicants, neurotoxicants and even endocrine disruptors [23]. Training programs on chemical substitution for health and safety representatives, combined with the development of detailed substitution assessment tools (such as RiscTox, which contains information on the health and environmental risks of more than 100,000 chemicals as well as information on alternatives) and case studies, provide important foundations for workers to advocate to employers for safer chemicals, processes, and products in an informed manner.

In addition, with the progress of REACH, more and more information on the hazardous effects of chemicals will become publicly accessible. This will influence companies and other stakeholders' behavior. Companies are now closely monitoring developments with regard to the classification and labeling of chemicals they use. In this respect REACH may become an important driver for future substitution processes, particularly for substances labelled as hazardous.

While there may be strong but often not very specific pressures to implement substitution from legislation, markets or the media, there are still many internal obstacles to substitution in enterprises. Such obstacles can be economic barriers, technological barriers, performance barriers, lack of knowledge both of chemical dangerous properties and of alternatives, lack of enforcement, or the lack of motivation and awareness.

For example, the CADimple project analyzed and evaluated the impact of the Chemical Agents Directive in EU Member States in terms of specific prevention approaches adopted by Member States, and by private and public sector employers, on protecting workers' health and safety from risks due to exposure to hazardous substances at work. As part of the project, Dutch, German, and Spanish occupational safety and health (OSH) practitioners and workers' representatives described their impressions of the barriers to substitution in enterprises [20, Chapter 7]:

> In theory it is a very good method. In practice it is hard. A lot of companies abandon this strategy because it costs too much (e.g., the whole production line should be adapted) or the appropriate products/substances are not available. (Netherlands, External OSH services, OSH practitioner)

> Substitution is without a doubt the best method for risk minimisation. However, substitution is rarely carried out in practice because economic reasons can always be found that stand in the way of an exchange or substitute for a hazardous material. So, for example, the material qualification measures are supposedly so time-consuming and cost-intensive that power stations cannot do without hydrazine use, although numerous alternatives are known; these, however, have only been certified up to now for other working materials than the one in question. (Germany, Representative of a Professional Association, OSH practitioner).

Findings in Spain mirror these, suggesting that the hierarchy of controls is often reversed because of cost considerations. As such, the use of personal protective equipment predominates and as a consequence, implementation of prevention is poor. Worker representatives interviewed in Spain as part of a Comisiones Obreras–led project on solvent substitution describe these barriers:

> The cheapest measure is chosen and which has the least consequence for the product and process. (Spain, Employee's representative)

> Companies tend to select the measure which is the easiest to implement and/or the cheapest. Recommendations from the risk assessment are ignored and personal protective equipment is (continued to be) applied. (Spain, OSH Practitioner)

> The hierarchy of measures does not normally play a role in the decision on which measures to implement. It is believed to be not well known. Mostly the cheaper options are selected. (Spain, Labour Inspector)

As a consequence, there is a great need for supporting tools and guidance to support substitution efforts.

CURRENT TOOLS AND GUIDANCE

Recognizing this need, tools, databases, and guidance documents to support substitution have been developed by a number of public authorities, industry associations, and related institutions, scientific bodies, and NGOs.

According to our experience, most of them are not specific to an industry sector, the type of chemical, or the type of process. Many substitution guidance documents are very general and do not go beyond the basic description of the substitution principle or simple steps—that is, replacing the hazardous by the less hazardous [24]. Process guidance that outlines a structured approach to substitution is scarce [25, 26]. There is a range of tools to support substitution, including tools that are designed to identify and screen out hazardous chemicals, tools that are designed to compare alternatives (e.g., decision criteria), and tools that are designed to identify safer chemicals. Some publicly available tools in Europe designed to partially or wholly support substitution include the Dutch

Stoffenmanager, the Swedish Kemiguiden, the German EMKG, and the Spanish RiscTox as well as software tools from private publishers (Table 1).

Several organizations have also developed databases with alternatives for different substances (Substitution-cmr database for alternatives to carcinogens), products (Clean Solutions Database for cleaners, Pesticide Action Network for pesticides) or applications (CLEANTOOL for metal parts cleaning). A number of databases include substitution case stories (CatSub, CLEANTOOL, Substitution-cmr and RiscTox) and some databases include general resources for pollution prevention (PPGems) or substitution (IFCSs) (see Table 1).

A number of methods to assess and compare alternatives have also been developed by different stakeholders (Table 2). Most of these methods consider intrinsic properties of chemicals and are used to assess and compare individual substances (Green Screen, Quick Scan); several compare products (Column Model, MAL Code); and some are also used to compare substances, products and processes (P2OASys).

While useful, these tools do not always lead to an unambiguous, easy decision as to substitutes because even in the absence of economic and technical considerations, conflicting targets and possible shifts in risks (e.g., from toxicological impacts to increased energy consumption or accident risks for workers) may occur and hence need to be evaluated and balanced. In many cases, information on alternatives (toxicity, performance) may not be available.

Further, due to lack of capacity and resources, smaller companies (but also enterprises without technical capacity or that are not manufacturers of particular products) often need to rely on easily accessible and visible tools when comparing alternative substances (i.e., many of the previously developed tools may be too sophisticated for many users), such as classification and labeling and also the information contained in safety data sheets. Some private software providers are beginning to develop tools that would allow non-experts to identify safer alternatives.

An analysis of the various tools, combined with our experience in training, research, and support of safer alternatives implementation, indicates that the most common approach for substitution assessment is to compare the current technology with one alternative (occasionally, with more than one) using a basic process model and a number of decision considerations. Typically the following are considered in the comparative assessment:

- risks of the alternatives (health and safety risks caused by chemicals, other health risks, environmental risks);
- technical suitability (compliance with product and process specifications, identification of necessary process or product adaptations);
- work organization (are changes needed—for example, use of different chemicals to achieve the function, changes in the workplace to accommodate the chemical change (e.g., in the cleaning sector));

Table 2. Alternative Assessment Methods

Assessment method	Description
Column Model for Chemical Substitutes Assessment (Germany) http://www.dguv.de/ifa/pra/spaltenmodell/index.jsp	The Institute for Occupational Safety (IFA) of German accident insurance businesses developed the Column Model to provide industry with a practical tool for identification of alternative substances. This is a simplified method to make a preliminary comparison between the risks of the different substances and products and offer a quick judgment on the convenience of substitution.
Green Screen for Safer Chemicals (United States) http://www.cleanproduction.org/Greenscreen.php	The Green Screen for Safer Chemicals, developed by Clean Production Action, is a hazard-based screening method that is designed to inform decision-makers in businesses and governments, as well as individuals concerned with the risks posed by chemicals, and to advance the development of green chemistry. The Green Screen defines four benchmarks on the path to safer chemicals, with each benchmark defining a progressively safer chemical. Green Screen assesses chemicals on the basis of intrinsic hazards.
Determination and work with code numbered products (MAL Code) (Denmark) Executive Order on Work with Code Numbered Products http://www.at.dk/~/media/E6DCB04DD3264D0CB2AA8D80AA259028.ashx	The National Working Environment Authority in Denmark has developed a code number system to provide users with a practical tool for choosing less harmful products and determining working routines and prevention measures for products with different code numbers. Once a code number is designated to a product it is easy for a user to compare products. The higher number—the more hazardous.
Pollution Prevention Options Analysis System (P2OASys) (United States) http://www.turi.org/home/hot_topics/cleaner_production/p2oasys_tool_to_compare_materials	P2OASys was designed by the Toxic Use Reduction Institute (TURI) to provide companies with a framework for complete and systematic evaluation of potential hazards of processes and products in use, and also of alternatives.
PRIO—a tool for risk reduction of chemicals (Sweden) http://www.kemi.se/, the PRIO-Guide under http://www.kemi.se/templates/PRIOframes4045.aspx	Developed by the Chemicals Agency of Sweden (KEMI), PRIO facilitates the assessment of health and environmental risks of chemicals. PRIO includes: a database of 4472 substances with properties hazardous to the environment and health that should be prioritized in risk-reduction work; priority-setting guide; and guidance on how to reduce chemical risks in practical use.

Table 2. (Cont'd.)

Assessment method	Description
Quick Scan (Netherlands) http://www.rijksoverheid.nl/documenten-en-publicaties/publicaties-pb51/uitvoering-strategie-omgaan-met-stoffen.html	Quick Scan is a screening method developed by the Dutch Ministry of Housing, Spatial Planning and Environment as part of a new chemicals policy to ensure that the potential risks and hazards associated with the use of substances in each stage of their life cycles are sufficiently controlled so as to remove, or to reduce to a negligible level, any harmful effects caused by substances on man or the environment.

- costs (material costs, material consumption, equipment and investment costs, energy, labour costs, organisation costs, transport costs, insurance costs, storage costs, costs of different protective measures);
- generation of solid waste or sewage (treatment and/or disposal equipment and organisation, treatment and/or disposal costs);
- other influencing factors such as corporate image, employee satisfaction, sustainability / planning reliability; and
- shift of risks—for example, between environmental media (from air to water), from health risks of a toxic substance to safety risks of a flammable substance (halogenated solvents to flammable solvents).

These considerations also form part of the methodology undertaken in the Subsport project.

SUBSPORT APPROACH

In 2007, several organizations that work on substitution from different perspectives at both the national and international levels (Kooperationstelle Hamburg, ISTAS, Lowell Center for Sustainable Production, and Chemsec) began discussing how to help and support enterprises and other interested stakeholders to promote substitution and to put it into practice.

Specific identified needs included, among others, support to find alternatives to POPs regulated under the United Nations Stockholm Convention; support to facilitate substitution during REACH authorization procedures, including identification of alternatives and guidance on alternatives assessment implementation; structured and accessible information on alternatives, tools, practical examples and tutorials to facilitate substitution in workplaces; and the building of cooperation between different stakeholders.

The European Commission LIFE+ Programme, with the financial assistance of the Federal Institute for Occupational Safety and Health of Germany (BAuA) and the Federal Ministry of Agriculture, Forestry, Environment and Water Management of Austria gave these organizations the opportunity to develop SUBSPORT. The goal of the project is to develop an internet portal, a comprehensive and innovative information resource on safer alternatives to the use of hazardous chemicals.

SUBSPORT seeks to overcome particular barriers to substitution. It is designed to help enterprises identify legal requirements for substitution quickly and easily. The portal includes criteria to identify substances of high concern to help companies prioritize chemicals to substitute. These criteria refer to acute toxicity and chronic toxicity (such as carcinogenicity, mutagenicity, reproductive toxicity, endocrine disruption, sensitization of the skin or respiratory system, neurotoxicity, and developmental toxicity) to environmental concerns (persistence and/or bioaccumulation, ozone depletion, environmental toxicity, aquatic toxicity) and to safety concerns (fire and explosion). It also includes a database of substances that have been identified as being of high concern by different governmental and nongovernmental organizations, including substances on restriction lists from large companies or industry associations.

SUBSPORT offers an overview of tools to help companies assess and compare alternatives in order to allow them to choose the most suitable tool for their substitution needs. For example, a simple substitution requirement at a specific workplace can be assessed via a less advanced and less complex tool; or specific sector information (with information on performance characteristics of a particular alternative) might be more useful for some companies than general information.

The experience of the SUBSPORT partners has shown that case studies play a core role in promoting substitution. Learning from colleagues in the same sector or at the same workplace is an effective means to motivate other actors in companies. Therefore SUBSPORT compiles substitution case stories, including "easy cases," where a simple exchange of a chemical substance or preparation was needed; examples of cases where adaptation of processes was required; and information on those complex cases which even required research and development.

In order to facilitate the identification and assessment of alternatives for the REACH authorization procedure, the Stockholm Convention, and other international legislative frameworks, the SUBSPORT project team and its network of experts will analyze in detail the substitution options for 10 substances of high concern.

These substances represent a broad range of sectors and applications in order to achieve the broadest impact:

1. chloroalkanes
2. chromium VI and compounds
3. bisphenol A
4. dialkylphthalate

5. lead and its inorganic compounds
6. octylphenol, nonylphenol
7. trichloroethylene, tetrachloroethylene
8. formaldehyde
9. brominated flame retardants: hexabromocyclododecane (HBCDD); tetrabromobisphenol A (TBBPA); decabromodiphenylether (deca-BDE); and pentabromodiphenylether (PBDE)
10. butylparaben

The project partners will offer the following information on SUBSPORT's internet portal and make it publicly available in four languages:

- a structured presentation of legal information on substitution in the EU and at international and national levels;
- a database of hazardous substances that are legally or voluntarily restricted or are subject to public debates;
- a compilation of prevailing criteria for the identification of hazardous substances;
- a description of existing substitution tools to compare and assess alternative substances and technologies;
- a database comprising general information on alternatives to the use of hazardous substances;
- a database containing detailed and evaluated case studies which document practical experiences in the substitution of 10 selected substances of very high concern in various essential applications;
- materials for substitution training programs; and
- interactive elements for discussion, networking, exchange of information and experience, as well as for updates.

In addition, the project aims at creating a network of experts and stakeholders who would become actively involved in substitution efforts. The network should assist in the development of content and the promotion of the portal as well as ensuring database updates and maintenance. Networking started with the creation of an expert committee made up of representatives of employers, unions, industry, government, and NGOs from all over Europe and also from the Lowell Center for Sustainable Production in the United States.

Finally, training is also part of SUBSPORT activities. The project will develop training guidance materials and carry out 15 training sessions on substitution for key stakeholders, including: environmental and health and safety technicians from companies, trade unions or governmental organizations; experts from NGOs, consultancies, industry, and consumer organizations; academics; and policymakers. Participants of these training seminars should learn a systematic approach towards effective substitution, and alternatives assessment methods. They can then become change agents in their own organizations.

CONCLUSION

It is interesting to see that substitution of chemicals is back on the public and research agenda, as in the last 10 years there has been very little financial or technical support for substitution from public authorities. Public and scientific concerns about health and environmental hazards, safety problems regarding the handling of chemicals in many companies, and the implementation of REACH and other legislation have contributed to this return.

Substitution is the preferred option in the prevention hierarchy as it eliminates risks at the source, avoiding the need for expensive environmental and health and safety control measures. The reduction of chemical risks by control solutions will continue to be important, but these can fail and are rarely a fully effective strategy. Substitution is a necessary complementary concept, not only in legislation, but also in practice.

The practical implementation of substitution has shown that it can be a complex process. Implementation is often disregarded and can be difficult in practice. Also, in order to avoid the shift of risks, all areas of potential risk have to be assessed and a comparison of levels and types of hazard factors is necessary. As such there is a need for a wide range of expertise and tools for assessment and decision-making. The rigorous work on the practical implementation of safe substitutes needs to be supported by specific and comprehensive information.

Case studies and practical information have been shown to play an important role in the implementation of substitution, in particular in small and medium-sized enterprises with fewer resources. Existing online databases receive thousands of visits per day from companies searching for safer products and processes.

It is notable that the work of SUBSPORT is based on individual initiatives from the sector of occupational safety and health, from trade unions, from environmental NGOs and from a small group of scientists. With the exception of the Substitution-cmr (carcinogen, mutagen, and reproductive toxicant) database from French Agency for Environmental and Occupational Health Safety, government agencies in Europe have not developed any substitution database.

However, many of the earlier substitution projects of the SUBSPORT project partners were moderately supported by European and national governments. SUBSPORT represents the first time that considerable funding from a European source is available to support substitution activities. The SUBSPORT project's approach is supported by many important stakeholders from national governments and also by the European Agency for Safety and Health at Work. There are good probabilities that major stakeholders, members of the scientific community, and the industrial sector will support the concept of SUBSPORT with their expertise and financial contributions. A gate is now open for a "sustainable" database to support the practical implementation of substitution for hazardous chemicals.

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NOTES

1. The European Chemical Industry Council, *CEFIC Paper on Substitution and Authorization under REACH*, May 23, 2005.
2. BASF, "Substitution," http://www.basf.com/group/corporate/en/sustainability/dialogue/in-dialogue-with-politics/european-chemicals-policy/substitution (accessed June 12, 2011).
3. Greenpeace, *Safer Chemicals Within Reach: Using the Substitution Principle to Drive Green Chemistry*, February 2005, http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/6031.pdf (accessed June 12, 2011).
4. European Parliament, Report on the Commission White Paper on Strategy for a Future Chemicals Policy (A5-0356/2001), October 17, 2001, http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A5-2001-0356+0+DOC+XML+V0//EN (accessed June 12, 2011).
5. Swedish Environmental Code (Part 1, Chapter 2, Section 6), http://www.sweden.gov.se/content/1/c6/02/28/47/385ef12a.pdf (accessed June 12, 2011).
6. Charles Auer, "U.S. Experience in Applying 'Informed Substitution' as a Component in Risk Reduction and Alternatives Analyses," Chemicals, Health, and the Environment Conference, Ottawa, Ontario, October 31-November 1, 2006.
7. European Union, Regulation Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), Establishing a European Chemicals Agency (Regulation (EC) No 1907/2006), December 18, 2006, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=oj:1:2006:396:0001:0849:en:pdf (accessed June 12, 2011).
8. Joachim Lohse et al., *Substitution of Hazardous Chemicals in Products and Processes*, May 2006, http://ec.europa.eu/environment/chemicals/pdf/substitution_chemicals.pdf (accessed June 12, 2011).
9. Swedish Chemicals Agency (KEMI), *The Substitution Principle*, August 2007, http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Report8_07_The_Substitution_Principle.pdf (accessed June 12, 2011).
10. United Nations Environment Programme, "Stockholm Convention," http://chm.pops.int/Convention/tabid/54/language/en-US/Default.aspx (accessed June 12, 2011).
11. United Nations Environment Programme, "Rotterdam Convention," http://www.pic.int/home.php?type=t&id=49 (accessed December 23, 2010).

12. United Nations Environment Programme, "The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer," http://ozone.unep.org/Ratification_status/montreal_protocol.shtml (accessed June 12, 2011).
13. United Nations Environment Programme, "Strategic Approach to International Chemicals Management," http://www.saicm.org/index.php?ql=h&content=home (accessed June 12, 2011).
14. European Union, *Directive Concerning the Placing of Biocidal Products on the Market* (Directive 98/8/EC), February 16, 1998, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:123:0001:0063:EN:PDF (accessed June 12, 2011).
15. European Union, *Directive on the Limitation of Emissions of Volatile Organic Compounds Due to the Use of Organic Solvents in Certain Activities and Installations* (Directive 1999/13/EC), March 11, 1999, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1999L0013:19990329:EN:PDF (accessed June 12, 2011).
16. European Union, *Council Directive on the Protection of the Health and Safety of Workers from the Risks Related to Chemicals Agents at Work* (98/24/EC), April 7, 1998, http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31998L0024&model=guichett (accessed June 12, 2011).
17. European Union, *Directive on the Protection of Workers from the Risks Related to Exposure to Carcinogens or Mutagens at Work* (Directive 2004/37/EC), April 29, 2004, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:229:0023:0034:EN:PDF (accessed June 12, 2011).
18. Lothar Lissner, "Analysis of Public Incentives for the Substitution of Dangerous Chemicals—Using the Examples of Germany, the Netherlands and Sweden," December 31, 2007, http://oops.uni-oldenburg.de/volltexte/2007/61/pdf/lisana07.pdf (accessed June 12, 2011).
19. Andreas Ahrens et al., *Hazardous Chemicals in Products and Processes—Substitution and Beyond* (Heidelberg: Physica-Verlag, 2006).
20. CADimple, *Contract to Analyse and Evaluate the Impact of the Practical Implementation in the Workplace of National Measures Implementing Directive 98/24/EC on Chemical Agents*, [unpublished final report], August 2010.
21. Lothar Lissner and Réka Zayzon, "Is the European Directive 98/24/EC on Chemical Agents Effective? Evaluation of its Practical Implementation at Workplaces," *Gefahrstoffe— Reinhaltung der Luft* 71(6) (2011): 247-254.
22. I. A. Koval, M. J. M. Jongen, and R. Visser, *Substitutiebeslissingen bij bedrijven: kansen op succes (Substitution decisions of enterprises—chances for success)*, 2007, http://www.arbeidshygiene.nl/~uploads/text/file/2007%203-4%20onderzoek%20koval%20et%20al.pdf (accessed June 12, 2011).
23. Eva Canaleta and Dolores Romano, *Catálogo de Experiencas Sindicales de Sustitución (Trade Union Substitution Experiences Catalog)*, 2009, http://www.istas.net/risctox/gestion/estructuras/_3532.pdf (accessed June 12, 2011).
24. United Kingdom Health and Safety Executive, *Seven Steps to Successful Substitution of Hazardous Substances*, 1994.
25. Rafael Gadea, Dolores Romano, and Tatiana Santos, *Sustitución de Sustancias Disolventes Peligrosas: Guía para Delegados y Delegadas de Prevención*, 2007, http://www.istas.net/web/abreenlace.asp?idenlace=4869 (accessed June 12, 2011).

26. Mark Rossi, Joel Tickner, and Ken Geiser, *Alternatives Assessment Framework of the Lowell Center for Sustainable Production*, July 2006, http://www.chemicalspolicy.org/downloads/FinalAltsAssess06.pdf (accessed June 12, 2011).

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