Undisclosed chemicals — implications for risk assessment: A case study from the mining industry

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Abstract

Many of the chemicals used in industry can be hazardous to human health and the environment, and some formulations can have undisclosed ingredients and hazards, increasing the uncertainty of the risks posed by their use. The need for a better understanding of the extent of undisclosed information in chemicals arose from collecting data on the hazards and exposures of chemicals used in typical mining operations (copper, platinum and coal). Four main categories of undisclosed chemicals were defined (incomplete disclosure; chemicals with unspecific identities; relative quantities of ingredients not stated; and trade secret ingredients) by reviewing material safety data sheet (MSDS) omissions in previous studies. A significant number of chemicals (20% of 957 different chemicals) across the three sites had a range of undisclosed information, with majority of the chemicals (39%) having unspecific identities. The majority of undisclosed information was found in commercially available motor oils followed by cleaning products and mechanical maintenance products, as opposed to reagents critical to the main mining processes. All three types of chemicals had trade secrets, unspecific chemical identities and incomplete disclosures. These types of undisclosed information pose a hindrance to a full understanding of the hazards, which is made worse when combined with additional MSDS omissions such as acute toxicity endpoints (LD50) and/or acute aquatic toxicity endpoints (LC50), as well as inadequate hazard classifications of ingredients. The communication of the hazard information in the MSDSs varied according to the chemical type, the manufacturer and the regulations governing the MSDSs. Undisclosed information can undermine occupational health protection, compromise the safety of workers in industry, hinder risk assessment procedures and cause uncertainty about future health. It comes down to the duty of care that industries have towards their employees. With a wide range of chemicals increasingly used, there is a balance that needs to be reached between disclosure requirements, trade secret provisions and definitions of hazardous ingredients for market needs, and the information required to protect the health of their workers.

Keywords

Mining chemicals; Undisclosed ingredients; Inaccurate material safety data sheets

1. Introduction

Many of the chemicals used in industry and consumer products can be hazardous to human health and the environment and the majority have yet to be tested for potential toxicity and impact on human diseases (Haynes, 2010). There is relatively little information on chemical constituents in many types of products such as personal care products and fragrances, and of those used in industry including cleaning agents, paints, lubricants, adhesives, pesticides, motor oils and dispersants. Usually ingredients and their hazards in chemical formulations are communicated to workers and consumers through material safety data sheets (MSDSs). These are documents provided with chemicals, as a guide for workers on the safe handling and use of the substances. The minimum requirements for the section on the composition/information on ingredients for MSDSs for mixtures, as documented by the UN Globally Harmonised System (UN GHS) are that: the ingredients are listed with their CAS numbers (or other identification number); full chemical name and concentration of all ingredients which are classified as a health hazard. There is however a significant percentage of chemicals in which some ingredients and their hazards are undisclosed, increasing uncertainty associated with their use. Steinemann (2009) defined undisclosed ingredients as chemicals in products that may not be identified through information provided to the public or regulatory services. Undisclosed information can undermine occupational health protection, compromise the safety of workers in industry, hinder risk assessment procedures and lead to uncertainty about future health.

Several previous studies have identified undisclosed ingredients in a range of consumer products and the issues associated with withholding information about ingredients in MSDSs have centred on the risk of injury to users as a result of inadequate hazard communication (Kolp et al., 1995, Welsh et al., 2000). This can be a barrier to chemical risk assessment procedures that should consider both the hazards and exposures to determine the overall risk posed by the chemicals. If this assessment is carried out at a company level, the first point of reference about the chemical hazards would be the MSDSs. It is important therefore that this source of information is complete and accurate, especially when the formulations in question are multi-component substances. The information in MSDSs is also important to the exposure assessment process and to monitor if the exposure limits of the ingredients listed in the MSDSs are adhered to. The MSDS regulations in different countries do not require the manufacturer to disclose ingredients regarded as nonhazardous, and procedures have always been in place for business confidentiality claims. Nevertheless, chemical legislation is being tightened globally, as the considerable extent of the health and

safety risks associated with exposure to chemical products is recognised. Mining operations use a wide range of different chemicals from specialist chemicals to those that are commercially available and with hazard classifications that range from known carcinogens to non-classifiable. The use patterns range from milligrammes per month to tonnes per day; and chemical exposure controls vary from local exhaust ventilation to the use of personal protection equipment (PPE). Mining companies are frequently multinational organisations and have to comply with different chemical legislations and different MSDSs. The mining industry is therefore an ideal case study to understand how undisclosed information in MSDSs hinders chemical risk assessments.

This work considered three different mine site commodities — copper, platinum and coal in order to understand the range of undisclosed chemicals used in their operations. These range from flotation reagents to separate ore minerals from gangue; oils, greases and lubricants in machinery maintenance; laboratory chemicals for analysis; explosives in the mines; and agricultural, gardening to cleaning products for the general maintenance of sites. Therefore, it focuses on the mining industry to evaluate the significance of undisclosed information in the chemical risk assessment process; and identify the impact on chemical management and the key issues faced by companies protecting their workers from uncertain chemical risks. This paper also reviewed previous studies of undisclosed ingredients, considered examples of how undisclosed, incomplete and inaccurate information can cause injury to human health and/or the environment, and examined chemical regulations that affect confidential business information (CBI) and MSDSs in a few key countries where there are mining activities.

2. Review of literature on previous MSDS deficiencies

It is widely accepted that trade secrecy undermines risk management, as it transfers the health and safety options from those who are exposed to those who profit. Secrecy also subsidises existing technologies, disguising their costs, and suppressing incentives to develop better ones (Lyndon, 2011). A range of consumer products contain undisclosed information, including fragranced products (such as air fresheners, laundry supplies and cleaners), paint thinner products, synthetic lubricants, detergents and oil dispersants. These studies have evaluated the chemical identification of ingredients provided in the MSDSs and some of the key omissions have been outlined as follows:

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The use of ranges instead of specific quantities of ingredients, which makes estimating the total amount of specific ingredients difficult (Winder and Ng, 1995) and creates uncertainty about dose and exposure (Schmidt, 2010).

- Failure to disclose any hazardous ingredients in the MSDS despite hazard inferences in statements about health effects, first aid and personal protection equipment (PPE) recommendations (Kolp et al., 1995, Welsh et al., 2000).
- The use of nonspecific chemical names, such as the use of a chemical family or class (Kolp et al., 1995, Winder and Ng, 1995).
- MSDSs with ingredients listed as trade secrets, which are exempt from public disclosure (Kolp et al., 1995, Steinemann, 2009, Winder and Ng, 1995).
- Ingredients regulated as toxic or hazardous under federal law in the USA, identified through chemical analysis, but were not disclosed in the MSDSs of fragranced consumer products (Steinemann, 2009).
- The failure of some MSDSs to adequately describe the known reproductive toxicity effects of some chemicals (Paul and Kurtz, 1994, Welsh et al., 2000).

Although information about chemical hazards has now become more accessible to the public, and consumers can make more informed choices about the products they choose, chemical legislation globally is still trying to find a balance between adequately informing the public of hazards and maintaining the competitiveness of the chemical industry by protecting business confidentiality. The main focus of each study, the country in which the study was conducted, the relevant MSDS and the conclusions are summarised in chronological order in Table 1.

Table 1. A summary of the key previous studies on undisclosed substances in consumer products (given in chronological order).

Year	Title and author of paper/article	Main concern of paper/article	Country	MSDS regulation	Conclusion
1994	Analysis of reproductive	The reproductive health hazard descriptions on	USA	Occupational Safety and Health Administration	The information provided to employers

Year	Title and author of paper/article	Main concern of paper/article	Country	MSDS regulation	Conclusion
	health hazard information on material safety sheets for lead and the ethylene glycol ethers - Paul and Kurtz	nearly 700 MSDSs for lead or ethylene glycol ether containing products were analysed, and the results showed that over 62% of the MSDSs made no reference whatsoever to effects on the reproductive system.		(OSHA) Hazard Communication Standard.	and workers about reproductive and developmental risks is grossly inadequate and much broader efforts are needed to assure that the health protective intent of the right-to-know legislation is realised.
1995	The problem of variable ingredients and concentrations in solvent thinners - Winder and Ng	Evaluated the contents of 20 proprietary thinner products using MSDSs, as part of a multidisciplinary study on solvent exposure and health effects in spray-painter apprentices.	Australia	In 1995, the Hazardous Substance Regulations to Occupational Health and Safety legislation was introduced in Australia, which meant that the provision of MSDS for hazardous substances had become mandatory.	The proportion of ingredients can vary quite significantly, and the hazards may change accordingly, and educational programmes should be developed that are aimed at informing users that thinners are different materials with different ingredients.
1995	Assessment of the accuracy of material safety data sheets - Kolp et al.	A study evaluated 150 MSDSs for the accuracy and completeness of five areas of information,	USA	OSHA Hazard Communication Standard.	Without the identification of a specific chemical name, no evaluation could be performed of the accuracy of the material presented.
2000	The verification of hazardous ingredients — disclosures in selected material safety data sheets - Welsh et al	Results were presented for three cases in which MSDS ingredient disclosures were incomplete	Canada	Workplace Hazardous Materials Information System (WHMIS), which is intended to reduce illness through workplace hazard communications.	Measures to address MSDS non-compliance, include the education of inspectors, suppliers, employers and MSDS writers in terms of the susceptibility of MSDSs to non-disclosures.
2006	Unidentified inert ingredients in pesticides: implications for human and environmental health - Caroline Cox and Michael Surgan	The shortcomings for the current procedure for assessing the hazards of pesticide formulations were described and it was documented that inert ingredients can increase the toxicity of potential exposures to pesticides.	USA	The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Unless an inert ingredient is determined to be highly toxic, it is not required to be identified by name or percentage on the label, but the total percentage of such ingredients must be declared (EPA US, 2012b)	To enable independent research and risk assessment, inert ingredients should be identified on product labels.

Year	Title and author of paper/article	Main concern of paper/article	Country	MSDS regulation	Conclusion
2009	Fragranced consumer products and undisclosed ingredients - Anne C. Steinemann	Six fragranced consumer products were analysed to compare the chemical disclosure of the chemical ingredients listed in the material safety data sheet (MSDS) with the actual constituents in the consumer products.	USA	In the USA, the manufacturers of consumer products and owners of chemical formulations on those products are not required to disclose all ingredients to consumers. - Consumer Product Safety Act - Occupational Safety and Health Administration (OSHA) Hazard Communication Standard. The MSDS requirement is designed for employers and employees. A consumer product ingredient does not need to be reported on an MSDS if the manufacturer or importer deems that the ingredient is not hazardous.	Further research can help to elucidate exposure mechanisms, the sources of risk and uncertainty, and the role of ingredient information.
2010	Between the devil and the deep blue sea — dispersants in the Gulf of Mexico - C.W. Schmidt	Chemical dispersants were being used that contained undisclosed proprietary component	Gulf of Mexico. US dispersant	- Occupational Safety and Health Administration (OSHA) Hazard Communication Standard. Nalco had no legal obligation to publicly disclose proprietary ingredients in its dispersants and that the EPA has agreed to keep it confidential.	NA

2.1. Inadequate hazard communication

Inadequate hazard communication is one of the issues associated with undisclosed information about chemicals. Previous work on the accuracy of MSDSs (Kolp et al., 1995) evaluated five areas of information: chemical identification of hazardous ingredients; reported health effects; necessary first aid procedures; appropriate personal protective equipment; regulations and guidelines on workplace exposure levels. In terms of the chemical identification of hazardous ingredients, it was concluded that without specific chemical names, no evaluation of the accuracy of the material presented could be undertaken. Without

knowing what chemical(s) was/were being addressed by the MSDS, it is impossible to evaluate whether the information presented is correct (Kolp et al., 1995).

The inaccurate listing of ingredients in MSDSs can lead to insufficient recommendations for personal protection which could compromise the safety of the workers and undermine injury prevention (Welsh et al., 2000). Welsh et al (2000)presented results for three cases in which MSDS ingredient disclosures were incomplete. The products included a synthetic lubricant used in a mining operation, a detergent concentrate used for aircraft cleaning and an epoxy reducer used in aircraft maintenance. In each case, undisclosed hazardous ingredients were detected at concentrations which required disclosure. An evaluation of the MSDSs indicated that a proportion failed to disclose any hazardous ingredients despite hazard inferences from other sections of the MSDSs including adverse health effects, first aid and PPE recommendations.

Paul and Kurtz (1994) analysed the reproductive health hazard descriptions on nearly 700 MSDSs for products containing lead or ethylene glycol ether. The results showed that over 62% of the MSDSs made no reference to effects on the reproductive system (Paul and Kurtz, 1994). It was concluded that the information provided to employers and workers about reproductive and developmental risks was grossly inadequate and much greater efforts are needed to ensure that the health protective intent of right-to-know legislation in the USA is realised (Paul and Kurtz, 1994).

2.2. The misconception amongst workers that all similar types of chemical products are equivalent

Paint thinners can vary significantly, because of the variation in the proportion of ingredients they contain, including solvent classes. Winder and Ng (1995) evaluated 20 proprietary thinners using MSDSs, as part of a multidisciplinary study on solvent exposure and health effects on spray-painter apprentices. The solvents in thinners can vary in the range of combinations and quantities, so that the health hazards to users are likely to differ significantly from those of individual solvents, because of possible synergistic action when they are combined (Winder and Ng, 1995). Despite the lack of complete disclosure of all ingredients on MSDSs, the use of ranges instead of specific quantities and the use of unspecific chemical names or trade secrets did not help to dispel the perception amongst industrial workers, that thinners are safe to use and that different types of thinner are equivalent (Winder and Ng, 1995).

2.3. Inadequate information about potential exposure risks, for the public

Inadequate information can lead to potential exposure risks. Chemical constituents in fragranced consumer products that are regulated as toxic or hazardous under the US federal law, but which are undisclosed may result in the public having inadequate information about potential exposure risks, or a false sense of assurance (Steinemann, 2009). Steinemann (2009) analysed six fragranced consumer products to compare disclosure of the chemical ingredients listed in the MSDS with the actual constituents in the products. Nearly 100 volatile organic compounds (VOCs) were identified but none of the VOCs were listed on any product label. One was listed on one MSDS, and ten of the VOCs were regulated as toxic or hazardous under the US federal law (Steinemann, 2009).

Pesticide ingredients are divided into two categories: active and inert (sometimes referred to as other ingredients, adjuvants, or coformulants) (Cox and Surgan, 2006). In this case, the US Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) defines an active ingredient as an ingredient which will prevent, destroy, repel, or mitigate any pest, whilst an inert ingredient, is defined as an ingredient which is not active (US Congress, 2008). Inert ingredients can act as solvents, surfactants or preservatives or have other functions and generally are not identified on product labels and are often claimed to be confidential business information. Despite their name, inert ingredients may be biologically or chemically active and are labelled inert only because of their function in the formulated product. Most of the tests required to register a pesticide are performed with the active ingredient alone, not the full pesticide formulation (Cox and Surgan, 2006). Some pesticide formulations contain inert ingredients that can affect human health and the environment significantly. Pesticide formulations have proved to be more potent genotoxic than active ingredients alone in a variety of test systems (Cox and Surgan, 2006). The full assessment of exposure to pesticide formulations is impeded by the lack of information about the concentration of individual inert ingredients.

In terms of confidential business information, FIFRA does not authorise the EPA (US Environmental Protection Agency) to disclose the identity or percentage of any inert ingredient in a pesticide unless the EPA has first determined that disclosure is necessary to protect against an unreasonable risk of injury to health or the environment (US Congress, 2008). If the EPA does propose to disclose confidential information, the EPA must notify the submitter by certified mail the intent to release such information (US Congress, 2008). Information protected from disclosure to the public may be disclosed to contractors if they request it and if the EPA decides that it is necessary for the satisfactory performance of the contractors (US Congress, 2008). This information is useful to the mining industry in considering the options available to reduce exposure to undisclosed ingredients in pesticides and other commercially available products.

2.4. Undisclosed proprietary components in MSDSs can lead to public concern

One of the remediation techniques used in response to the explosion and collapse of the BP-owned Deepwater Horizon oil rig in the Gulf of Mexico in April 2010 was the use of chemical dispersants. These contained mixtures of solvents, surfactants and other proprietary additives (Schmidt, 2010). The MSDSs for the dispersants referred to undisclosed proprietary components which lead newspapers to warn that "secret formulations" were being dumped into Gulf waters. The public demand for transparency leads to the manufacturer posting a full list of the products' ingredients on its website (Schmidt, 2010). Another example where undisclosed ingredients may mask the health and environmental impacts of an activity, is hydraulic fracturing (fracking). This involves pumping millions of gallons of fluid or gel into the rock. The chemical mixtures used are considered proprietary but contain at least some toxins (Lyndon, 2011) which can migrate and affect groundwater (US Congress, 2005). The full costs of hydraulic fracturing cannot be assessed without knowledge of the identity and amounts of chemicals used in the fracking liquid (Lyndon, 2011).

The Department of the Interior has the authority to oversee and regulate all activities on federal lands and it has recently released a proposed chemical disclosure rule for companies drilling on public lands. However, its chemical disclosure requirements do not commence until after drilling is complete (Department of the Interior: Bureau of Land Management, 2012).

Concerns about undisclosed chemicals in consumer products, lead to the introduction of the Cleaning Product Right-to-Know Act in the US House of Representatives in November 2011 that would require full disclosure of ingredients in cleaning products, and permit users to report failures in product compliance to the Consumer Product Safety Commission (CPSC) (Israel, 2011).

The concerns about undisclosed information in detergents lead to new amendments to the EU detergents Regulation (EC 648/2004) in 2012, which require the manufacturers or importers of detergents to prepare an ingredient data sheet (IDS) available upon request. Confidential business information will continue to be protected under this measure, however a member state must withdraw a detergent from the market if it constitutes a risk to the safety or health of humans or the environment (The European Parliament and The Council Of The European Union, 2012).

2.5. Compromising human health through legislative failure

Findings also indicate that legislative failure could compromise human health. The Toxic Substances Control Act (TSCA) was proposed in 1971 and enacted in 1976. The objective of

TSCA was to allow the EPA to regulate new commercial chemicals before they enter the market; to regulate existing chemicals (since 1976) when they pose an unreasonable risk to health or the environment as well as to regulate their distribution and use (US EPA, 2012b). The act also stated that confidential business information should be disclosed if the Administrator determines it necessary to protect health or the environment against an unreasonable risk of damage (US Congress, 2000).

In December 2000, the US EPA announced the Voluntary Children's Chemical Evaluation Program (V CCEP) which was designed to help the public understand the potential health risks to children from certain chemical exposures (US EPA, 2010). The EPA developed a list of twenty-three chemicals to which children have a high likelihood of exposure and asked companies that manufacture or import one or more of the chemicals to volunteer to provide information on health effects, exposure, risk and data needs (US EPA, 2010). An evaluation report from the EPA Office of Inspector General in 2011, claimed that the VCCEP pilot had not achieved its goals. The pilot study was reported to have had a flawed chemical selection process and the effectiveness of the programme was hampered by industry partners who chose not to collect and submit information voluntarily, (US EPA Office of Inspector General, 2011). In 2010, in order to increase transparency and public access to chemical information the EPA issued a new policy that denies, with limited exemptions, confidentiality claims for the identity of chemicals in health and safety studies under TSCA (US EPA, 2010). The EPA also reviewed past claims of concealing the CBI in health and safety studies submitted to the EPA (US EPA, 2012a).

3. Undisclosed information: data from three mining industry sites

3.1. Chemical legislation

The mining industry uses a wide range of chemicals in its operations, and it is important to determine the extent of undisclosed information, in terms of the types of the chemical products, the operational areas in which they are used, and their hazard classifications. Mining companies are frequently multi-national, and it is important therefore also to understand international chemical legislation on the disclosure of ingredients in products. Chemical legislation in the United States, Canada, Australia, Chile and Europe is considered here. All of the legislation is similar regarding confidential business information in the chemical industry and the manufacturers generally are not required to disclose the identity of ingredients in a consumer product if it is not deemed hazardous (Table 2).

Table 2. Summary of regulations with respect to CBI criteria.

Regulation	Year of enforcement	Country/region	Key CBI criteria
Toxic Substances Control Act	1976		• A manufacturer, processor, or distributor in commerce may designate the data which such person believes is entitled to confidential treatment, but may be disclosed to protect health or the environment.
Occupational Safety and Health Administration (OSHA) Hazard Communication Standard	Updated 2012	United States of America	• The only information that can be withheld from an MSDS, is the specific chemical identity, and only when the effects of the hazardous chemical are disclosed to health professionals, employees and relevant unions.
Hazardous Materials Information Review Act (HMIRA)	1987	Canada	• A claimant may be ordered to disclose information for reasons of health and safety in a work place.
Occupational Health and Safety (Safety Standards) Regulations	1994	Australia	• If there is a medical emergency involving the dangerous goods, the manufacturer must disclose the name of the ingredient.
Industrial Property Law (Law No. 19.039 Modified by Law 19.996)	2005	Chile	• The protection of trade secrets can be terminated for justified reasons of public health, national security, non-commercial public use, national emergency or other extremely urgent circumstances.
Registration Evaluation Authorisation and Restriction of Chemical Substances (REACH)	2007	Europe	• If the identity of a substance will put at risk the confidential nature of intellectual property, it may refer to by a name that identifies the most important functional chemical groups, or an alternative name. • In cases where urgent action is essential to protect human health, safety or the environment, ECHA may disclose information that would normally be considered confidential.

3.2. Material and methods

Three mine sites for (copper, platinum and coal) were visited between 2008 and 2009, and data was collected about the chemicals used and/or stored at each site, in order to understand the hazards and exposures of chemicals used in typical mining operations. A photographic archive of the chemicals identified was prepared, and the information later recorded in an electronic database. Information was collected on the chemicals' entry to the site, storage, patterns of use (quantity and frequency of use), route of disposal and exposure controls. Processing the hazard information revealed that a significant number of chemicals had undisclosed information and the need to investigate the extent of this uncertainty further.

A summary of the stages of the method and final outcomes is illustrated in the flow diagram (Fig. 1).

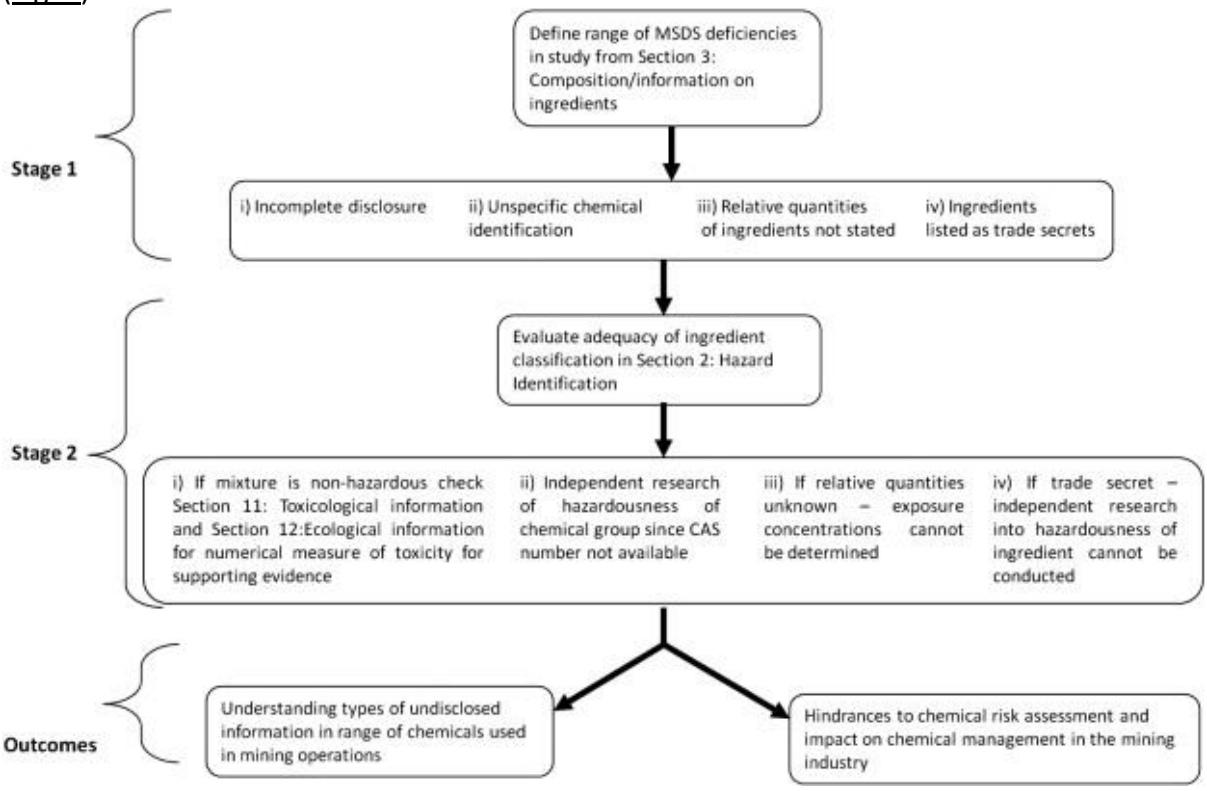

Fig. 1. Stages of the methodology to categorise and analyse undisclosed information.

The MSDSs were the primary source of chemical safety information used in the study. The current versions of the MSDSs were requested from the chemical manufacturer, or retrieved from the mining company's chemical database. The study focused mainly on the type of MSDS deficiencies in the section: Composition/information on ingredients, documented in the GHS

fourth revised edition (Table 3) (United Nations, 2011). The UN GHS was chosen to represent the ideal MSDS requirements, as GHS is being adopted worldwide and sets out to standardise hazard communication requirements for safety data sheets and labelling. Since this study involved evaluating MSDSs governed under different legislation, the eventual consistency and accuracy in MSDS contents are important.

Table 3. GHS requirements for Section 3: Composition/information on ingredients.

GHS requirements for section 3: composition/information on ingredients	
Substances	Mixtures
1. Chemical identity of the substances	1. Chemical identity of the substances
2. Common name(s), synonyms(s) of the substances	2. CAS number and other unique identifiers for the substance
3. CAS number and other unique identifiers for the substance	3. Concentration or concentration ranges of all hazardous ingredients…present above cut-off levels
4. Impurities and/or stabilising additives, which are themselves classified and which contribute to the classification of the substance	

If the MSDSs in the mining operation case study fulfilled these requirements they were classified as having adequate information. Deviations from this level of information were identified as a deficiency in information. The scope of deficiencies was identified by an initial survey of the MSDSs (stage 1 in Fig. 1).

The MSDS omissions presented in the literature review of previous studies were used as a guide to identify the deficiencies for the current study. Nonspecific names were presented by Kolp et al (1995) and Winder and Ng (1995). Ingredients listed as trade secrets were presented by Kolp et al (1995), Steinemann (2009) and Winder and Ng (1995).

The MSDS scope also revealed that several MSDSs did not contain the concentrations of the ingredients, and several MSDSs had incomplete ingredient lists. The undisclosed categories chosen for assessment in this study, and the corresponding criteria are listed in Table 4.

Table 4. Undisclosed categories selected for case study and corresponding criteria.

Undisclosed category	Criteria
i) Incomplete disclosure	Identifies products for which the MSDS lists less than 50% of the ingredients.
ii) Unspecific chemical identification	One or more chemical groups are mentioned but the full identity of the substance is not disclosed and the CAS number is absent.
iii) Relative quantities of ingredients not stated	One or more ingredients in a formulation are not listed.
iv) Ingredients listed as trade secrets.	One or more ingredients have been deliberately withheld and classified as trade secret or proprietary information by the manufacturer.

Other deficiencies such as missing toxicological and ecological data points (sections 11 and 12 of MSDS) to support the classifications, and inaccurate or insufficient information about the hazard classification of the individual ingredients were also highlighted (by cross-checking the classification of ingredients in the MSDS against independent databases) for the chemicals that fall within the 4 assessment categories (stage 2, Fig. 1).

Inaccurate information on hazards will compromise health protection and lead to uncertain hazard communication. Therefore the range of undisclosed information was evaluated alongside the qualitative exposure control information acquired during the mine site data collection.

For the purpose of this study, the chemicals investigated included: Laboratories, mechanical maintenance (which includes greases, lubricants, adhesives used in workshops), cleaning products (used in all locations), motor oils*, paints*, agricultural/gardening chemicals, cathode plant/water treatment reagents, flotation reagents, explosives and drilling fluids.

* Due to the large quantity of different types of motor oils and paints, these chemicals have been placed in their own categories, even though they form part of the mechanical maintenance group of products.

3.3. Results

A total of 957 chemicals across the three commodity mine sites were identified. Twenty percent (188) contained undisclosed information from one of the four categories. Of the 188 chemicals with undisclosed information, 33% has incomplete disclosure, 39% unspecific chemical identities, 6% had unstated relative quantities and 22% contained ingredients listed as trade secrets. In cases where chemicals contained more than one type of undisclosed information, the priority used was as follows: trade secrets > unspecific chemical

identities > unstated relative quantities > incomplete disclosure. Other types of MSDS deficiencies included inadequate or inaccurate hazard classifications for some ingredients and unsupported numerical evidence for the classifications. Sixty-three percent (122 chemicals) of the MSDS of these chemicals did not contain an acute toxicity endpoint (LD_{50}) and/or an acute aquatic toxicity endpoint (LC_{50}).

The relationship between the type of mining and the number of chemicals with undisclosed information is explored here. Therefore the proportion of chemicals for each commodity that contain undisclosed information is shown in Table 5.

Table 5. Proportion of the total number of chemicals per commodity at each site that contain undisclosed information.

Commodity	**Copper**	**%**	**Platinum**	**%**	**Coal**	**%**	**Total**
Total no. of chemicals	525	55%	229	23%	206	22%	957
Total no. of undisclosed chemicals	68	36%	43	23%	77	41%	188 (20%)

The undisclosed information is not localised to one type of mining operation, but is distributed amongst all three, with the highest percentage found on the coal site (Table 5).

The link between the chemicals that are critical for mining operations and the undisclosed information was explored per mine site (Table 6a, Table 6b, Table 6c).

Table 6a. Types of chemicals with undisclosed information on copper mine.

	Laboratories	**Mechanical maintenance**	**Cleaning products**	**Motor oils**	**Paints**	**Gardening chemicals**	**Cathode/water treatment reagents**	**Flotation reagents**	**Drilling lubricants**
Adequate information	182	78	36	59	50	28	17	4	3
Undisclosed information	4 (3%)	16 (17%)	12 (25%)	15 (20%)	5 (9%)	7 (20%)	2 (11%)	4 (50%)	3 (50%)
Total	186	94	48	74	55	35	19	8	6

Table 6b. Types of chemicals with undisclosed information on platinum mine.

	Laboratories	**Mechanical maintenance**	**Cleaning products**	**Motor oils**	**Paints**	**Water treatment**	**Flotation/nickel sulphate plant**
Adequate information	98	36	12	11	10	1	18
Undisclosed information	7 (7%)	5 (12%)	17 (59%)	8 (42%)	1 (9%)	3 (75%)	2 (10%)
Total	105	41	29	19	11	4	20

Table 6c. Types of chemicals with undisclosed information on Coal Mine.

	Mechanical maintenance	**Cleaning products**	**Motor oils**	**Paints**	**Pesticide**	**Water treatment**	**Explosives**
Adequate information	30	29	13	27	17	6	7
Undisclosed information	14 (32%)	8 (22%)	33 (72%)	15 (36%)	5 (23%)	1 (14%)	1 (13%)
Total	44	37	46	42	22	7	8

This included determining whether there was a link between the chemicals that are critical for mining operations and the undisclosed information. This was examined per mine site (Table 6a, Table 6b, Table 6c).

Each mine site has at least 7 different categories of chemical uses with common categories across the three sites being mechanical maintenance products, cleaning products, motor oils and paints (Table 6a, Table 6b, Table 6c). For all three commodities, motor oils have > 26% of its total containing undisclosed information, followed by cleaning products which are > 22% and the mechanical maintenance chemicals at > 12%. Laboratory chemicals have < 10%. In the case of platinum more than half of the cleaning products (59%) had undisclosed information. This shows that the highest distribution is within commercially available products that can be substituted, and not localised to chemicals specific for mining activities such as flotation reagents, laboratory chemicals and water treatment reagents.

The relationship between the range of categories of undisclosed information and the chemical types per mine site was examined (Fig. 2A–C).

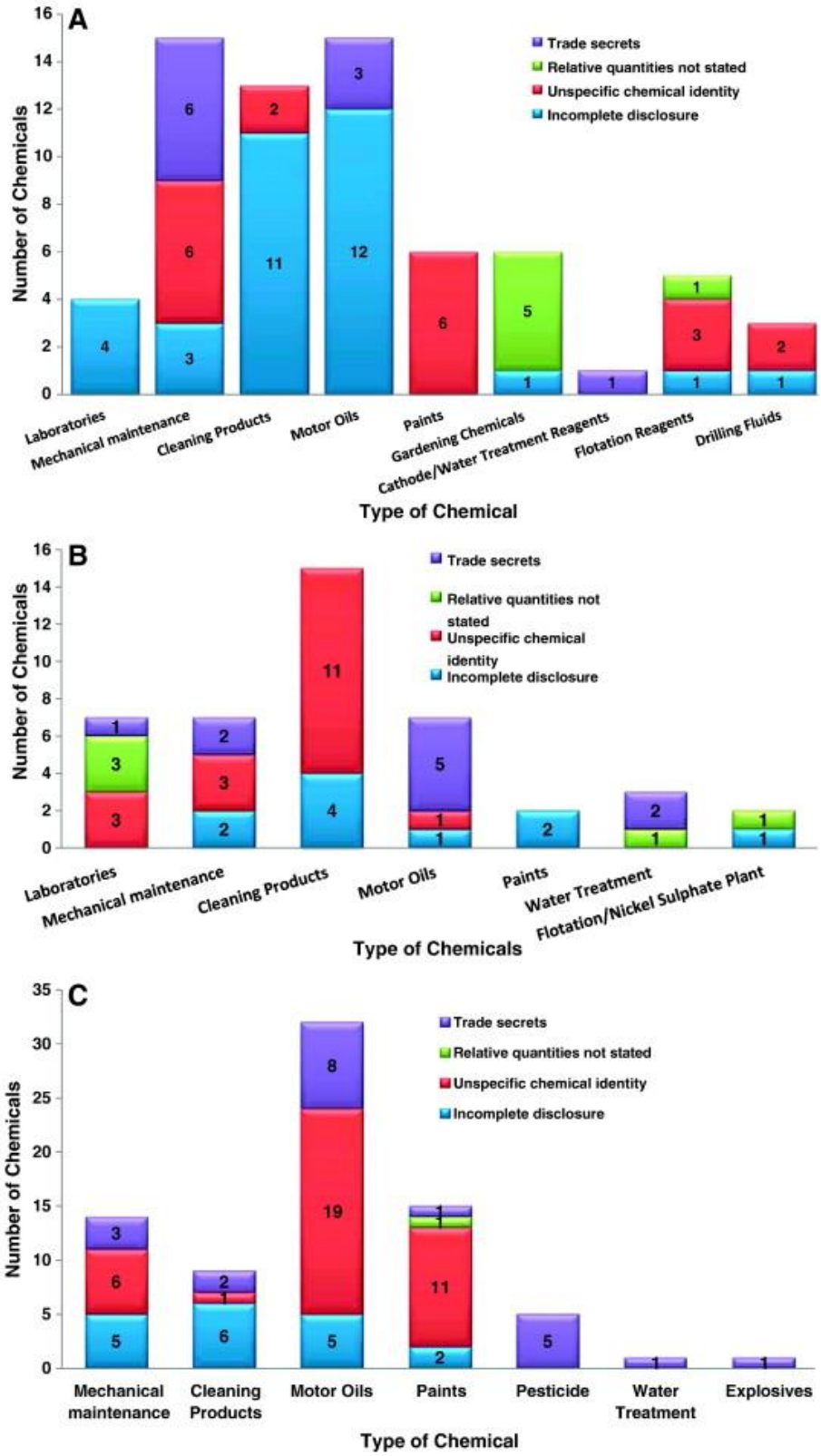

Fig. 2. A. Distribution of chemicals with undisclosed ingredients per chemical type and undisclosed category for copper mine. B. Distribution of chemicals with undisclosed ingredients per chemical type and undisclosed category for platinum mine. C. Distribution of

chemicals with undisclosed ingredients per chemical type and undisclosed category for coal mine.

The majority of chemical types on each mine site contain at least 2 different categories of undisclosed information (Fig. 2A–C). However some chemical types were found to have a single category, such as pesticides, water treatment reagents, and the explosives on the coal mine operation and the cathode reagents on the copper operation that contained trade secrets. The results also revealed that the same chemical types had different undisclosed information across the mining operations. For example, the laboratory chemicals for the copper operation contained only incomplete disclosures, whilst they contained three types of undisclosed information on the platinum site. This difference might be a result of the different types of laboratories (analytical and metallurgical). Similarly, the paints on the copper site had unspecific chemical identities only, the platinum site had incomplete disclosures only and the coal site had paints with all 4 categories of disclosure. Some chemical types have similar trends in undisclosed information across the three sites, in the case of motor oils and mechanical maintenance products.

The comparison of results in Fig. 2A–C highlights the need to understand the collective distribution of undisclosed information per chemical type, which is given in Fig. 3.

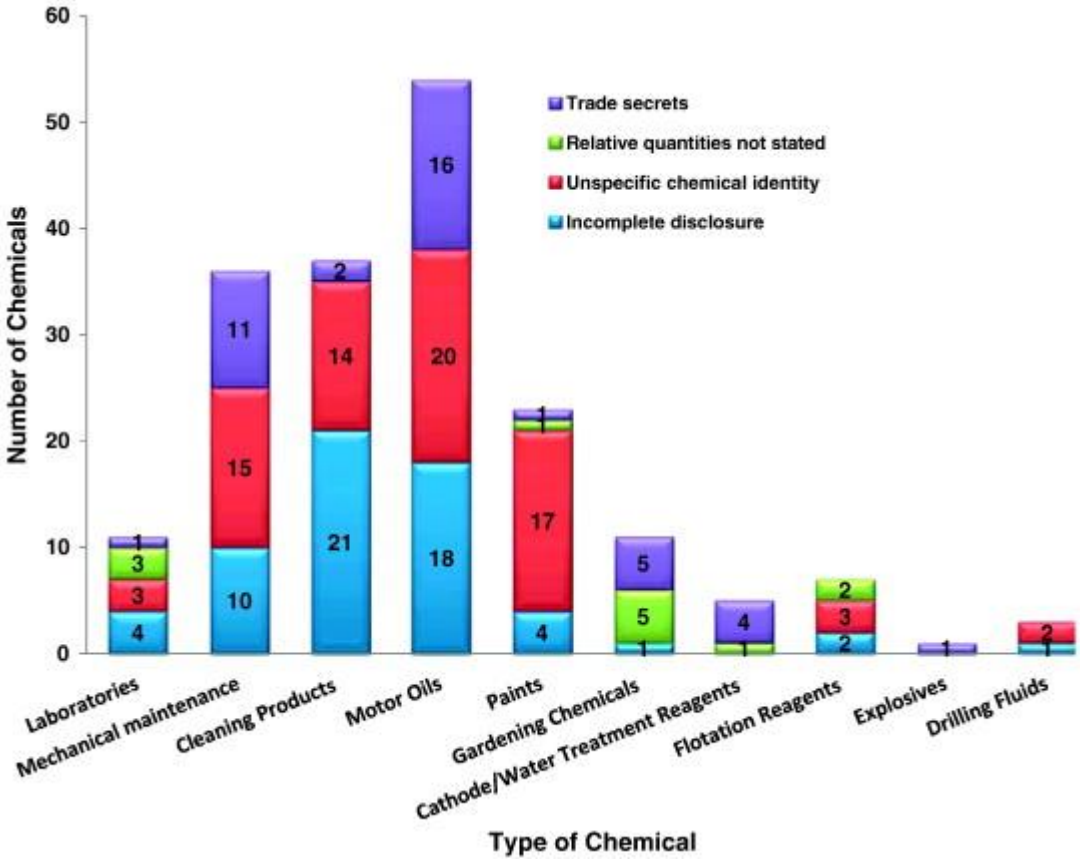

Fig. 3. Combined distribution of chemicals with undisclosed ingredients per type of chemical and undisclosed category.

Both laboratory chemicals and paints have chemicals in one of the 4 categories of undisclosed information and explosives are the only chemical type that contains a single category (Fig. 3). The combined results also show the distribution of the number of chemicals per chemical type (Table 7):

Table 7. Total number of undisclosed chemicals per chemical type.

	Laboratories	**Mechanical maintenance**	**Cleaning products**	**Motor oils**	**Paints**	**Gardening chemicals**	**Cathode/water treatment reagents**	**Flotation reagents**	**Explosives**
Incomplete disclosure	4	10	21	18	4	1	0	2	0
Unspecific chemical identity	3	15	14	20	17	0	0	3	0
Relative quantities not stated	3	0	0	0	1	5	1	2	0
Trade secrets	1	11	2	16	1	5	4	0	1
Total	11	36	37	54	23	11	5	7	1

Motor oils have the largest quantity of undisclosed information in the mining industry followed by cleaning products and mechanical maintenance products. All three having trade secrets, unspecific chemical identities and incomplete disclosures. These are commercially available products and therefore would be relevant to other industries with similar maintenance activities.

The link between the categories of undisclosed information and the limitations faced by mining companies in adequately protecting their workers is explored, focusing on key examples of chemicals in the four categories. The examples per undisclosed category are summarised in Table 8a, Table 8b, Table 8c, Table 8d in order of the categories with the largest amount of chemicals per disclosure type. Other MSDS omissions are considered alongside these categories, which include hazard classifications that have not been adequately communicated or the lack of numerical evidence to support classifications such as no LD_{50} value for the acute toxicity or the LC_{50} value for the acute aquatic toxicity.

Table 8a. Results of incomplete disclosure.

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
Cleaning products			
Repass	Wax emulsion (10%)	Unknown acute toxicity	Copper
View	2-Butoxyethanol (> 10%)	Unknown acute toxicity; unknown acute aquatic toxicity	Copper
Pink Antibacterial Handsoap	Formaldehyde (50-00-0) (0.2%); Sodium Sulphate (1%)	Unknown acute toxicity;	Coal
Motor oils			
Esso Gear Oil GX 80 W–90	1-Propene, 2-methyl-, sulphurised (1–5%) (68511-50-2)	Unknown acute aquatic toxicity	Copper
Lubrene	Ingredients considered hazardous not to health:	Unknown acute toxicity; unknown acute aquatic toxicity	Coal
Mechanical maintenance			
Rota-Z	Benzenamine, N-phenyl-, reaction products with 2,4,4-trimethylpentene (2%) (68411-46-1)	Unknown acute aquatic toxicity	Copper
Spanjaard — Electro kleen	No ingredients listed	Unknown acute toxicity; unknown acute aquatic toxicity	Coal
Laboratory chemicals			
Buffer solution — pH7	Thymol (< 1%)	Unknown acute toxicity	Copper
Paints			
Plascon — EMS18-Plascosafe 18 Primer — RedOxide	2-Butoxyethanol (< 2%) (000111-76-2)	Unknown acute aquatic toxicity	Platinum
Flotation reagents			
Magnafloc 333	Adipic acid (1–3%) (1242-04-9)	Not applicable	Platinum

Table 8b. Results of Unspecific Chemical Identity.

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
Motor oils			
Castrol Dynamax	Highly refined mineral oil, synthetic lubricants and additives	Unknown acute toxicity; unknown acute aquatic toxicity	Coal
Engen — Dieselube 600 Super	Base oils (> 80.00%); additives (< 20.00%)	Not applicable	Coal

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
Paints			
Sigma Coatings — Sigma Thinner	Xylene, Toluene, MEK, Aromatic hydrocarbons, Alcohol's.	Suspected reprotoxin; insufficient CMR communication	Coal
Community Paints — Road Marking — White	Aliphatic solvent (Stoddard solvent) > 25% (8052-41-3); lead content < 5%; soluble < 3%; soluble on Nv. < 5%	Unknown acute toxicity; unknown acute aquatic toxicity	Coal
Cleaning products			
Cristal Black Dip (C14)	HHBTA (> 10%); Rafinate solvents (< 10%); Tall Oil Refine (> 10%); Rosin solutions (> 10%); Meths (> 10%); Ethanolamines (> 5%); Additives (< 5%)	Harmful if swallowed; Unknown acute aquatic toxicity	Platinum
Cristal Shower Clean (C15)	Surfactants (< 10%); cleaning solvents, ethylene (< 7%); water softeners (> 1%); biocides (> 2%); soft acid, citric (< 10%); natural cleaning additives (< 5%)	Unknown acute toxicity; unknown acute aquatic toxicity	Platinum
Marvel Hot C-14	Oxygenated solvents and alkaline salts	Unknown acute toxicity; unknown acute aquatic toxicity	Copper
Mechanical maintenance			
Corpro 800 P.L — B component	Polyisocyanate based on MDI (30–60%); 4,4'-Diphenylmethane diisocyanate (MDI) (15–40%) (101-68-8); diphenylmethane diisocyanate (MDI) (10–30%) (26447-40-5)	Suspected carcinogen; Insufficient CMR communication	Coal
Laboratory chemicals			
Flomin C-4440	Allyl isobutyl xanthate ester (85–95%); isobutyl alcohol (5–15%) (78-83-1)	Not applicable	Platinum
Gardening chemicals			
Enrai Zante	Iba (0.15%); Captan (6%)	Suspected carcinogen; insufficient CMR communication;	Copper
Flotation reagent			
Aero-3752 Promotor	Inorganic sulphides	Toxic if swallowed; unknown acute toxicity	Copper
Hostaflot Lib K	Potassium dibutyl dithiophosphate; sodium hydroxide and other ingredients	Not applicable	Copper
Drilling fluids			
Poly-plus drilling fluid additive	Anionic polyacrylamide (20–40%); petroleum distillates, hydrotreated light 64742-47-8 (20–40%); trace acrylamide	Not applicable	Copper

Table 8c. Results of relative quantity unknown.

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
Gardening chemicals			
Goal 2EC	Oxyfluorfen (42874-03-3)	Not applicable	Copper
Laboratory chemicals			
Senkol 9	Ethyl-dithiophosphate sodium salt/dithiocarbamate, sodium hydroxide mixture.	Not applicable	Platinum
Flotation reagent			
Senkol 65	N-Butyl dithiocarbamate; Sodium hydroxide	Not applicable	Platinum
Water treatment chemicals			
Inhibitor ZP8501	2-Phosphonobutane-1,2,4-tricaroxylic acid (37971-36-1); zinc sulphate (7733-02-0); phosphoric acid (7664-38-2); nitric acid (7697-37-2); 1-H-benzotriazole (95-14-7)	Unknown acute aquatic toxicity	Platinum
Paints			
Cedar spray — marking paint	Methylene chloride (dichloromethane)	Suspected carcinogen; insufficient CMR communication; unknown acute toxicity	Coal

Table 8d. Results of trade secrets.

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
Motor oils			
Essontrans 10w	Calcium sulphonate (0.1–1%) (Polymer); tetrapropenyl phenol (0.1–1%) (121158-58-5); Zinc Aryldithiophosphate (1–5%) (Confidential)	Not applicable	Copper
Shell-Tellus 46	Synthetic hydrocarbon base oil (90–99%) (blend); proprietary additives (1–3%) (proprietary)	Unknown acute aquatic toxicity	Platinum
Castrol — EPX SAE 80 W–90	Not classified as dangerous — highly refined base oil (IP 346 DMSO extract < 3%). Proprietary performance additives.	Unknown acute toxicity; unknown acute aquatic toxicity	Coal
Mechanical maintenance			
Durall Fine Line	Part A: bisphenol A epoxy resin (25068-36-6); multifunction acrylate monomer (13048-33-4) amorphous silicia (7631-86-9); trade secret. Part B: benzyl alcohol (100-51-6); nonylphenol (25154-52-3); vestamin IPD (*2855-13-2); modified aliphatic polyamine (trade secret); trade secret	Unknown acute toxicity; unknown acute aquatic toxicity; suspected endocrine disruptor	Copper
Wurth — Pneumatic S10	Óleo mineral (98.98%) (8042-47-5); silicone (0.02%) (63148-62-9); INC 80 (1%) (trade secret)	Unknown acute toxicity; unknown acute aquatic toxicity	Copper

Chemical	Undisclosed ingredient(s)	Other MSDS omissions	Commodity
CRC-2-26 — Multipurpose lubricant	Isoparaffinic hydrocarbon (65–75%) (64742-47-8); white mineral oil (15–25%) (8042-47-5); Corrosion inhibitor blend (TS) (5–15); Carbon dioxide (1–5%) (124-38-9)	Not applicable	Platinum
Satcoflor 098 — Hardener	Benzyl alcohol (40%) (100-51-6); Isophoronediamine (IPD) (30%) (2855-13-2); remainder is TS	Not applicable	Platinum
Gardening chemicals			
Roundup	Glyphosate\(360.0 g/l\0 a.e. As N-(phosphonomethyl) glycine, IPA salt. (1071-83-6); surfactant (TS); inerts (balance)	Not applicable	Coal
Efekto — Garlon 4	Triclopyr (61.0–62.0%) (064700-56-7); surfactant (< 5.0%) (TS); kerosene (20.0–40.0%) (008008-20-6)	Not applicable	Coal
Rosecare 3	Bifenthrin (2.0 g/l) (82657-04-3); myclobutanil (7.5 g/l) (88671-89-0); inerts balance	Suspected reprotoxin; insufficient communication; toxic to aquatic life	Coal
Snail Ban	1-Naphyl methylcarbamate (Carbyl) (20 g/kg) (63-25-2); Captan (0.05 g/kg)(133-06-2) Metaldehyde (30.0 g/kg) (108-62-3); inerts	Suspected carcinogen	Coal
Cathode plant/water treatment reagents			
Fluororad — Mist Control Agent-FC 1100	Acrylate adduct + (5965P) (45–55%) (trade secret); residual perfluoroalkyl sulphonates (< 5%) (mixture)	Unknown acute toxicity; harmful to aquatic life; potential POP	Copper
Explosive			
Anfo Silos	Ammonium nitrate (6484-52-2) (> 90%); fuel additive (< 10%)	Suspected carcinogen	Coal

3.3.1. Incomplete disclosure

Incomplete ingredient lists, coupled with unreported toxicological information can lead to the inability to cross check hazard information and therefore can lead to an uncertainty about chemical safety.

The incomplete disclosure category identifies products for which the MSDS lists less than 50% of the ingredients. The chemical categories that had the largest amount of chemicals with incomplete disclosures were cleaning products, followed by motor oils and mechanical maintenance products (Fig. 3).

The examples in Table 8a are of products with less than 15% of the ingredients listed in the MSDSs. Some chemicals only list 1% of their ingredients such as the buffer solution, whilst some do not list any at all, such as the Electro kleen used in the mechanical workshops. This

poses a particular problem when the MSDSs have additional inadequacies such as the absence of overall LD_{50} and/or LC_{50} endpoints. Example of these chemicals includes Repass floor cleaner and the Pink Antibacterial Handsoap that also contains the known carcinogen (Group 1) formaldehyde(International Agency for Research on Cancer, 2012), as well as the cleaning product View and the motor oil Lubrene. The latter two examples have been classified as non-hazardous, but are not supported by the relevant endpoints.

The manufacturers are not obliged to disclose hazardous ingredients present below the cut-off level concentrations and that is why so many chemicals have this level of undisclosed information, especially in commercially available products such as cleaning products. However the incomplete disclosure prevents cross-checking of all ingredients within a product during the hazard assessment stage of a company level risk assessment. Users of chemicals will not have the reassurance that the chemicals not listed in a product are nonhazardous and within the cut-off level concentration. This is especially true for chemicals used outside of the EU that are not currently regulated to the same standard as REACH.

3.3.2. Unspecific chemical identification (chemical group mentioned), but the full identity of the substance is not disclosed

Unspecific chemical identities alongside unreported endpoints and inadequate hazard classifications can lead to uncertainty about chemical safety and therefore hinder the ability to adequately protect their workers. The unspecific chemical identity category includes products in which one or more chemical groups are mentioned in the ingredients, but the full identity of the substance is not disclosed. The absence of the CAS number hinders the exact identification of a chemical. Knowledge of the chemical group allows research into the properties of the group and provides a better understanding of any potential hazards and reactivities, however different derivatives of a chemical group can have different properties and hazards and be subjected to different legislative measures.

The chemical categories with the largest number of chemicals with unspecific chemical identities were motor oils, followed by paints, mechanical maintenance products and cleaning products (Table 8b). Similar to the previous undisclosed category, this type of undisclosed information hinders independent research and many examples in this category also have absent toxicological endpoints, such as the additives in Castrol Dynamax motor oil and unspecified inorganic sulphides in the Aero-3752 Promotor flotation reagent. Similar flotation reagents containing inorganic sulphides have been classified as toxic to the environment, and therefore the absent LC_{50} value and unspecific chemical identities prevent adequate identification of hazards for this chemical used on an industrial scale. Similar hindrances are

posed for the cleaning products, Cristal Black Dip and Cristal Shower Clean that have ingredients with undefined abbreviations and no CAS numbers.

This category also highlights the inadequate hazard communication of the ingredients which are disclosed. An example is the Sigma paint thinner which contains Toluene, but the MSDS lists neither the CAS numbers of the ingredients, their relative quantities nor Toluene's classification as a suspected reproductive toxin. There was a similar case for the Community Paints which had a lead content of < 5% but omitted the LD_{50} and LC_{50} values despite the toxicity of lead which has been banned in paints in Europe since 1992 (The European Parliament and The Council Of The European Union, 1989). Several other ingredients classified as suspected carcinogens have been inadequately communicated, such as Captan (IARC group 3) (IARC, 1987) in the Enrai Zante herbicide, 4-tert-butyl-3,5-dinitro-2,6-dimethylacetophenone (musk ketone) (IARC group 3) in the 'Inspirations — Sense of Wonder' air freshener and 4,4'-diphenylmethane diisocyanate, (IARC group 3)(IARC, 1999b) for the Corpro hardener maintenance product, which also contains an unspecified Polyisocyanate compound.

The limitation that unspecific chemical identities pose to chemical risk assessment is the inability to independently research the intrinsic hazards of the ingredients and the examples showed that the other inadequacies of hazard communication within the same MSDS can lead to doubts of the classifications of the ingredients which are not fully disclosed.

3.3.3. Relative quantities of ingredients not stated

This category identifies products where the relative quantities of one or more ingredients in a formulation are not listed. The regulatory paradigm is that low level chemical exposures are generally tolerable; however this has been challenged in instances where diseases have been associated with low doses of chemicals in the environment. This is particularly true for endocrine disrupting chemicals that have effects at low doses that are not predicted at higher doses (Melnick et al., 2002, Vandenberg et al., 2012, Zoeller et al., 2012). The implication is that ignorance about chemical effects can no longer be accepted and it is therefore important to know the relative quantity of components in a formulation. Unknown quantities can lead to uncertain exposure quantification. The chemical categories that had the largest amount of chemicals with relative quantities of ingredients unknown, were gardening chemicals followed by laboratory chemicals and flotation reagents (Table 8c).

In terms of gardening chemicals, the absence of the relative quantity of active ingredients hinders estimation of user exposure and the amount of the harmful active ingredient introduced into the environment, as is the case with Goal 2EC which is toxic to aquatic life.

Hindrances to exposure estimation are observed for paints such as the Cedar Spray Marking Paint that contains an unlisted quantity of dichloromethane (possible carcinogen to humans (Group 2B)) (IARC, 1999a). This classification was not communicated in the MSDS and the acute toxicity value was not given either.
The uncertainties from unknown concentrations and chemical identities become more serious for chemicals used daily in large quantities (more than 1 tonne per year) such as the Senkol 65 flotation reagent, which is very toxic to aquatic life.

These examples clearly illustrate that unknown concentrations of ingredients in products prevent the quantity of potential hazardous releases to be estimated and hinder compliance with exposure limits. Withheld information does not allow for adequate exposure evaluation and scenario development of a chemical risk assessment. The worst case has to be assumed in the cases where the concentration is unknown. The relative concentration of ingredients within mixtures is also a requirement for MSDS regulations in most countries as well as prescribed by GHS.

3.3.4. Ingredients listed as trade secrets

Products that contain one or more ingredients, the identity of which has been deliberately withheld and classified as a trade secret or as proprietary information by the manufacturer can lead to uncertainty about hazards and hinder exposure quantification and therefore prevent appropriate chemical risk measures from being applied. Secrecy distorts the market, the research and development agenda and society's management of health and the environment, and prevents the development of the information needed to make a balanced assessment of risk (Lyndon, 2011).
Motor oils had the largest amount of chemicals with trade secret ingredients (due to proprietary additives), followed by mechanical maintenance products and gardening chemicals. This category is similar to the unspecified chemical identities but these ingredients are labelled as trade secrets. The mechanical maintenance products listed in Table 8d all contain components classified as trade secrets, such as the lubricating oil Wurth — Pneumatic S10, which has a trade secret component identified as INC 80, the multipurpose lubricant, CRC-2-26, the hardener Satcoflor 098 and the adhesive Durall Fine Line. The adhesive also contained nonylphenol which is a suspected endocrine disruptor (OSPAR Commission, 2009), which was not communicated on the MSDS as has the additional uncertainty of absent toxicological endpoints.

For gardening chemicals, the trade secrets are in the form of the inert ingredients and surfactants that are stated but not identified as is the case with Efekto Garlon 4 where the entire product has been classified as being very toxic to aquatic organisms, but the LC_{50} value of active ingredient (Triclopyr) is above 100 mg/l, (Sigma-Aldrich, 2012b) suggesting it is not harmful. Hence it is suspected that it is the unidentified surfactant that increases the toxicity of the overall product. Both Efekto Rosecare 3 and Snail Ban contain unidentified inert compounds as well as suspected CMR compounds. Snail Ban contains the suspected carcinogens, Captan and Carbaryl (IARC group 3) (IARC, 1987). Rosecare 3 contains the suspected reproductive toxin myclobutanil (Sigma-Aldrich, 2012a), but the MSDS specifically states that none of the ingredients have any genotoxic effects (Efekto, 2011).

The uncertainty in chemical identities becomes more important when chemicals are used on a large scale with the possibility of widespread exposure, as in the case of Fluorarad Mist Control Agent used in the electrowinning plant and Anfo explosive booster used in underground coal mine blasting. The mist control agent contains a trade secret ingredient as well as residual perfluoroalkyl sulphonate(PFAS), which could include the homologue perfluorooctane sulphonate (PFOS), which is a persistent organic pollutant (POP) (Stockholm Convention on Persistent Organic Pollutants, 2007).

The explosive contains a fuel additive that has been classified as a suspected carcinogen and the identity of the additive is not given. It may be considered that this information is not important as the ingredients are decomposed to carbon oxides and nitrogen oxides on explosion. Nevertheless, it is clearly an issue of concern, as Dinitrotoluene which is also a component of some explosives is on ECHA's Authorisation list, with a sunset date of 21/08/2015 (ECHA, 2012). The European Commission states that the conclusion for the assessment of risks is reached because of 'concerns for repeated dose toxicity and toxicity for reproduction (fertility) as a consequence of dermal exposure arising from the manufacture and use of explosives' (European Union, 2008). These examples show that undisclosed identities and trade secrets lead to uncertainty in indentifying hazards, estimating exposure and quantifying the risks, which hinders appropriate chemical risk management measures.

4. Discussion

The wide ranging chemical types, from specialist flotation reagents to commercially available cleaning products with undisclosed information illustrate the extent of the problem, and indicate the potential for industry workers to be exposed to such chemicals.

Out of a total of 957 different chemicals used across the three mining operations examined (copper, platinum, coal), 188 (20%) contained undisclosed information, with the coal

operation accounting for majority of the undisclosed chemicals (41%). It was also the operation that had the highest percentage of undisclosed chemicals per site (37%). Each of the operations had a similar trend in terms of types of undisclosed chemicals, and when combined into one analysis, motor oils accounted for the highest percentage (29%) followed by cleaning products (20%) and mechanical maintenance chemicals (19%). These types of chemicals are commercially available and reflect activities present in all industries that require cleaning and maintenance, suggesting that this problem is widespread.

Evaluation of the MSDSs of the undisclosed chemicals revealed that the most common type of omission was unspecific chemical identifications, with motor oils having the highest quantity in this category. The issues associated with this type of disclosure were documented in past studies and are reinforced by this work. When the full chemical identities of ingredients are withheld, and the CAS numbers are not given, the intrinsic hazards of the ingredients cannot be cross-checked, especially in cases where the acute toxicity value is not reported. The ability to cross-check intrinsic hazards with other sources is important as several examples show that chemical products contain suspected CMR ingredients, but the relevant classification was not reported in the MSDS and discovered only by cross-checking their CAS numbers. Results showed that there is particular concern about cleaning products, paints and gardening chemicals. The issue of uncertainty is similar for the incomplete disclosure category, where the absence of a full list of ingredients means that workers are exposed to known active ingredients as well as undisclosed and possibly untested ingredients. Although such ingredients have been omitted because they are not classified as hazardous; in many cases the overall acute human health and acute aquatic toxicity endpoints are absent. This is a common problem with commercially available cleaning products, as well as motor oils, and mechanical maintenance products.

The trade secret ingredient category was given priority over the others when grouping the chemicals because it represented a deliberate form of undisclosed information, and is protected by regulations relating to confidential business information. This category accounted for 22% of the total undisclosed chemicals, and 4% of all chemicals used across the three sites. Trade secret ingredients raise similar concerns to the other categories in that there are doubts about the safety of the products in cases where the overall endpoints are not reported or if the hazard classification of a known ingredient is not adequately communicated. Again there is a concern with gardening chemicals which contain undisclosed surfactants with the ability to increase the overall toxicity of the chemical. The case of undisclosed fuel additives in explosives is also of concern in cases where the additive is a suspected carcinogen.

If the relative quantity of ingredients is absent the exposure estimation to the users of the chemicals is hindered and the amount of harmful active ingredients introduced into the environment cannot be quantified. This is of particular concern for gardening chemicals as well as flotation reagents, of which large volumes are used daily.

Analysis of the four categories of undisclosed ingredients shows that the main is the inability to independently research the intrinsic hazards, especially when there is doubt about the accuracy of the classifications that is communicated. In these cases, the worst case classifications should be used which may lead to an unrealistic risk characterisation and a waste of resources in chemical management.

A detailed scrutiny of the chemical management effects caused by the undisclosed information on each chemical type studied, is given in Table 9. This was determined by consideration of MSDS inadequacies as well as the exposure data collected and the controls in place.

Table 9. The impact of undisclosed information on chemical management in the mining industry.

Type of chemical	MSDS inadequacies	General exposure controls	Impact on chemical management
Laboratory chemicals	6% (11 out of 188) of the total undisclosed chemicals are used in the laboratory.	Used daily in small quantities; fumehoods; labcoats; gloves; spillage kits; all MSDSs available; emergency procedures in place; appropriate storage.	The good exposure controls reduce exposure to all chemicals.
Mechanical maintenance products	19% (36 out of 188) of total undisclosed chemicals; hardener with suspected CMR not communicated	Used as required in small quantities; extractive ventilation not required; MSDSs not always referred to; chemical risks overlooked in comparison to risk of injury from machinery; most products used are commercially available.	Poor MSDS communication reduces effectiveness of occupational safety.
Cleaning products	20% (37 out of 188) of total undisclosed chemicals; 89% of these had unknown acute toxicity and/or acute aquatic toxicity endpoint.	Used daily in small quantities; varying stringencies in chemical management and PPE worn; several cleaning products from local manufacturers and used by contractors; internationally renowned brands also used.	Workers may be exposed to several untested ingredients on a daily basis.
Motor oils	29% (54 out of 188) of total undisclosed chemicals and 1 out of 6 suspected CMR; the MSDSs	Used on a daily basis in large quantities. Controlled use and disposal.	The exposure controls for oils reduce possible risk of harm from undisclosed information.

Type of chemical	MSDS inadequacies	General exposure controls	Impact on chemical management
	for most motor oils disclose minimal ingredient information; the LD_{50} and/or LC_{50} values are not reported in majority of cases (70%).		
Paints	12% (23 out of 188) of total undisclosed chemicals; two contain suspected CMRs that are not communicated in MSDS	Used as required in many operation areas; stored in designated area in workshops, and often used by contractors; PPE usage varies.	Poor hazard communication leads to insufficient exposure controls.
Gardening chemicals	6% (11 out of 188) of total undisclosed chemicals. Three contain suspected CMRs that are not communicated in MSDS; surfactants unknown, but may increase toxicity of substances.	Used when required; used by contractors; not recorded on databases; storage not always appropriate	Poor hazard communication leads to insufficient exposure controls.
Cathode/water treatment reagents	3% (5 out of 188) of total undisclosed chemicals; majority contain trade secret ingredients	Used daily in large quantities; PPE worn; MSDSs available; restricted access	Hazard information cannot be cross-checked and large quantities of unknown substances can be released into environment. Exposure controls in place, protect workers from undisclosed information
Flotation reagents	4% (11 out of 188) of total undisclosed chemicals	Used daily in large quantities; PPE worn; hazard fume detectors present; MSDSs available; restricted access; staff appropriately trained.	
Explosives	0.5% (1 out of 188) of total undisclosed chemicals and the unidentified fuel additive is a suspected carcinogen.	Highly regulated by contractors.	Workers are exposed via inhalation and dermal contact to unidentified explosive ingredients.

The risk of harm to workers from undisclosed ingredients is low for chemicals used on a large scale in the plants and those used in laboratories because they are well regulated by consistent exposure controls and the use of appropriate PPE. If there were an accidental release of bulk chemicals, both humans and the environment would be exposed to a large quantity of unidentified substances. In such cases, the accuracy of the hazard classifications would be critical for those reported and unreported ingredients. This study showed however that the majority of MSDS deficiencies were in products such as mechanical maintenance and cleaning products which are used in smaller quantities. Extractive ventilation was not required in the areas where these products were used and the level of PPE worn was variable. Workers were therefore exposed to a greater variety of known and undisclosed components and the risk of harm is greater in the cases where there is poor hazard communication in the MSDSs. It is critical that chemical management focuses on a more stringent and consistent

standard of exposure controls in these work areas as well as ensuring that the chemicals used have complete, accurate and fully compliant MSDSs.

Disclosure and warnings enable workers to protect themselves. Keeping chemical risks shifts the burden of uncertainty to those with little capacity to bear it and withholds the data necessary to study and respond to the exposure (Lyndon, 2011). The main source of information about the safety and handling of a chemical product is its MSDS. If this information is undisclosed, misleading or inaccurate, a company's ability to protect its workers as well as consumer choice is hampered. This can affect certainty when purchasing chemical products as well as potentially affecting industry's reputation if the use of such chemicals is linked to injury, death or environmental contamination. Understanding the nature and type of undisclosed information in MSDSs is essential to correct the deficiencies and obtaining MSDSs that are in line with current legislation and industry best practice.
This study highlighted the extent of undisclosed information and the hindrances posed to chemical risk assessment generally. These hindrances are summarised in Table 10.

Table 10. Hindrances to risk assessment caused by undisclosed information.

Undisclosed category	**Hindrance to risk assessment**
Incomplete disclosure	Prevents cross-checking of ingredients during hazard assessment
Unspecific chemical identities	Inability to independently research the intrinsic hazards of the ingredients. Uncertainties about accuracy of hazard classification of undisclosed ingredients
Relative quantities unknown	Prevents the quantity of potential hazardous releases to be estimated in exposure assessment
Trade secret	Inability to independently research the intrinsic hazards of ingredients.

The findings of this study are relevant to other industries as they provide examples of the chemical inadequacies they might be facing also, and might be of greater use to multinational companies that have to accommodate different legislations and practices in a similar context. Particularly as this study showed that the MSDS deficiencies described in previous studies from 1995 are still in existence, with not much progress made since then and compliance not always being enforced. At the end of 2008, the Forum for Exchange of Information on Enforcement of the REACH regulation commenced a forum enforcement (REACH-en-force 1) project to verify the compliance of the manufacturers and importers with REACH obligations on (pre-) registration and MSDSs. In 2010, the results of inspection indicated that of the 5338 MSDSs checked, 808 (15%) were incorrect (in terms of being dated and containing

information under 16 headings) (ECHA, 2010). These MSDS inspections are still carried out in REACH-en-force 3 (2011–2013 work programme).

The lack of applied international standards for MSDSs means that the importation of chemical products from countries having diverse disclosure requirements, trade secret provisions and definitions of hazardous ingredients can result in ineffective disclosure (Welsh et al., 2000). Until similar approaches of MSDS inspections are carried out globally, companies have to implement their own MSDS compliance policy. The global implementation of the GHS in standardising hazard communication requirements for labelling and safety data sheets should further facilitate a high standard of protection for mine workers across all commodities of a multi-national mining company. It is important to understand and question how the role of REACH, its enforcement by ECHA, the implementation of GHS and the legislative milestones for the future will achieve a balance between protecting human health and the environment and ensuring the competitiveness of the chemical industry.

Citizens are entitled to know the chemicals to which they are exposed and their effects, so that they can respond to the information with individual choices (such as purchasing or not), with litigation, with political action, or with all three (Applegate, 2009). Industries that use a wide range of chemicals should be entitled to such information in order to protect the health of their workers.

5. Conclusions

This study identified the extent of the problem of undisclosed information in chemicals used on mining operations and the hindrances to adequately protect the health of the workers. In order to address these inconsistencies and safeguard workers from known and undisclosed chemical hazards, a company-level policy should be implemented into the hazardous materials standard to ensure that hazard communication is consistent and comparable for all chemicals in all commodities of a mining company. The policy should stipulate that the quality of the safety information provided in MSDSs be screened during the procurement stage. The MSDSs should be GHS compliant for comparability which should include: the ingredients being listed with their CAS numbers (or other identification number) full chemical name and concentration of all ingredients which are classified as health hazards and in cases where CBI is withheld, this should be indicated. If there are cases of ambiguity in information disclosure, then the policy should state that an agreement be made with the manufacturer of the chemical that all ingredients be disclosed to a health professional if required.

It comes down to the duty of care that industries have towards their employees. With a wide range of chemicals increasingly used, there is a balance that needs to be reached between

disclosure requirements, trade secret provisions and definitions of hazardous ingredients for market needs, and the information required to protect the health of their workers.

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