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Green Jobs in Quebec: Definition and Assessment of Potential Chemical and Biological Risks to Workers' Health

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ABSTRACT

There is currently a boom in jobs generated by the greening of the economy. In 2010, there were an estimated 155,000 "green jobs", as they are commonly called, in Quebec and 682,000 in all of Canada. While these figures depend to some extent on the definitions of the terms "green" and "environment", they do give some idea of the size of this growing field. With many new technologies being developed, an appraisal of their potential risks to workers' health is essential.

The goal of this study was to produce a profile of green jobs in Quebec and assess the potential risks to workers' health as a result of their exposure to chemicals and biological agents. More specifically, we aimed to (1) define the "green economy" in Quebec; (2) identify "green jobs"; (3) determine which chemicals and biological agents workers might be exposed to; and (4) conduct a qualitative assessment of potential risks to workers' health.

We had to adapt or create a number of instruments to achieve these objectives. Green jobs were identified chiefly on basis of the criteria in Quebec's Sustainable Development Act. The North American Industry Classification System (NAICS) and the National Occupational Classification (NOC) were used to determine green job titles in Quebec. Assessment of workers' risk was based on the control banding system. The aim of this qualitative risk management method is to ensure the safety of workers exposed to substances about which very little information is available. Substances are assigned to a hazard (toxicity) level, or band, by comparing them to similar substances for which the hazard is known; exposure to those substances at a workstation is also estimated semiquantitatively (exposure band). Most models use four or five broad hazard bands and an equivalent number of exposure bands, which together represent from 16 to 25 possible situations.

The entire process enabled us to identify some 400 job titles that could be considered green under the proposed definition and selected criteria. The jobs were grouped into 63 different occupations for which the potential chemical and biological risks were assessed, and 21 of them were deemed high risk. Those occupations should therefore be the top priorities for health and safety research. More specifically, our findings highlight the risks involved in waste management, a growing industry with which an increasing number of other activities, including power generation, agricultural production and raw material recovery, are associated. There are more and more sorting centres, the purification of industrial effluent is expanding and landfill authorization certificates are not being issued as easily as they used to be.

Although the term "green jobs" is fashionable and is in keeping with sustainable development, there is very little information available on the subject. As this is the first study of its kind in Quebec, it can hopefully serve as a basis for setting future research priorities in the field. Furthermore, occupational hygienists will be able to use our method for prevention or protection purposes and enrich our findings by contributing more precise or quantitative data.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH®	American Conference of Governmental Industrial Hygienists
BLS	Bureau of Labor Statistics (U.S.)
COSHH	Control of Substances Hazardous to Health
CSA Group	Canadian Standards Association Group
CNESST	Commission des normes, de l'équité, de la santé et de la sécurité du travail [Quebec workers' compensation board]
HSE	Health and Safety Executive
ILO	International Labour Organization
IRSST	Institut de recherche Robert-Sauvé en santé et en sécurité du travail
ISO	International Organization for Standardization
NAICS	North American Industry Classification System
NOC	National Occupational Classification
PAH	Polycyclic aromatic hydrocarbons
TNO	Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
UNEP	United Nations Environment Program

1. INTRODUCTION

Consistent with the vision of sustainable development, the "green economy" has been growing since the 1990s. The governments of Canada and Quebec have incorporated sustainable development principles into their economic strategies, among other things, by offering serious incentives for research and marketing of new technologies and the creation of jobs in recycling, alternative energy, transportation, natural resource management, environmental protection and many other industries [1, 2]. The jobs created in these fields are often called green jobs or environmental jobs. In 2010, there were over 155,000 such jobs in Quebec and 682,000 in Canada as a whole [3]. While the inclusion of the term "environmental" in the titles of these jobs influences people's perception of them, such occupations are chiefly found in engineering, communication and training, as well as in materials or hazardous substance handling, including work in recycling sorting centres (organic or inorganic contaminants, biological agents, etc.), battery manufacturing or recycling (lead, nickel, cadmium, etc.), solar panel manufacturing (silica, cadmium telluride, etc.) or composting (bioaerosols and gases produced by anaerobic decomposition).

There are all sorts of green industries. They can be divided up into several categories (Table 1 shows one classification system). Of course, these categories are not closed: waste management, for example, can be viewed from the point of view of environmental protection or resource management, if we think about recycling. The same applies to industrial effluent used for power cogeneration. But the distinctions proposed in studies on the subject nevertheless make it possible to establish broad categories and underscore the important aspects of an economy that is increasingly incorporating a sustainable development perspective [3-7]. Some industries, such as the manufacture of solar panels or wind turbines, or, generally speaking, renewable energy technologies or recycling, are considered to be exclusively green. Other industries, in contrast, such as construction, may include activities that can be labelled green only with difficulty. Building a greener house may require specialized materials without involving any different work by the builder. The United Nations Environment Program (UNEP) and the International Labour Organization (ILO) talk about "shades of green", while ECO Canada talks about degrees of "greening" [8-10]. This tendency, although natural in booming economic sectors, necessarily blurs the lines of these industries, illustrating divergences in definitions and classifications of green industries and hampering accurate comparison of findings between countries.

The interest of industrialized countries and emerging economies in the job category associated with the industries discussed above and lumped together as "green" is clear. In Quebec, a number of papers published by various government departments underscore the government's intentions with respect to new technologies, environmental protection and responsible natural resource management. That is the case of the policy paper titled *Pour un Québec vert et prospère [For a Green and Prosperous Quebec]*, a development strategy for Quebec's environmental and green technology industry [2], which announces measures to support environmental industries and promote technological innovation in the province.

Table 1 – Green economic sectors or industries

Environmental protection	Resource management	Environmental services
Air	Energy generation	Training
Water	Environmental preservation	Research and development
Soil	Farming	Policy and legislation
Waste management	Green construction	Communications
Environmental health and safety	Energy business	
	Energy efficiency	
	Manufacturing	
	Transportation	
	Carbon storage	
	Energy storage	

Source: This classification, based on the work of ECO Canada, groups together areas suggested by a number of green economy researchers [3-7].

Although it is fashionable to talk about green jobs, there are several interpretations and definitions of the term, and an increasing number of issues are now associated with it. A central concern is the health and safety of workers, a key aspect of the sound development of a green economy. UNEP has defined a green economy as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" [9]. Green jobs are decent jobs, and they go hand in glove with sustainable development. Here are some fundamental definitions of green jobs, or the green economy, from Quebec, elsewhere in Canada and around the world.

UNEP

Decent work which contributes directly to reducing the environmental impact of enterprises, economic sectors or the economy as a whole by reducing energy and resource consumption, reducing emissions, waste and pollution and by preserving or restoring ecosystems [...] [...] Green jobs need to be decent work, i.e. good jobs which offer adequate wages, safe working conditions, job security, reasonable career prospects, and worker rights. [11]

ECO Canada

ECO Canada defines a green job as one that works directly with information, technologies, or materials that minimize environmental impact, and also requires specialized skills, knowledge, training, or experience related to these areas [10].

Quebec government

The environmental industry consists of firms that produce goods and services to assess, prevent, limit or correct environmental damage to water, air, soil and ecosystems, and to similarly handle problems relating to waste and wastewater management. *A green technology* is one that can reduce the use of raw and other

> materials, reduce energy consumption, recover useful by-products, reduce polluting emissions or curb waste elimination problems. [2]

These definitions have a great deal in common and allow us to define the concept by concentrating on reducing the environmental impact of human activity. On the other hand, the definitions may be focused either on employment areas (UNEP) or actual occupational roles (ECO Canada). The ECO Canada definition adds the concept of specific skills, thus including the need to adapt worker training, a very significant point when the quality of these jobs and occupational health and safety are considered. Another interesting distinction is made by the U.S. Bureau of Labor Statistics, which defines green jobs in terms of two broad categories: (1) the output approach: jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources; and (2) the process approach: jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources [4].

On the other hand, some analyses condemn the lack of rigour of certain reports that see the green economy as a panacea for economic problems [12, 13]. Various U.S. studies have tried to assess or quantify this emerging field in their country in economic terms, such as the number of employees, revenue, percentage of the regional economy, etc. The differing conceptual approaches taken by these reports make it impossible to draw clear conclusions about trends in green jobs, except that there well and truly are shades of green, and that these jobs are for the time being basically the same as conventional jobs, although they may involve risks and require additional training or knowledge [12]. The approach taken in a report by the Occupational Information Network focuses on workers rather than jobs, thus avoiding having to differentiate definitively between "green" or "not green", emphasizing instead the importance of the "greening of the economy." From this point of view, which rejects a static concept of jobs, "greening" influences the workplace and workforce training in a dynamic process [14].

Finally, although green jobs is a fashionable term that is in keeping with the principles of sustainable development, very little information is available on the subject. Establishing a common basis for assessment, starting with a definition of these jobs and the potential health risks for workers in relation to the associated chemicals and biological agents, would seem to be an urgent necessity. An overview of the industry is therefore required. A number of studies have clearly demonstrated that there are many contaminants in green jobs and note that further research is needed on worker protection [5, 15]. First, manufacturing processes are changing quickly, often incorporating materials or technologies straight out of research and development centres. Second, a company may use a large number of processes to remain competitive and as "green" as possible. It therefore seems essential to be able to conduct a quick appraisal of the risks to workers, in order to protect their health and prevent potential harm.

Assessing a wide range of occupational situations in a wide range of industries presents considerable challenges. One promising avenue for evaluating and comparing many kinds of situations is control banding. It is a qualitative risk management method originally developed by the pharmaceutical industry [16] as a way to safely work with chemicals about which there is little or no toxicity information. Substances are placed into hazard (toxicity) bands by comparing them with similar substances for which the hazard is known; exposure to those substances at a workstation is also estimated semiquantitatively (exposure band). Most models use four or five

broad hazard bands and an equivalent number of exposure bands, which together represent from 16 to 25 possible situations. For each situation (combined hazard band/exposure band), there is a matching control strategy [16, 17], which is incorporated into the company's prevention program. In the United Kingdom, the Health and Safety Executive (HSE) has developed an improved and simplified control banding model called Control of Substances Hazardous to Health) (COSHH) for small and medium-sized businesses that cannot afford a full-time occupational hygienist [18].

The Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek (TNO, Netherlands Organisation for Applied Scientific Research) developed the COSHH further, designing a Web tool, the Stoffenmanager, which assigns an exposure band based on a simplified, easy-to-understand exposure model that is usable by non-experts [19, 20]. These tools are discussed in detail later in this report.

Control banding is especially appropriate in new or emerging situations for which there is not enough data to do a quantitative risk assessment. That is one of the main reasons this approach was proposed in nanotechnology [21, 22] and is now the subject of an ISO standard [23]. It has also been incorporated into a CSA Group standard (Z12885, Nanotechnologies: Exposure Control Program for Engineered Nanomaterials in Occupational Settings) [24], and the CSA is in the process of examining the ISO control banding standard with a view to adapting it for Canada. Closer to home, the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) is currently adapting and applying the approach to the selection of respiratory protection against bioaerosols [25]. Control banding, which is an integral part of a prevention program, may be used for a variety of purposes:

a) to determine the risk level at a specific workstation while at the same time requiring fewer resources than the usual industrial hygiene process, which necessitates a full assessment of the worker's exposure;

b) to prioritize action to be taken after assessing the risk associated with several work situations;

c) to propose the implementation of an appropriate level of risk control, reassessed as scientific and technical knowledge about the products and processes involved becomes available;

d) to assess the residual risk when preventive measures have already been taken.

In the current context, which is characterized by a high degree of uncertainty with respect to health risks associated with green jobs, control banding is an alternative that has not, to the best of our knowledge, ever been explored in the field. Part of a comprehensive occupational risk assessment process, it can be applied to green jobs to help determine the occupations for which preventive measures would be the most appropriate in terms of priority needs, on the basis of the available information and the assumptions made.

2. OBJECTIVES

The goal of this study is to produce a profile of green jobs in Quebec and assess the potential risks to workers' health as a result of their exposure to chemicals and biological agents. The specific objectives are described below.

2.1 Identify the Green Economy, Green Industry and Environmental Industry

There are several possible approaches to the green economy, green industries or green jobs. To ensure a clear, consistent process, it seemed like a good idea to present an operational definition as part of this paper, with the focus on workers, and the potential health and safety risks of these jobs. Our method is not inspired by a new or different conception of the problem, but rather seeks consensus and adds its vision to those already proposed by many provincial, national and international organizations, both public and private.

2.2 Draw up a List of Green Jobs in Quebec

An operational definition of green jobs, drafted from the point of view of risks to workers, led us to identify criteria specific to sustainable development and applicable to the jobs in question in order to determine how "green" they are. Job titles could thus be selected from generally agreed upon classification systems, such as the North American Industry Classification System (NAICS) and the National Occupational Classification (NOC), and government databases.

2.3 Determine Chemical Contaminants and Biological Agents to Which Workers Are Likely to Be Exposed

Once the job titles were identified, we had to determine what type of chemical contaminants or biological agents workers might be exposed to. The information on occupations and industries in NAICS and NOC, as well as the specialized literature, enabled us to draw up the most complete list possible of hazards, from a macroscopic occupational perspective. The hazard level was assessed using hazard bands based on indicators and similarities in the scientific and technical literature. Then, exposure was assessed.

2.4 Assess Risk by Control Banding

On the basis of data on hazards and worker exposure, an occupation can be rated using the control banding approach. These ratings can then be used to establish a hierarchy of occupations by risk, which can provide guidance for future occupational health and safety studies of green jobs.

3. METHOD

There were many steps in the approach we followed to achieve our goals. They are described in detail below. See Appendix A for a chart illustrating the process and providing an overview of our approach.

3.1 Definition and Identification of Green Jobs

3.1.1 Definition

The concept of green jobs, which depends on the observer's point of view, is difficult to define precisely. Nonetheless, for analysts and decision makers, definitions are essential and lay the foundation for the research process. A definition of green jobs should reflect their newness and dynamic state, and avoid trying to pin down something that is by nature changeable. By combining the various points of view we presented in the introduction and especially by keeping occupational health and safety in mind, we propose the following definition:

> *Any job that has the direct aim of reducing the environmental impact of human activity and is consistent with the principles of sustainable development can be considered green. Green jobs, which may require specific skills and knowledge, involve the development, innovation or use of special technologies, techniques or processes.*

This definition is based on two fundamental aspects of occupational health and safety: (1) the impact of human activity on the environment and (2) potential changes in the workplace. This second aspect calls for the training or adaptation of workers, who are facing changes at work. At the moment, these aspects must be considered within the fields concerned by the environment or the green economy.

The concepts of "green" and "sustainable" are often considered to be equivalent or synonymous. Yet the two terms are not fully interchangeable: "green" refers more directly to the environmental impact, the raw materials used and pollution; "sustainable" is more general, encompassing the environmental, economic and social impacts of an activity [26]. While green jobs are consistent with sustainability principles, and their development must go beyond the physical surroundings to include economic and social aspects of human activity, it is essential for researchers and decision makers to adopt a rigorous approach and be able to define their field of investigation using operational criteria for the development of analytical or statistical models. In this study on the risks to workers using new technologies, we therefore gave special priority to both the narrower concept of "green" and the broader concept of "sustainability", in order to target the impact of these technologies on the environment and, of course, on occupational health and safety, more precisely [27].

3.1.2 Identification Criteria for Green Jobs

The wide range of industries in the green economy makes the identification of green jobs complex, all the more so since to some economists, all jobs should eventually become "green". Yet the definition used here allows us to propose some criteria for differentiating right now

between a conventional job and a green job. There are many advantages to using a criteria-based approach: it is more systematic; methodological choices are simplified; and the process can be replicated more easily. The main disadvantage is that it limits fine distinctions in a still-fuzzy field. As mentioned above, the dynamics created by the sustainability movement are evolving quickly and it is very hard to predict which technologies will be more successful, as they themselves will have to change and adapt to needs and to scientific discoveries. That should not be allowed to hamper research, however, as the more decision-making tools we have, the better.

On the basis of the above definition, two questions must be asked to determine whether a job is green or not:

1. Is the job directly connected to reducing the environmental impact of human activity?

2. Is the job consistent with principles of sustainable development?

It is important to note that although all jobs meeting the first criterion on environmental impact are necessarily consistent with at least one principle of sustainable development, this characteristic is important because the reverse is not true. Both criteria are essential to the definition and assessment of a green job, so they were given equal weight. It should also be pointed out that it is not a question of determining whether for each job, one or more workers' specialities have to do with environmental impacts, but rather whether some duties of the job have the reduction of environmental impact as an outcome.

Quebec is one of the few jurisdictions in the world to have a Sustainable Development Act. In drafting the act, the Quebec government referred to 16 principles of sustainable development from among those in the Rio Declaration on the Environment and Sustainable Development [28]. In its Government Sustainable Development Strategy 2008–2013, the Quebec government laid out a number of strategic directions, including Direction 2, "Reduce and manage risks to improve health, safety and the environment" [29]. This direction is based on 5 of the 16 principles (the letters used to refer to them match the order they are stated in the act):

a) "Health and quality of life": People, human health and improved quality of life are at the centre of sustainable development concerns. People are entitled to a healthy and productive life in harmony with nature.

c) "Environmental protection": To achieve sustainable development, environmental protection must constitute an integral part of the development process.

f) "Access to knowledge": Measures favourable to education, access to information and research must be encouraged in order to stimulate innovation, raise awareness and ensure effective participation of the public in the implementation of sustainable development.

i) "Prevention": In the presence of a known risk, preventive, mitigating and corrective actions must be taken, with priority given to actions at the source.

j) "Precaution": When there are threats of serious or irreversible damage, lack of full scientific certainty must not be used as a reason for postponing the adoption of effective measures to prevent environmental degradation.

These five principles were selected as criteria for determining whether a job is consistent with sustainable development principles. Jobs may meet anywhere from one to five of the criteria. We reworded the principles to focus on jobs and have provided a few details to facilitate interpretation and clarify our method:

a) Health and quality of life. The job promotes or is concerned with people's health and quality of life.

The principle applies to activities directly connected to people's health and quality of life. In fact, any action that protects the environment can be interpreted as indirectly benefiting the population. From that point of view, the distinction is unnecessary. In this study, environmental protection is considered to have an indirect effect on human health, and only jobs having a direct connection to health and the quality of life (e.g., water treatment, pollution control, green space clean-up and management, or urban transit) score a point for this principle.

c) Environmental protection: The job helps protect the environment.

Three other sustainable development principles (out of the 16) that we felt were relevant were used to define the scope of this concept: (l) biodiversity preservation; (m) respect for ecosystem support capacity; and (n) responsible production and consumption. Just one of them was required for a job to qualify as helping to protect the environment. Thanks to these specifics, it was possible to distinguish between the principles of protection and prevention by limiting the possible interpretations of the statement.

f) Access to knowledge: The job promotes education, access to information and research, and stimulates innovation.

This principle is to be understood in its broadest sense: Any job that is directly or indirectly involved in education or research, or promotes innovation, by commercializing new technologies, for example.

i) Prevention: The job involves the prevention, mitigation or remediation of environmental damage.

The concept of environmental damage is of fundamental importance, while the idea of prevention depends on highly reliable knowledge of known risks and impacts. So jobs involving pollution control, organic farming and recycling qualify. In the case of agriculture, the boom in organic farming is considered to stem from concern about pollution problems or the hazards (to humans or the environment) associated with the use of fertilizers or petrochemically derived biocides.

j) Precaution: The job favours the precautionary principle where there is a risk of potential environmental damage.

This principle is fairly complex to apply. The two components that characterize it, lack of total scientific certainty and extent of perceived risk, weaken the assessment of the job's contribution to this principle.

Finally, we should point out that the degree of "greenness", within the perspective of this study, depends on the number of sustainable development principles associated with the job title, and thus on the importance attributed to health, safety and environmental risks. Other principles with a different perspective (social, economic, etc.) would change the degree of greenness, or even the job titles selected.

Many job titles cannot be considered without taking into account a particular industry or specialization within the occupation. The case of architects is revealing: some specialize in designing "green" buildings, whether from the point of view of energy efficiency, materials or space reserved for nature (like green roofs or walls). It is therefore reasonable to include architects on the list of green jobs, but it is not possible to distinguish green architects from conventional architects without a special mention.

In short, the weighting used to classify a job as green is the following. The criterion of reducing the environmental impact, corresponding to the first question asked in identifying a green job, is mandatory and given a weight of 50%. Each green job identified by this means also had to be consistent with at least one of the five sustainable development principles discussed earlier. Each of the principles was worth 10% of the points, for a total maximum of 50%. To count as "green", then, jobs had to score between 60% and 100%. See Appendix B for the full list of job titles and their scores.

3.1.3 Industry and Occupation Classification Systems

Green jobs are being created through the increasingly strict enforcement of government sustainability policies. That is why we based our list of job titles on information primarily from federal and provincial government and quasigovernmental agencies, as well as some organizations working in the field. A good part of our research relied on data from government sources like the industry and occupational classifications used by Statistics Canada and Human Resources and Skills Development Canada, as well as reports by trade organizations and industry committees, like EnviroCompétences and ECO Canada (Environmental Careers Organization of Canada). U.S. points of view and those of large international organizations, such as the United Nations or the International Labour Organization, are also especially relevant.

In Canada, industries were classified using codes adopted by the United States, Canada and Mexico: the North American Industry Classification System (NAICS). The system is used by Statistics Canada and its counterparts in the other two countries in the analysis of industrial activity. The NAICS has several levels: the system is based on 20 sectors (two-digit codes), subdivided into subsectors (three-digit codes), industry groups (four-digit codes) and industries (five- or six-digit codes). The NAICS was last updated in 2012 [30]. Data from the Statistics Canada 2006 census were used to determine the number of workers per industry group (four-digit code), but figures were not available for industries (five-digit codes). These are the most recent data available.

The combination of the NAICS and the National Occupational Classification (NOC), which categorizes Canadian occupations and jobs, results in a more precise classification of job titles, based on both industry and occupation. The NOC was established jointly by Statistics Canada and Human Resources and Skills Development Canada. It also has a hierarchical structure. The

four-digit codes we used represent 500 occupational group descriptions, in which the first digit refers to the occupational skill type. The NOC was last updated in 2011 [31]. Based on 2006 census data, Statistics Canada determined which occupations were associated with each NAICS code. The census asked respondents to name the company for which they worked, specify the type of business (so it could be assigned an NAICS code) and describe their main duties (so the occupation could be assigned an NOC code). In the NOC, occupations are described in terms of tasks, duties and responsibilities, materials processed or used, industrial processes and equipment used, and products made and services provided. This information can then be used to assess the toxicity of various chemicals and biological agents, and workers' potential exposure.

Many analysts have used the NAICS as a codified way to determine the sectors considered to be green in North America. Among them are the U.S. Bureau of Labor Statistics (BLS), the Quebec government's Centre d'étude sur l'emploi et la technologie [employment and technology research centre], ECO Canada and EnviroCompétences, and Canadian and Quebec sector committees on labour [4, 10, 32]. The scope of the studies and the definition of green sectors vary from one organization to another.

In order to take the broadest possible approach, while at the same time respecting the framework of this study, we started by listing all the NAICS industry groups employing workers in Canada (according to the 2006 census) and selected by any of those organizations: 160 NAICS groups out of a total of 323.

Next we extracted all the occupations in which there were workers in the selected NAICS groups, according to the 2006 census.

There were 500 different occupations, encompassing some 40,000 job titles. Statistics Canada defines occupation as follows:

> An occupation is defined as a collection of jobs, sufficiently similar in work performed to be grouped under a common label for classification purposes [31].All occupations associated with the definition of green jobs proposed in this study were selected, with care being taken to use a sufficiently broad interpretation that some jobs with titles seemingly removed from the occupation would not be missed. A labour statistics specialist and an industrial hygienist were consulted several times as the list was being drawn up and in the end, it was narrowed down to 160 occupations. Statistics Canada classifies a total of 11,229 job titles under those 160 occupations. Last, the match between the selected job titles and the predetermined criteria was checked.

3.2 Occupational Health and Safety Risks

3.2.1 Adapting the Control Banding Method

Because of their new or unusual nature, some green jobs, like those in photovoltaics, are characterized by a level high of uncertainty as to working conditions and the quantitative assessment of the health risks of various substances, the toxicological properties and exposure levels of which are not well known. In such a context, control banding is considered to be the best assessment option. This method was developed in the 1970s and 1980s to manage risks of explosion, radiation, lasers and biological agents, then improved by the pharmaceutical industry

to manage chemical risks about which there was little or no toxicity information. It is also being used in a growing number of situations, such as substance mixtures, in which only limited information is available [16, 21-26, 33-50].

Chemical contaminants

A number of control banding approaches have been developed [16, 21-26, 33-50], often specific to a category of substances or a new field, such as nanotechnology [21-24, 26, 41, 45-47, 49].

The method proposed here is based on a simultaneous consideration of three existing approaches:

- The British *COSHH*, which bands hazards on the basis of risk phrases (R-phrases[1]), commonly used in Europe, and determines exposure bands by taking into account a substance's physical and chemical properties (dustiness and volatility), process temperature and quantity involved, but not exposure frequency or time or control measures taken [36, 40, 42].
- The *Stoffenmanager* (Netherlands TNO), which uses the same hazard bands as the COSHH. On the other hand, the approach also takes exposure frequency and time into account, as well as existing control measures, workplaces, etc. It is more thorough than the COSHH approach, but requires more information [19, 37, 38, 43, 47, 51].
- The recently published ISO/TS 12901-2 nanotechnologies standard, which takes an interesting approach to the assessment of potential aerosol emissions based on the types of products used to start with and the various processes involved [23].

Given the lack of information in some workplaces, not to mention that the purpose of this study was to draw up a general profile of the situation, the following variables were used to estimate occupational exposure: the substance's physical and chemical properties (dustiness and volatility) and the frequency of use. Potential toxicity was assessed for each contaminant using R-phrases and various databases (see description in section 3.2.2, *Chemical contaminants*, below).

The chemical control banding model we have developed is based on the three approaches discussed above, focusing on a worst-case scenario. The scenario makes use of the most pessimistic data and assessments. It is therefore unnecessary to take into account the amount of the product used or the number of workers involved. There are four exposure bands, ranging from 1 (minimum exposure) to 4 (maximum exposure), and five hazard (toxicity) bands, going from 1 (minimum) to 5 (maximum). Finally, there are four risk categories: low, moderate, high and very high (see Table 2).

[1] The phrases are defined in Annex III of the Dangerous Substances Directive, 67/548/EEC: *Nature of Special Risks Attributed to Dangerous Substances and Preparations* (see Appendix E).

Table 2 – Chemical control banding (adapted from COSHH)

		Potential exposure bands			
		1	**2**	**3**	**4**
Hazard bands	**1**	low	low	moderate	moderate
	2	low	moderate	moderate	high
	3	moderate	high	high	very high
	4	high	very high	very high	very high
	5	very high	very high	very high	very high

Biological agents

Control banding for biological agents associated with green jobs was based on control banding models for chemicals [19, 42] and nanoparticles [22, 50, 52], McCullough and Brosseau's work on infectious agents [53], the new CSA standard Z94.4-11 [54], work by Lavoie *et al.* on control banding for respirator selection against bioaerosols [25, 55, 56] and the international classification of microorganisms into risk groups based on their pathogenic nature [54, 57, 58].

It is a qualitative management model that can then be confirmed by industrial hygiene data. A four-by-four model was developed, made up of the four risk groups used in biosecurity listed downward and four levels of potential exposure across (see section 3.2.3, *Biological agents*).

3.2.2 Identification of Chemical Contaminants and Biological Agents and Hazard Assessment

Chemical contaminants

The data from the NOC and the NAICS specify workers' main duties and skills and their workplace. From this information, we drew up a list of contaminants likely to be associated with an occupation (set of jobs) and sectors in which these occupations are practised, according to the 2006 census. Additional information was taken chiefly from the database of the U.S. National Occupational Exposure Survey, conducted between 1981 and 1983 [59], and the results of chemical analyses done at the IRSST for the period 2001–2005 [60].

On the basis of this information and some documentary research on the use, handling and production of chemicals, we were able to make a qualitative judgment about the nature and variety of substances to which workers in different jobs are likely to be exposed. In order to specifically target green job workplaces, we intentionally crossed off some sectors for some occupations from the 2006 census.

For example, the carpenter occupation was analyzed from a green construction perspective, so only industries connected to green construction (residential or industrial) were selected. The same applies to electricians, who were analyzed solely from the point of view of production, management and maintenance of renewable energy systems.

Some occupations, like managers and architects, were also eliminated from the analysis because their exposure could only be less than or equal to that of other workers in the same industry.

Chemical contaminants were first classified by the likelihood of their presence ("possible," "probable" or "known"), then only those deemed probable or known were selected.

The potential toxicity of each contaminant was determined using R-phrases, where available. The main sources of information on contaminants were industry, the material safety data sheets of the Sigma-Aldrich chemical company and the Reptox toxicological database of Quebec's CNESST [workers' compensation board]. Potential toxicity was also based on the assessment of the American Conference of Governmental Industrial Hygienists (ACGIH®).

When the toxicity classifications of the Sigma-Aldrich and ACGIH® systems differed, priority was given to those of the ACGIH®, but the Sigma-Aldrich information was kept. Where there was no ACGIH® classification, the classification was based on the Sigma-Aldrich assessment. As mentioned earlier, potential toxicity is classified into five hazard bands, where 1 is the lowest and 5 the highest (see Table 3 and Appendix C).

Table 3 – Classification of hazard bands for chemicals

Hazard band	Effects on humans	Standard or reference value, dust (mg/m^3)	Standard or reference value, fumes (ppm)	R-phrase (see Appendix E)
1 Very low risk or no significant risk for health	Not classified; skin or eye irritant	1–10	50–500	R36; R38; all substances without R-phrases ranked in hazard band 2 to hazard band 5
2 Low risk, slight toxic effects rarely requiring medical follow-up	Single exposure harmful	0.1–1.0	5–50	R20/21/22; R68/20/21/22
3 Moderate to significant risk requiring medical follow-up	Toxic, corrosive	0.01–0.1	0.5–5.0	R23/24/25; R34; R35; R37; R39/23/24/25; R41; R43; R48/20/21/22
4 High risk	Highly toxic, toxic for reproduction	< 0.01	< 0.5	R26/27/28; R39/26/27/28; R40; R48/23/24/25; R60; R61; R62; R63; R64
5 Very high risk	Asthma, cancer, genetic damage	Requires expert advice	Requires expert advice	R42; R45; R46; R49; R68

Source: Table adapted from websites 8 and 12 on control banding, Appendix D.

For mixtures and groups of substances, such as polycyclic aromatic hydrocarbons (PAHs), solvents and pigments, the toxicity level was established by professional judgment based on the hazard represented by a single substance, the one most likely to be used or found in the industry or occupation concerned. For instance, if PAHs were present, a potential toxicity of 5 was assigned, although the toxicity of each PAH is different. Agents classified as carcinogenic or probably carcinogenic to

humans by the International Agency for Research on Cancer (groups 1 and 2A) were automatically put into band 5.

Workers' exposure was therefore assessed for each contaminant (see section 3.2.3, Chemical contaminants). The interactive effects (additive, potentiation, antagonistic or synergistic) of chemicals were not considered. Although such effects are highly significant in terms of workers' health and safety, the qualitative approach and macroscopic view of this study made it impossible to incorporate those variables in a satisfactory manner.

Biological agents

As far as biological agents are concerned, it was possible to determine by professional judgment for each job whether the worker might be exposed to agents in one of the four risk groups from the international classification of biological agents (see Table 4 and Appendix F for a more complete list of biological agents in groups 2, 3 and 4). Only three groups are represented among green jobs, as the fourth includes only viruses that cause very serious diseases for which no curative treatment is available (smallpox, certain hemorrhagic fevers like Ebola, etc.). Fortunately, those pathogens are not found in Canadian workplaces.

Table 4 – Biological risk groups

Risk group	Description
1	***Low individual and community risk*** A biological agent not likely to cause diseases in healthy workers. Non-infectious bioaerosols are in this category. *Bacillus subtilis, Escherichia coli K12*, most moulds
2	***Moderate individual risk, low community risk*** Pathogen that can cause disease in humans but that, under normal circumstances, is not likely to pose a serious threat. Effective treatments and preventive measures exist that limit the risk of propagation. Bacteria: *Salmonella* spp., *Legionella* spp., *Chlamydia* spp., *Clostridium* spp., *Vibrio cholerae*, *Listeria* spp., *Streptococcus* spp., *Helicobacter pylori* Fungal agents: *Blastomyces dermatitidis, Cladosporium bantianum, Cryptococcus neoformans, Microsporum, Penicillium marneffei* Parasites: *Leishmania* spp., *Plasmodium* spp., *Trypanosoma* Viruses: Hepatitis A, B, C, D and E, Epstein-Barr, influenza types A, B and C, human papillomavirus, measles
3	***High individual risk, low community risk*** Potentially infectious pathogen that generally causes a serious or lethal disease in humans. Curative treatments sometimes exist. Bacteria: *Mycobacterium tuberculosis, Brucella* spp., *Yersinia pestis* Fungal agents: *Coccidioides immitis, Histoplasma capsulatum* Viruses: Hantavirus, Rift Valley fever virus, Japanese encephalitis virus, yellow fever virus, human immunodeficiency virus (HIV) types 1 and 2 Prions: Creutzfeldt-Jakob disease, kuru
4	***High individual and community risk*** Pathogen that generally causes a very serious disease in humans and for which no treatment exists. This group consists only of viruses. Crimean-Congo hemorrhagic fever, Ebola, Marburg, Lassa, Herpes B or simian herpes, hemorrhagic fever agents, smallpox and undefined viruses

Source: [25]

The only place in Canada where those viruses are stored is the National Microbiology Laboratory in Winnipeg, Manitoba. The worst-case scenario approach enabled us to determine the potential hazard of each job, in other words, in case of exposure to multiple agents, the most hazardous were selected in order to estimate the risk to workers. Unlike control banding for chemical agents, where the classification of the hazard level varies with the organization responsible for the classification, the risk groups used for biological agents have been agreed upon internationally.

3.2.3 Exposure and Risk Assessment

Chemical contaminants

Workers' potential exposure to chemical contaminants was assessed for each occupation, one contaminant at a time; there is no overall score for exposure to contaminants in the work environment, but rather a score for each contaminant potentially present. The exposure score was based on two criteria: the frequency of use and the dustiness or volatility of each substance identified in the preceding step. The two criteria were assessed semiquantitatively: "low" frequency of use corresponded to a substance contact time of less than 10%; a "moderate" frequency meant using the substance from 10% to 80% of the time; and a "high" frequency meant it was used more than 80% of the time at work.

"Low" dustiness/volatility meant very little visible dust (solids) or a boiling point above 150°C (liquids); "moderate" dustiness/volatility referred to particles suspended in the air, but that settled fairly quickly, or a boiling point between 50°C and 150°C; "high" dustiness/volatility referred to clouds of dust remaining in suspension for several minutes or a boiling point below 50°C. For substances naturally in a gaseous state, the vapour density and ambient temperature, as well as the nature of the processes, were taken into consideration in determining the possibility that they might be found in the worker's breathing zone. Potential exposure was determined using the model shown in Table 5.

Table 5 – Potential exposure to chemical contaminants

Potential exposure		**Dustiness/volatility**		
		low	***moderate***	***high***
Frequency of use	***low***	low	moderate	high
	moderate	moderate	high	very high
	high	high	very high	very high

As chemical contaminants and occupational exposure were estimated by contaminant within a given occupation, we obtained a series of risk ratings for the occupation in question. Two methods were used to assign a final score to an occupation. The first was to multiply the risk ratings of all the contaminants for each occupation, and the second was to use a risk priority model. In the first method, we chose multiplication over addition to avoid giving too much importance to contaminants that are not very or not at all toxic (potential toxicity 1). With an

additive method, for example, an occupation for which many contaminants were listed would have obtained a higher score than one with fewer contaminants, even though the latter were potentially more toxic.

Of course, the number of contaminants can in itself be an indication of hazardousness: a worker exposed to a large number of substances may be at greater risk than a worker exposed to very few substances. Conversely, it could be argued that it is more hazardous to be exposed to a single highly toxic contaminant with a score of 5 than to 10 contaminants with a score of 1. In order to compensate for this potential bias, the second method used a priority model that takes into account both variables: the number of contaminants and their risk ratings (see Table 6). Across the top of the table, the number of contaminants identified is classified by quartiles, while down the side, the frequency of risk ratings greater than or equal to 3 is shown as a percentage. The intersection shows the priority level: high (red), medium (yellow) or low (green) (see Table 6). This priority model is the one we finally chose for assessing chemical risks.

Table 6 – Chemical risk priority model

Frequency of risk ratings ≥ 3 (%)	Number of contaminants (quartiles)			
	0–13 (I)	14–16 (II)	17–20 (III)	21–29 (IV)
0–24	low	low	low	moderate
25–49	low	moderate	moderate	moderate
50–74	low	moderate	high	high
75–100	moderate	moderate	high	high

Biological agents

Unlike the assessment of exposure to chemical contaminants, exposure to biological agents was assessed for each job title and an overall score was assigned to each job within an occupation. Exposure was also rated on the basis of two separate criteria: overall exposure was determined on the basis of control measures (C) and exposure level (E). C is characterized by the percentage of the time spent performing risk tasks and by the measures taken to control exposure. E is based on the distance between the source and the workers and the generation rates of biological agents. C and E (Table 7) were classified into five bands, each with a corresponding score.

The sum of the C and E scores gives an overall exposure rating [25]. In our model, E accounts for 80% of the total score because emission or generation rates and proximity to source are much more important in calculating overall exposure than C, which here accounts for 20% of the total score [25, 34, 53, 55, 56]. According to the American Industrial Hygiene Association [34], the exposure level of a worker near an emission source can be four times higher than when farther away, hence the use of 80% for E in our model's calculation of overall exposure level. The intersection of overall exposure with the risk group represented by the microorganisms concerned gives a potential risk in one of four categories (low, moderate, high and very high). The model is presented in Table 8.

Table 7 – Control measures (C) and exposure levels (E) for biological agents

Score	**Frequency band**
Control measures and frequency of exposure (C)	
2.0	ACH* ≤ 2; little or no general ventilation; confined, unmaintained spaces or similar, **continuous exposure to microorganisms 100% of the time**
1.5	2 < ACH ≤ 6; general ventilation or open windows, weekly maintenance or similar, **exposure to microorganisms 75% of the time**
1.0	ACH > 6; negative-pressure room; laboratory ventilation; isolation chamber; displacement ventilation, daily maintenance or similar, **exposure to microorganisms 50% of the time**
0.5	ACH > 12; mechanized operations; operations with laboratory hood; some hospital departments (bronchoscopy, operating room, etc.); frequent daily maintenance, outdoor work or similar, **exposure to microorganisms 25% of the time**
0	operations in laminar flow cabinet; sources in closed circuit or similar, **no exposure**
Exposure level (E)	
8.0	**Uncontrolled exposure to biological contaminants**; proximity to emission sources; work in emission plumes; work producing aerosols or similar
6.0	**High exposure**; decontamination work or similar
4.0	**Moderate exposure**; contact with biological contaminant; far from source or similar
2.0	**Low exposure**; employees assigned to other duties
0	**No exposure**

*ACH = Air changes per hour

Table 8 – Biological risk control banding

Biological risk assessment model		**Overall exposure level (C + E)**			
		1 (1–5)	**2** (5.5–7)	**3** (7.5–9)	**4** (9.5–10)
Risk group	**1**	low	moderate	moderate	moderate
	2	low	moderate	high	high
	3	low	moderate	high	very high
	4	very high	very high	very high	very high

4. RESULTS

4.1 Identification of Green Jobs

In the first phase of the process of identifying green jobs, we used the NAICS groups employing workers in Canada that had also been selected by the organizations that produced lists of green job titles. We thus came up with 160 NAICS groups out of a total of 323. Then, 160 occupations were selected after the NOC occupational groups had been examined, producing 11,229 job titles. In all, 466 of those 11,229 job titles obtained a score of at least 60%, the percentage set by the research group as the cutoff for qualification as a green job. Note that this percentage is based on the job's contribution to the reduction of environmental impacts (50%) and its consistency with the principles of sustainable development (10 percentage points per principle, with a maximum of 50% for all five principles selected). The job titles come under 71 different occupations (13% of all occupations with NOC codes). By way of comparison, 211 jobs in 31 occupations scored 80% or more. See Appendix B for the full list of selected jobs and their scores.

Table 9 below shows the breakdown, by the NOC's broadest categories, of the number of occupations with green job titles and the number of such titles. The NOC's broadest categories are based on skill types, which are influenced by similarity with the field of study required for entry into an occupation [31].

Table 9 – NOC occupational skill types and number of occupations with green job titles

NOC code	**Occupational skill type**	Occupations (4-digit NOC code)	*Green job titles*
0	Management occupations	9	*45*
1	Business, finance and administration occupations	–	–
2	Natural and applied sciences and related occupations	26	*181*
3	Health occupations	–	–
4	Occupations in education, law and social, community and government services	1	*28*
5	Occupations in art, culture, recreation and sport	–	–
6	Sales and service occupations	–	–
7	Trades, transport and equipment operators and related occupations	18	*110*
8	Natural resources, agriculture and related production occupations	7	*37*
9	Occupations in manufacturing and utilities	10	*65*
	Total	**71**	***466***

NOC: National Occupational Classification

Most occupations with green job titles are in the natural sciences. It is hard to arrive at an accurate count of job titles, because the NOC list is not exhaustive, since any employer can make up new job titles. Furthermore, there are many similar job titles, and differences in terminology do not necessarily reflect distinctions in duties (e.g., wastewater treatment operator versus wastewater treatment plant operator; electrician versus electrician – construction, etc.).

On the other hand, some distinctions between job titles related to the same occupation are important, such as the differences between a controller, an operator and a technician (NOC 9243), or the differences between waste treatment and water treatment (NOC 9212). Responsibilities and tasks may change, as well as the workplace.

4.2 Potential Risks of Chemical Contaminants

4.2.1 Chemical Contaminants

The occupational situations obtained by seeing where an occupation intersects with various appropriate industries provides a macroscopic view of the workplace. Some occupations were eliminated from the analysis because their exposure could only be less than or equal to that of other workers in the same industry (see section 3.2.2, *Identification of Chemical Contaminants and Biological Agents and Hazard Assessment*). We therefore drew up a list of potential contaminants for 63 of 71 occupations (comprising 432 of 466 job titles). Sometimes specific contaminants could be identified, and sometimes only groups or classes (e.g., cadmium, as opposed to soil dust). Anywhere from 5 to 29 contaminants were identified for each occupation. A total of 220 chemical contaminants were associated with the 63 occupations analyzed (see Appendix C). The number of contaminants can be broken down by their potential toxicity as follows:

	Potential toxicity	Number of contaminants
Minimum toxicity		
	1	68
	2	48
	3	39
	4	30
	5	35
Maximum toxicity		

Among the 35 contaminants with a maximum potential toxicity (5), 30 (86%) are considered to be known or probable carcinogens, classified as Group 1 or 2A by the International Agency for Research on Cancer.

4.2.2 Control Banding Adapted to Chemical Risks

Table 10 gives the breakdown of the 63 occupations using the dual-input model for prioritizing the risks of chemical contaminants. The stratification of the number of contaminants into quartiles helped to attenuate a potential effect of the lack of knowledge of exposure in some occupations, which could have emphasized extremes (well-known occupation → many contaminants identified; less-known occupation → fewer contaminants identified). The 13 occupations deemed to be high risk (high priority) according to the priority model are listed in Table 11.

Table 10 – Breakdown of 63 occupations by number of identified contaminants and frequency of risk ratings of 3 or higher

Frequency of risk ratings ≥ 3 (%)	Number of contaminants (quartiles)				
	0–13 (I)	*14–16 (II)*	*17–20 (III)*	*21–29 (IV)*	*Total*
0–24	3	4	0	0	**7**
25–49	12	5	7	8	**32**
50–74	7	4	6	5	**22**
75–100	0	0	1	1	**2**
Total	**22**	**13**	**14**	**14**	**63**

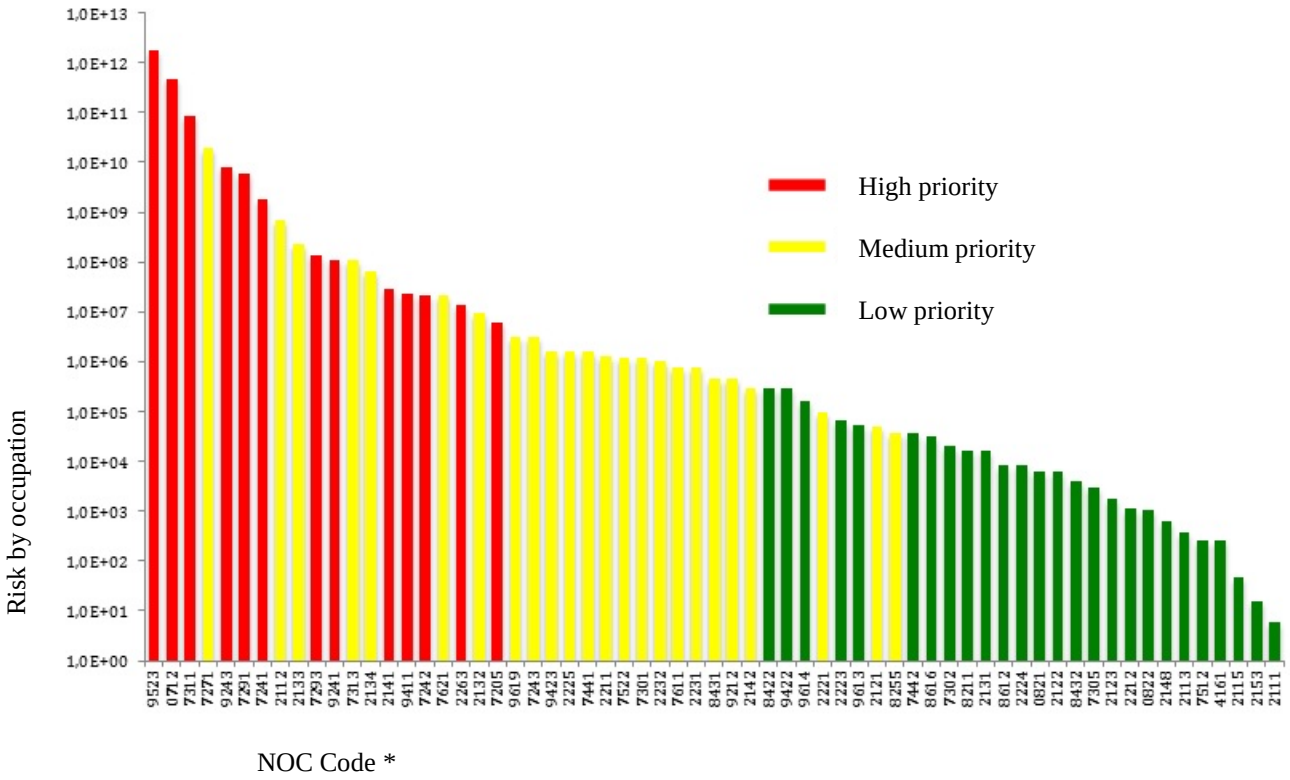
The 13 high-risk occupations are in the red cells.

Table 11 – List of occupational codes* deemed to be of high chemical risk

National Occupational Classification (NOC), 2011	
0712	Home building and renovation managers
2141	Industrial and manufacturing engineers
2263	Inspectors in public and environmental health and occupational health and safety
7205	Contractors and supervisors, other construction trades, installers, repairers and servicers
7241	Electricians (except industrial and power system)
7242	Industrial electricians
7291	Roofers and shinglers
7293	Insulators
7311	Construction millwrights and industrial mechanics
9241	Power engineers and power systems operators
9243	Water and waste treatment plant operators
9411	Machine operators, mineral and metal processing
9523	Electronics assemblers, fabricators, inspectors and testers

*See Table 13 for the titles of green jobs in each occupation.

In Figure 1, the scores have been classified according to the two risk prioritization methods followed: in descending order of final score obtained by multiplying risk ratings by contaminants, and using the priority model, the results of which are indicated in colour in the figure (high priority red, medium priority yellow, low priority green; see Table 6). This figure shows the convergence of the two methods developed to obtain a risk rating for each occupation analyzed. The priority model clearly echoes the results of the multiplication of risk ratings. As the final score is a theoretical value, it is not represented on the y-axis in Figure 1. The scale of the y-axis is logarithmic and values range from 1 to 10^{12}.



*See Appendix B for the list of NOC codes and their meanings.

Figure 1 – Occupations classified by chemical risk levels, in descending order by final score, and in accordance with the priority model (high priority red, medium priority yellow, low priority green)

The skill types (see Table 9) *Trades, transport and equipment operators and related occupations* and *Occupations in manufacturing and utilities* are the most frequently represented (10/13) among high-risk occupations, followed by *Natural and applied sciences and related occupations* (2/13). *Management occupations* are the skill type representing general construction contractors, who are frequently found on construction sites.

4.3 Potential Risks of Biological Agents

4.3.1 Biological Agents

Biological agents are everywhere around us. Viruses like the flu, or bacteria like *Clostridium tetani*, represent varying degrees of danger to human health. In our study, it was not essential to identify all the biological agents in a given workplace; rather, we listed those most hazardous to workers' health and assessed their occupational exposure to them.

The most hazardous agents (risk group 3) identified are fungal agents, such as *Histoplasma capsulatum*, and hantaviruses or other viruses (19/63 occupations assessed).

Most of the agents identified are in risk group 2: fungal agents like *Aspergillus*; *Orthohepadnavirus* (hepatitis A, B or C) and flu viruses; and bacteria including *Legionella* (e.g., *L. pneumophila*), *Escherichia* (e.g., *E. coli*) and *Clostridium* (e.g., *C. tetani*) (23/63 occupations). Risk group 1 consists mainly of moulds found everywhere in the environment (16/63 occupations) and non-pathogenic bacteria of human origin. A biological risk assessment was deemed not applicable for 5 of the 63 occupations. That does not mean that these workers are not exposed, but rather that their occupational exposure is deemed to be no different than normal exposure in the environment. (See Table 4 and Appendix F for examples of biological agents in each risk group.)

4.3.2 Control Banding Adapted to Biological Risks

A total of 13 occupations obtained a risk score of moderate or high. No occupation was found to be at very high risk (chiefly characterized by exposure to biological agents in risk group 4). Two of those 13 occupations were high risk; they are highlighted in red in Table 12 below.

Table 12 – List of occupational codes* deemed to be of high or moderate biological risk

National Occupational Classification (NOC), 2011	
2134	Chemical engineers
2211	Chemical technologists and technicians
2263	Inspectors in public and environmental health and occupational health and safety
4161	Natural and applied science policy researchers, consultants and program officers
7293	Insulators
7311	Construction millwrights and industrial mechanics
7522	Public works maintenance equipment operators and related workers
7621	Public works and maintenance labourers
9241	Power engineers and power systems operators
9243	Water and waste treatment plant operators
9613	Labourers in chemical products processing and utilities
9614	Labourers in wood, pulp and paper processing
9619	Other labourers in processing, manufacturing and utilities

*See Table 13 for the titles of green jobs in each occupation.
The two occupations in red are considered to be high risk.

Most of the occupations are of the same skill types (see Table 9) as those identified for chemical risks: *Occupations in manufacturing and utilities* (5/13), *Trades, transport and equipment operators and related occupations* (4/13), and *Natural and applied sciences and related occupations* (3/13).

The last occupation (NOC code 4161) comes under the group *Occupations in education, law and social, community and government services*, which includes green job titles in waste management and the environment.

5. DISCUSSION

5.1 Limitations and Constraints

There are a number of constraints associated with the lack of definition and oversight of green jobs that this study sought to address. The Statistics Canada data are fairly crude, chiefly characterized by the lack of statistics at any level beyond industry group (four-digit NAICS code). There was therefore no simple yet effective way to quantify "green" jobs in Quebec. Similarly, an occupation, as defined by the NOC, encompasses a set of job titles that can be extremely diverse in terms of occupational exposure. Identifying the chemical contaminants or biological agents to which workers in an occupation may be exposed is a macroscopic approach to the subject, and cannot represent all the workers or all the job titles comprised by the occupation equally. Furthermore, in the absence of exposure data, chemical contaminants and biological agents were identified by expert judgment, which can involve uncertainty. So the study results are not exhaustive and the information is not necessarily standardized for all occupations, because some of it has been modified by expert opinion. In addition, the 2006 census data used by the classification systems have significantly influenced the final picture obtained using the method we developed. More precise, more refined data would have given more precise, more refined results.

The study also has certain limitations stemming from methodological choices: the use of sustainable development criteria was inclusive. In other words, all job titles, even "very light green", were included. A more restrictive approach would have reduced the number of job titles, which would in turn have allowed more in-depth work on risks. The outcome might have been more precise, but at the expense of the project's objective of establishing an overview of the question.

With respect to risk assessment, our method enabled us to draw some distinctions between job titles in our approach to biological risks, but not in our approach to chemical risks, which examined them by occupation. On the other hand, the approach to chemical assessed risk (toxicity and exposure) contaminant by contaminant, so in much greater detail. Once again, the choice of a macroscopic examination of the situation led us to give priority to the occupational approach. The sample size (more than 400 job titles) and the huge variety of work situations justified this decision, because it would have been impossible to identify contaminants for each job title as part of this study. Last, it should be recalled that only chemical and biological risks were considered here, meaning that there could still be safety and ergonomic hazards in these green jobs.

5.2 Opportunities

One of the advantages of the method we developed is its adaptability. The instruments we used are flexible, and many were created originally for more specific workplace situations. So it is entirely possible to replicate the same process for a given industrial sector or for a given company: identifying "green" jobs, determining risks to workers and even proposing solutions, using the same tools with more precise data or quantitative data (exposure measurements, quantities involved, etc.). In addition, some control banding models, like the COSHH and

Stoffenmanager, are available free on the Web. The COSHH website also presents a series of situations for which risk assessments have already been done, thus facilitating the process for identical situations (see Appendix D). In the case of the Stoffenmanager, the application performs the risk assessment using a multifactorial mathematical approach to estimating exposure, which would make manual calculations extremely laborious. Nevertheless, by entering the data requested, even non-experts in small and medium-sized businesses can get an assessment of the risk level without having to do a costly environmental assessment, and this is true for both approaches: COSHH and Stoffenmanager. Many countries and organizations have also developed their own approaches (see the various websites in Appendix D).

The process we have developed in this study provides a macroscopic risk assessment. The control banding model we have used complements existing tools because it is based on the same principle. The availability of quantitative data is what determines whether to use the COSHH, the Stoffenmanager or some other data-processing model. The advantages of our approach are that it is based on qualitative information and is compatible with the other approaches. It can therefore be used without the need for precise measurements and can quickly indicate which control measures to take. It could first be applied to various priority occupations in the relevant industries, then be used for individual companies or applied to the positions at greatest risk within an organization.

5.3 Research priorities

Our findings indicate that 21 occupations have chemical or biological risks that may be deemed priorities (see Table 13). In view of their number, only high chemical risks were selected, along with moderate/ high biological risks. To suggest the best direction for future research, the green job titles of hazardous occupations have been specified.

Most of these jobs (see Table 9) are in *Occupations in manufacturing and utilities* and *Trades, transport and equipment operators and related occupations*, two skill types that do not always require very advanced qualifications. This finding is not surprising per se, but underscores once again that the greening of the labour market is not necessarily associated with safer jobs, nor totally new jobs, but rather with a transformation of conventional jobs and changes in chemical and biological risks as technologies develop.

Table 13 – Green jobs identified among the occupation codes considered to be at high chemical risk or high/moderate biological risk

Code and name of occupation National Occupational Classification (NOC), 2011 *Job title in NOC occupation considered to be green*	Note	Risk*	
		Chemical	Biological
0712 Home building and renovation managers *Housing rehabilitation specialist – builder*	*Green construction*	X	
2134 Chemical engineers *Chemical engineer, research;* *Environmental chemical engineer;* *Fuels engineer;* *Waste (including industrial waste) treatment engineer;* *Industrial hygiene engineer.*	*Green chemistry* *Biogas, biomethane and biofuels from non-food sources (2nd or 3rd generation);* *Chemist, physicist*		X
2141 Industrial and manufacturing engineers *Industrial efficiency engineer.*	*Energy efficiency*	X	
2211 Chemical technologists and technicians *Water purification technician;* *Forest products technologist;* *Industrial hygiene technologist.*			X
2263 Inspectors in public and environmental health and occupational health and safety *Environment officer;* *Environmental health officer/Enforcement officer – environmental health;* *Environmental health inspector: hazardous waste and environmental health; safety and sanitary inspector – public and environmental health; sewage disposal and wastewater treatment; industrial waste control;* *Inspector and supervisor, wastewater/sewage treatment plant; pollution control; general environmental health; hazardous waste management*		X	X
4161 Natural and applied science policy researchers, consultants and program officers *Waste reduction and recycling officer;* *Waste reduction program coordinator;* *Environmental/waste diversion/environmental education consultant/advisor (except engineer);* *Recycling program, solid or industrial waste diversion, management or reduction coordinator/manager;* *Environmental consultant (except engineer)*			X
7205 Contractors and supervisors, other construction trades, installers, repairers and servicers *Contractor, foreman/forewoman or supervisor, building, refrigeration, air-conditioning equipment and other insulators*	*Energy efficiency*	X	
7241 Electricians (except industrial and power system) *Electrician*	*Renewable energy*	X	

Code and name of occupation National Occupational Classification (NOC), 2011 *Job title in NOC occupation considered to be green*	Note	Risk*	
		Chemical	Biological
7242 Industrial electricians *Industrial electrician*	*Renewable energy*	X	
7291 Roofers and shinglers *Flat, built-up or built-up flat roofer*	*Green construction*	X	
7293 Insulators *Building, refrigeration and air-conditioning equipment insulator;* *Insulator*	*Energy efficiency* *Energy efficiency*	X	X
7311 Construction millwrights and industrial mechanics *Water treatment or filtration plant mechanic;* *Windmill repairer*		X	X
7522 Public works maintenance equipment operators and related workers *Utility tree trimmer;* *Garbage collector or garbage truck, sewer flush, recycling truck or sewer-pipe-cleaning machine driver*			X
7621 Public works and maintenance labourers *Helper – garbage collection;* *Sanitation man/woman, sanitation worker;* *Sewer maintenance worker or manual sewer pipe cleaner;* *Garbage truck loader*			X
9241 Power engineers and power systems operators *Energy from waste plant operator;* *Energy recovery incinerator plant operator*		X	X
9243 Water and waste treatment plant operators *Filtration plant controller – water treatment;* *Wastewater, sewage and liquid waste collection, purification and treatment/processing operator/technician; Water plant pump operator* *Sewage, wastewater and waste treatment plant operator*		X	X
9411 Machine operators, mineral and metal processing *Cadmium or thallium recoverer*	*Recycling*	X	
9523 Electronics assemblers, fabricators, inspectors and testers *Salvage operator – electronic equipment manufacturing*	*Recycling*	X	
9613 Labourers in chemical products processing and utilities *Waterworks labourer*			X
9614 Labourers in wood, pulp and paper processing *Recovery plant helper – pulp and paper*	*Recycling*		X
9619 Other labourers in processing, manufacturing and utilities *Oil reclaimer;* *Sorter, recyclable materials*			X

*Occupations listed are considered to have a high chemical risk rating or a moderate-to-high biological risk rating.

It is interesting to see which economic sectors are associated with these occupations. Waste management (NAICS 56) is well represented, as are construction (NAICS 23), manufacturing (NAICS 31–33), and professional, scientific, and technical services (NAICS 54). Once again, these findings are not surprising, but underscore the fact that new technologies result from research and development and may be used by workers in traditional sectors like construction.

Waste management is one specific sector that is booming; it is hiring more and more workers, in positions that require no qualifications and where there are major hazards. It should be noted that 8 of the 21 occupations listed in Table 13 are directly related to waste management, and many of the other 13, like electricians, engineers, and occupations in construction and labouring, may be associated with waste management or reclamation. This sector certainly deserves special attention.

6. CONCLUSION

Green jobs account for a growing proportion of workers, most of them in existing, but changing economic sectors. By following a systematic method, we were able to produce a fairly precise profile of these jobs. This inclusive, relatively consensual approach—one that most government, institutional and private stakeholders agree upon—is not intended to provide a narrow vision of the impact of sustainable development on workers, but rather to confirm the scope of the impact and the essential role of oversight in the workplace so that changes occur in a manner consistent with occupational health and safety.

Our findings clearly show that waste management is especially hazardous; it is a growing industry with which an increasing number of other activities, including power generation, agricultural production, raw material recovery and decontamination, are associated. There are more and more sorting centres, the purification of industrial effluent is expanding and landfill authorization certificates are not being issued as easily as they used to be.

Technologies associated with the shift from fossil fuels to electric power are also developing very quickly. Their arrival on the market does not always go hand in hand with updated information for workers and the general public that would facilitate understanding and control of new risks. Energy efficiency efforts are also leading to the invention of new processes, and the replacement of old products, without necessarily preparing workers for those changes. The transformation of our economy and of our society must include everyone, so that sources of potential problems can be identified and managed.

The chemical and biological workplace risks we assessed are concrete and known. Most control measures already exist and are available. The instruments developed in this study have been adapted from easily accessible tools that can be used to achieve a more accurate understanding of the reality of workers in many industries, and to offer them appropriate control measures. Green jobs are the jobs of today and tomorrow, and their attendant risks are occupational health and safety challenges that our society must address.

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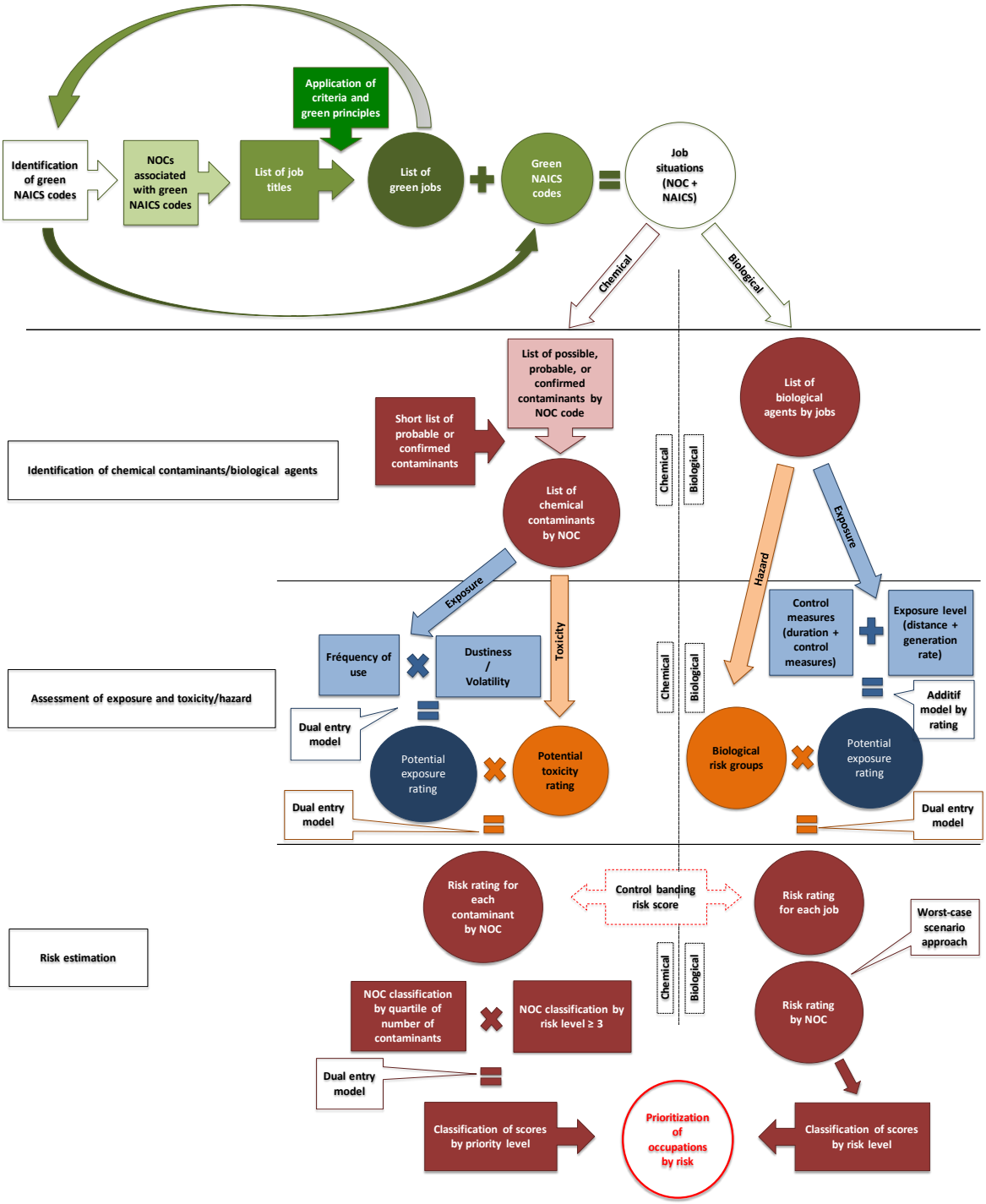
APPENDIX A METHODOLOGICAL PROCESS CHART



APPENDIX B GREEN JOBS

Green jobs: environmental criteria		1. Impact	2. Sustainable development							Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%	Note (some jobs can only be considered green in a particular sector or specialization)	Chemical	Biological
0012	**Senior government managers and officials**										
	chief – disaster management	1	1	1	1	1	1	100			
0211	**Engineering managers**										
	director, engineering research and development	1			1			60	Environmental engineering		
0212	**Architecture and science managers**										
	director of research – forestry	1		1	1			70			
	ecological research manager	1		1	1	1		80			
	oceanographic research director	1		1	1			70			
	research director – forestry	1		1	1			70			
	agricultural chemistry branch director	1	1	1	1			80	Organic farming		
	environmental science manager	1		1	1	1		80			
	ecology manager	1		1	1	1		80			
0411	**Government managers – health and social policy development and program administration**										
	director, industrial hygiene and health – government services	1	1	1	1	1	1	100	Chemist, physicist, ergonomist		
	environmental health services director – government services	1	1	1	1	1	1	100	Chemist, physicist, ergonomist		
0711	**Construction managers**										
	construction special project manager	1	1	1	1			80	Green construction		
0712	**Home building and renovation managers**									high	low
	housing rehabilitation specialist – builder	1	1	1	1			80	Green construction		N/A
	rehabilitation and renovation specialist	1	1	1	1			80	Green construction		low
0821	**Managers in agriculture**									low	low
	organic grower	1	1	1	1	1		90			low
0822	**Managers in horticulture**									low	low
	tree grower – nursery	1	1	1				70			low
	nursery operator	1	1	1				70			low
	tree nursery operator	1	1	1				70			low
	nursery manager	1	1	1				70			low
	nurseryman/nurserywoman	1	1	1				70			low
	evergreen grower	1	1	1				70			low
	shrub grower	1	1	1				70			low
	plant grower – tree nursery	1	1	1				70			low
	grower, evergreens	1	1	1				70			low
0912	**Utilities managers**										
	solid waste processing district manager	1	1	1	1	1		90			
	waste management director	1	1	1	1	1		90			
	water pollution control director	1	1	1	1	1		90			
	sewage treatment plant manager	1	1	1	1	1		90			
	wastewater treatment system director	1	1	1	1	1		90			
	sewage plant manager	1	1	1	1	1		90			
	manager, sewage plant	1	1	1	1	1		90			
	manager, sewage treatment plant	1	1	1	1	1		90			
	director, sewage treatment system	1	1	1	1	1		90			
	plant manager, sewage treatment	1	1					60			
	sanitary sewer service manager	1	1	1	1	1		90			
	sewage treatment system director	1	1	1		1		80			
	director, wastewater treatment system	1	1	1	1	1		90			
	wastewater treatment system director	1	1	1	1	1		90			
	solid waste processing manager	1	1	1	1	1		90			
	water filtration plant manager	1	1	1	1	1		90			
	sewage treatment plant manager	1	1	1	1	1		90			

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	solid waste processing district manager	1	1	1	1	1		90			
	solid waste processing operations planning manager	1	1	1	1	1		90			
	compost facility manager	1	1	1	1	1		90			
2111	**Physicists and astronomers**									low	N/A
	atmospheric physicist	1		1	1			70			N/A
2112	**Chemists**									moderate	low
	agricultural chemist	1	1	1		1		80	Organic farming		low
	oceanographic chemist	1		1	1			70			N/A
	atmospheric chemist	1		1	1			70			N/A
	water chemist	1		1	1			70			N/A
	environmental chemist	1		1	1	1		80			N/A
	oceanographic chemist	1		1	1			70			N/A
	soil chemist	1		1	1			70			N/A
	water purification chemist	1	1	1	1	1		90			N/A
	nanochemist	1			1			60			N/A
	soil chemist	1		1	1			70			N/A
	atmospheric chemist	1		1	1			70			N/A
2113	**Geoscientists and oceanographers**									low	low
	environmental geologist	1		1	1	1		80			low
	groundwater geologist	1		1	1			70			low
	hydrogeologist	1		1	1			70			low
	hydrologist	1		1	1			70			low
	hydrographic surveyor – geology	1		1	1			70			low
	oceanographer	1		1	1			70			low
	biological oceanographer	1		1	1			70			low
	fisheries oceanographer	1		1	1			70			low
	chemical oceanographer	1		1	1			70			low
	geological oceanographer	1		1	1			70			low
	physical oceanographer	1		1	1			70			low
	ice specialist – oceanography	1		1	1			70			low
	physical oceanographer	1		1	1			70			low
2115	**Other professional occupations in physical sciences**									low	low
	pedologist	1		1	1			70			low
	soil scientist	1		1	1			70			low
2121	**Biologists and related scientists**									moderate	low
	environmental biologist	1		1	1	1		80			low
	ecobiologist	1		1	1	1		80			low
	ecologist	1		1	1	1		80			low
	animal ecologist	1		1	1	1		80			low
	forest ecologist	1		1	1	1		80			low
	animal ecologist	1		1	1	1		80			low
	rural ecologist	1		1	1	1		80			low
	environmental toxicologist	1	1	1	1	1		90			low
	hydrobiologist	1		1	1			70			low
	marine hydrobiologist	1		1	1			70			low
	limnologist	1		1	1			70			low
	limnological biologist	1		1	1			70			low
	agricultural scientist	1	1	1	1	1		90	Organic farming		low
	environmental toxicologist	1	1	1	1	1		90			low
	environmental and occupational toxicologist	1	1	1	1	1	1	100			low
2122	**Forestry professionals**									low	low
	urban forester	1	1	1				70			low
	forester	1		1				60			low
	research forester	1		1	1			70			low
	forest engineer	1		1	1			70			low
2123	**Agricultural representatives, consultants and specialists**									low	low
	agrologist	1	1	1	1			80			low
	agronomist	1	1	1	1			80			low

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	soil fertility expert	1		1	1			70			low
	agricultural specialist	1	1	1	1			80	Organic farming		low
2131	**Civil engineers**									low	low
	environmental engineer, civil	1		1	1	1		80			low
	reclamation engineer	1		1	1	1		80			low
	building envelope engineer	1			1			60	Green construction		low
	water and sewer engineer	1	1	1	1	1		90			low
	soil engineer	1		1	1			70			low
	architectural engineer	1	1	1	1			80	Green construction		low
	construction engineer	1	1	1	1			80	Green construction		low
	environmental engineer	1		1	1	1		80			low
	solid waste management engineer	1	1	1	1	1		90			low
	water management engineer	1	1	1	1	1		90			low
	hydrological engineer	1		1	1			70			low
	pollution control engineer	1	1	1	1	1		90			low
	water treatment engineer	1	1	1	1	1		90			low
	water systems engineer	1	1	1	1	1		90			low
2132	**Mechanical engineers**									moderate	low
	heating specialist	1		1	1			70	Geothermal/Solar		low
	refrigeration engineer	1		1	1			70	Geothermal		low
	mechanical power engineer	1		1	1			70	Renewable energy		low
	power plant engineer	1		1	1			70	Renewable energy		low
	heating specialist engineer	1		1	1			70	Geothermal/Solar		low
	heating, ventilation and air-conditioning (HVAC) engineer	1		1	1			70	Geothermal		low
	energy conservation engineer	1		1	1			70			low
	power generation engineer	1		1	1			70	Renewable energy		low
	refrigeration engineer	1		1	1			70	Geothermal		low
2133	**Electrical and electronics engineers**									moderate	low
	research engineer – nanoelectronics	1		1	1			70	Energy efficiency		low
	electrical research engineer	1		1	1			70	Energy efficiency		low
	electrical and electronics research engineer	1		1	1			70	Energy efficiency		low
	electronics research engineer	1		1	1			70	Energy efficiency		low
2134	**Chemical engineers**									moderate	moderate
	chemical engineer, research	1		1	1			70	Green chemistry		low
	environmental chemical engineer	1		1	1	1		80			low
	fuels engineer	1		1	1			70	Biogas, biomethane and biofuels from non-food sources (2nd or 3rd generation)		low
	liquid fuels engineer	1		1	1			70			low
	fuels engineer	1		1	1			70			low
	liquid fuels engineer	1		1	1			70			low
	environmental chemical engineer	1		1	1	1		80			low
	industrial hygiene engineer	1	1	1	1	1	1	100	Chemist, physicist, ergonomist		low
	waste treatment engineer	1	1	1	1	1		90			moderate
	industrial waste treatment engineer	1	1	1	1	1		90			moderate
2141	**Industrial and manufacturing engineers**									high	low
	industrial efficiency engineer	1		1	1			70	Energy efficiency		low
2142	**Metallurgical and materials engineers**									moderate	low
	materials engineer	1		1	1			70	Energy efficiency		low
2148	**Other professional engineers, n.e.c.**									moderate	low
	agricultural engineer	1	1	1	1	1		90	Organic farming		low

	Green jobs: environmental criteria	1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
	NOC 2011	Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	agronomy engineer	1	1	1	1	1		90			low
	agroprocessing engineer	1	1	1	1	1		90			low
2151	**Architects**										
	architect	1	1	1	1			80	Green construction		
2152	**Landscape architects**										
	landscape architect	1	1	1	1			80	Green construction		
2153	**Urban and land use planners**									low	low
	mass transit services analyst	1	1					60			low
	environmental planner	1	1	1	1	1		90			low
	urban renovation planner	1	1	1	1			80	Refurbishment (retrofit)		low
2211	**Chemical technologists and technicians**									moderate	moderate
	water purification technician	1	1	1	1	1		90			low
	forest products technologist	1		1				60			low
	industrial hygiene technologist	1	1	1		1		80			moderate
2212	**Geological and mineral technologists and technicians**									low	low
	hydrology technician	1		1				60			low
	groundwater technologist	1		1				60			low
	sea-floor technologist	1		1				60			low
	marine geoscience technologist	1		1				60			low
2221	**Biological technologists and technicians**									moderate	low
	agricultural technician	1	1	1		1		80	Organic farming		low
	agricultural sciences technician	1	1	1		1		80	Organic farming		low
	agrology technician	1	1	1		1		80	Organic farming		low
	agronomy technician	1	1	1		1		80	Organic farming		low
	ecological technician	1		1		1		70			low
	nanobiotechnology technician	1			1			60			low
	agricultural technologist	1	1	1		1		80	Organic farming		low
	agrology technologist	1	1	1		1		80	Organic farming		low
	agronomy technologist	1	1	1		1		80	Organic farming		low
2223	**Forestry technologists and technicians**									low	low
	research assistant – forestry	1		1	1			70	Sustainable development		low
	conservation technician – forestry	1		1		1		70			low
	technician, forestry conservation and preservation	1		1		1		70			low
	research technician, forest conservation	1		1	1	1		80			low
	forestry conservation technologist	1		1		1		70			low
	technologist, forestry conservation and preservation	1		1		1		70			low
	research technologist – forest conservation	1		1	1	1		80			low
	forest research technologist	1		1	1			70	Sustainable development		low
2224	**Conservation and fishery officers**									low	low
	conservation officer	1	1	1		1		80			low
	park ranger	1	1	1		1		80			low
2225	**Landscape and horticulture technicians and specialists**									moderate	low
	arboriculturist, landscape	1	1	1				70			low
	landscape designer	1	1	1				70			low
	landscape gardener	1	1	1				70			low
	horticulture specialist	1	1	1				70			low
	landscape architectural technician	1	1	1				70			low
	hydroponics technician	1	1	1				70			low
	horticulture technician	1	1	1				70			low
2231	**Civil engineering technologists and technicians**									moderate	low
	environmental technician	1		1		1		70			low
	technician, environmental	1		1		1		70			low

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	pollution control technician	1	1	1		1		80			low
	technician, pollution control	1	1	1		1		80			low
	air pollution field technician	1	1	1		1		80			low
	pollution control technician	1	1	1		1		80			low
	land use technician	1		1		1		70	Sustainable development		low
	soil testing technologist – civil engineering	1		1		1		70	Sustainable development		low
	soil testing technologist	1		1		1		70	Sustainable development		low
2232	**Mechanical engineering technologists and technicians**									moderate	low
	heating designer	1		1	1			70	Geothermal		low
	heating, ventilation and air-conditioning (HVAC) systems specialist	1		1				60	Geothermal		low
	HVAC (heating, ventilation and air-conditioning) systems specialist	1		1				60	Geothermal		low
	heating, ventilation and air-conditioning (HVAC) technologist	1		1				60	Geothermal		low
	HVAC (heating, ventilation and air-conditioning) technologist	1		1				60	Geothermal		low
2263	**Inspectors in public and environmental health and occupational health and safety**									high	moderate
	environmental officer	1		1	1	1		90			low
	environmental health officer	1	1	1	1	1	1	100			moderate
	enforcement officer – environmental health	1	1	1	1	1	1	100			moderate
	environmental health officer	1	1	1	1	1	1	100			moderate
	hazardous waste inspector – environmental health	1	1	1	1	1	1	100			moderate
	inspector, hazardous waste – environmental health	1	1	1	1	1	1	100			moderate
	safety and sanitary inspector – public and environmental health	1	1	1	1	1	1	100			moderate
	water inspector	1	1	1	1	1	1	100			low
	sewage disposal inspector – environmental health	1	1	1	1	1	1	100			moderate
	inspector, sewage disposal – environmental health	1	1	1	1	1	1	100			moderate
	sanitary department inspector – environmental health	1	1	1	1	1	1	100			moderate
	inspector, sanitary department – environmental health	1	1	1	1	1	1	100			moderate
	wastewater treatment plant inspector	1	1	1	1	1	1	100			moderate
	pollution control inspector	1	1	1	1	1	1	100			low
	industrial waste control inspector	1	1	1	1	1	1	100			moderate
	environmental health inspector	1	1	1	1	1	1	100			low
	inspector, environmental health	1	1	1	1	1	1	100			low
	pollution control inspector	1	1	1	1	1	1	100			low
	safety practitioner	1	1	1	1	1	1	100			low
	environmental health inspectors supervisor	1	1	1	1	1	1	100			low
	environmental health and safety technician	1	1	1		1		80			moderate
	hazardous waste management technologist	1	1	1		1		80			low
	environmental health and safety technologist	1	1	1		1		80			moderate
4161	**Natural and applied science policy researchers, consultants and program officers**									low	moderate
	waste reduction and recycling officer	1		1	1	1		80			low
	waste reduction program coordinator	1		1	1	1		80			moderate
	environmental impact analyst	1	1	1	1	1	1	100			low
	energy policy analyst	1		1	1			70			N/A
	wind energy analyst	1		1	1	1		80			low
	environmental advisor (except engineer)	1		1	1	1		80			low
	environmental consultant (except engineer)	1		1	1	1		80			low
	waste diversion consultant	1		1	1	1		80			low

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	environmental education consultant	1		1	1	1		80			low
	regional recycling and waste reduction program coordinator	1		1	1	1		80			low
	waste management program coordinator	1		1	1	1		80			low
	waste diversion program coordinator	1		1	1	1		80			low
	recycling program coordinator	1		1	1	1		80			low
	municipal recycling program coordinator	1		1	1	1		80			low
	waste reduction program coordinator	1		1	1	1		80			low
	solid waste program coordinator	1		1	1	1		80			low
	program coordinator – environmental organization	1		1	1	1		80			low
	industrial waste reduction program coordinator	1		1	1	1		80			low
	environmental program coordinator	1		1	1	1		80			low
	recycling coordinator – residuals management	1		1	1	1		80			low
	environmental consultant (except engineer)	1		1	1	1	1	90			low
	program manager, solid waste	1		1	1	1		80			low
	environmental program manager	1		1	1	1		80			low
	waste diversion program manager	1		1	1	1		80			low
	environmental program manager	1		1	1	1		80			low
	environmental issues lobbyist	1		1	1	1		80			low
	environmental program development supervisor	1		1	1	1		80			low
	supervisor, environmental program development	1		1	1	1		80			low
7205	**Contractors and supervisors, other construction trades, installers, repairers and servicers**									high	low
	insulators foreman/forewoman	1		1				60			low
	fibreglass insulation specialists foreman/forewoman	1		1				60			low
	insulation foreman/forewoman	1		1				60			low
	foam insulators foreman/forewoman	1		1				60			low
	refrigeration and air-conditioning equipment insulators foreman/forewoman	1		1				60			low
	foam insulation foreman/forewoman	1		1				60			low
	insulation foreman/forewoman	1		1				60			low
	insulators foreman/forewoman	1		1				60			low
	building insulators foreman/forewoman	1		1				60			low
	boiler and pipe insulators foreman/forewoman	1		1				60			low
	building insulation specialists foreman/forewoman	1		1				60			low
	building insulation material installation foreman/forewoman	1		1				60	Energy efficiency		low
	foreman/forewoman, foam insulators	1		1				60			low
	fibre insulators foreman/forewoman	1		1				60			low
	foreman/forewoman, insulation specialists	1		1				60			low
	foreman/forewoman, fibre glass insulation specialists	1		1				60			low
	foreman/forewoman, building insulation specialists	1		1				60			low
	foreman/forewoman, boiler and pipe insulation specialists	1		1				60			low
	insulation contractor	1		1				60			low
	insulation supervisor	1		1				60			low
	supervisor, building insulation	1		1				60			low
	insulation supervisor	1		1				60			low
7241	**Electricians (except industrial and power system)**									high	low
	electrician	1		1				60	Renewable energy		low
7242	**Industrial electricians**									high	low
	industrial electrician	1		1				60	Renewable energy		low

	Green jobs: environmental criteria	1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
	NOC 2011	Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
7243	**Power system electricians**									moderate	low
	electrician – electricity production	1		1				60	Renewable energy		low
7271	**Carpenters**									moderate	low
	carpenter	1		1				60	Green construction		low
7291	**Roofers and shinglers**									high	low
	built-up roofer	1		1				60	Green construction		low
	flat roofer	1		1				60	Green construction		low
	built-up flat roofer	1		1				60	Green construction		low
7293	**Insulators**									high	moderate
	building insulator	1		1				60	Energy efficiency		moderate
	refrigeration and air-conditioning equipment insulator	1		1				60	Energy efficiency		low
	insulator	1		1				60	Energy efficiency		low
7301	**Contractors and supervisors, mechanic trades**									moderate	low
	foreman/forewoman, heating systems mechanics	1		1	1			70	Geothermal/Solar		low
	heating, ventilating and air-conditioning (HVAC) mechanics foreman/forewoman	1		1	1			70	Geothermal		low
	air-conditioning mechanics foreman/forewoman	1		1	1			70	Geothermal		low
	foreman/forewoman, air-conditioning and refrigeration mechanics	1		1	1			70	Geothermal		low
	foreman/forewoman, HVAC (heating, ventilating and air-conditioning) mechanics	1		1	1			70	Geothermal		low
	furnace installers foreman/forewoman	1		1	1			70	Geothermal/Solar		low
	foreman/forewoman, air-conditioning and refrigeration	1		1	1			70	Geothermal		low
	foreman/forewoman, air-conditioning and refrigeration	1		1	1			70	Geothermal		low
	heating and air-conditioning contractor	1		1	1			70	Geothermal		low
	air-conditioning contractor	1		1	1			70	Geothermal		low
	air-conditioning and refrigeration contractor	1		1	1			70	Geothermal		low
	contractor, heating system installation and repair	1		1	1			70	Geothermal/Solar		low
	refrigeration contractor	1		1	1			70	Geothermal		low
	heating systems contractor	1		1	1			70	Geothermal/Solar		low
	heating and air-conditioning systems contractor	1		1	1			70	Geothermal		low
7302	**Contractors and supervisors, heavy equipment operator crews**									moderate	low
	sewer construction foreman/forewoman	1	1	1		1		80			low
	sewer installation foreman/forewoman	1	1	1		1		80			low
7305	**Supervisors, motor transport and other ground transit operators**									low	N/A
	urban transit system foreman/forewoman	1		1				60			N/A
	subway operators foreman/forewoman	1		1				60			N/A
	light rail transit (LRT) operators foreman/forewoman	1		1				60			N/A
	subway controller	1		1				60			N/A
	ground transit inspector – public transit	1		1				60			N/A
	subway traffic controller	1		1				60			N/A
	subway system traffic controller	1		1				60			N/A
	traffic inspector – public transit system	1		1				60			N/A
	bus drivers supervisor	1		1				60			N/A
	streetcar operators supervisor	1		1				60			N/A
	subway operators supervisor	1		1				60			N/A
	subway and streetcar operators supervisor	1		1				60			N/A
	light rail transit (LRT) operators supervisor	1		1				60			N/A
7311	**Construction millwrights and industrial mechanics**									high	moderate

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	water filtration plant mechanic	1	1	1		1		80			moderate
	treatment plant mechanic	1	1	1		1		80			moderate
	water treatment plant mechanic	1	1	1		1		80			moderate
	upgrading plant mechanic	1		1		1		70			moderate
	sewage treatment plant mechanic	1	1	1		1		80			moderate
	mechanic, sewage treatment plant	1	1	1		1		80			moderate
	windmill repairer	1		1		1		70			moderate
7313	**Refrigeration and air-conditioning mechanics**									moderate	low
	heating, ventilation and air-conditioning (HVAC) mechanic	1		1		1		70	Green construction		low
	air-conditioning and heating mechanic	1		1		1		70	Green construction		low
7441	**Residential and commercial installers and servicers**									moderate	N/A
	air treatment installer	1	1	1		1		80			N/A
	solar heating equipment installer	1		1	1			70			N/A
	solar heating technician	1		1	1			70			N/A
7442	**Waterworks and gas maintenance workers**									low	low
	underground lines inspector – utilities	1	1	1		1		80			low
7512	**Bus drivers, subway operators and other transit operators**									low	N/A
	electrobus operator	1		1		1		70			N/A
	public passenger transit driver	1		1				60			N/A
	urban transit operator	1		1				60			N/A
	subway train operator	1		1		1		70			N/A
	transit operator – transportation	1		1				60			N/A
7522	**Public works maintenance equipment operators and related workers**									moderate	moderate
	utility tree trimmer	1	1	1				70			low
	garbage truck driver	1				1		60			moderate
	garbage truck driver – public works	1				1		60			moderate
	sewer-flushing truck operator – public works	1				1		60			moderate
	recycling truck driver	1				1		60			moderate
	sewer flusher operator-driver – public works	1				1		60			moderate
	sewer jet cleaner operator – public works	1				1		60			moderate
	sewer-pipe-cleaning machine operator – public works	1				1		60			moderate
	sewer flusher operator-driver	1				1		60			moderate
	sewer flusher operator-driver – public works	1				1		60			moderate
	garbage collector – driver	1				1		60			moderate
	drain roto servicer – public works	1				1		60			moderate
	municipal servicer drain roto	1				1		60			moderate
7611	**Construction trades helpers and labourers**									moderate	low
	insulator helper	1		1				60			low
	insulation blower	1		1				60			low
7621	**Public works and maintenance labourers**									moderate	high
	helper – garbage collection	1				1		60			moderate
	sanitation man/woman	1	1	1		1		80			moderate
	sanitation worker	1	1	1		1		80			moderate
	manual sewer pipe cleaner	1		1		1		70			high
	sewer maintenance worker	1		1		1		70			high
	sewer system maintenance worker	1		1		1		70			high
	sewer system maintenance worker	1		1		1		70			high
	garbage truck loader	1				1		60			moderate
8211	**Supervisors, logging and forestry**									low	low
	forestry conservation contractor	1	1	1		1		80			low
8255	**Contractors and supervisors, landscaping, grounds maintenance and horticulture services**									moderate	low
	park section head – arboriculture	1	1	1				70			low
	park maintenance supervisor	1	1	1				70			low
	nursery worker crew chief	1		1				60			low
	nursery foreman/forewoman	1		1				60			low
	nursery workers foreman/forewoman	1		1				60			low

Green jobs: environmental criteria		1. Impact	2. Sustainable development						Note (some jobs can only be considered green in a particular sector or specialization)	Risk prioritization	
NOC 2011		Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%		Chemical	Biological
	landscaping foreman/forewoman	1		1				60			low
	groundskeeping foreman/forewoman	1		1				60			low
	landscape design contractor	1	1	1				70			low
	tree service contractor	1	1	1				70			low
	landscaping contractor	1	1	1				70			low
	grounds maintenance contractor	1	1	1				70			low
	landscape maintenance contractor	1	1	1				70			low
	landscape design contractor	1	1	1				70			low
	park labourers supervisor	1		1				60			low
	supervisor, public works grounds maintenance workers	1		1				60			low
	nursery workers supervisor	1		1				60			low
	park maintenance supervisor	1		1				60			low
	nursery supervisor	1		1				60			low
	tree service supervisor	1		1				60			low
8422	**Silviculture and forestry workers**									moderate	low
	fire crewman/crewwoman	1		1		1		70			low
	fire suppression crewman/crewwoman	1		1		1		70			low
	forest firefighter	1		1		1		70			low
	forestry conservation worker	1		1		1		70			low
8431	**General farm workers**									moderate	low
	organic farm worker	1	1	1		1		80			low
8432	**Nursery and greenhouse workers**									moderate	low
	forest nursery assistant	1		1		1		70			low
	forest nursery worker	1		1		1		70			low
8612	**Landscaping and grounds maintenance labourers**									low	low
	greenskeeper helper	1		1				60			low
	plant doctor helper	1		1				60			low
	tree surgeon helper	1		1				60			low
	plant care worker	1		1				60			low
	park maintenance labourer	1		1				60			low
	landscape worker	1		1				60			low
	grounds maintenance worker	1		1				60			low
	greens worker	1		1				60			low
	plant care worker	1		1				60			low
8616	**Logging and forestry labourers**									low	low
	seasonal tree planter	1		1		1		70			low
9212	**Supervisors, petroleum, gas and chemical processing and utilities**									moderate	low
	water treatment plant superintendent	1	1	1		1		80			low
	water pollution control foreman/forewoman	1	1	1		1		80			low
	water purification plant foreman/forewoman	1	1	1		1		80			low
	sewage disposal foreman/forewoman	1	1	1		1		80			low
	water and sewer foreman/forewoman	1	1	1		1		80			low
	sewer services foreman/forewoman	1	1	1		1		80			low
	foreman/forewoman, sanitary service	1	1					60			low
	water treatment plant foreman/forewoman	1	1	1		1		80			low
	pilot plant foreman/forewoman – chemical processing	1		1		1		70			N/A
	lead collections operator – water treatment	1	1	1		1		80			low
	sewage treatment plant supervisor	1	1	1		1		80			low
	water treatment plant supervisor	1	1	1		1		80			low
	sewage treatment plant supervisor	1	1	1		1		80			low
	waste treatment supervisor	1	1	1		1		80			low
	compost facility supervisor	1		1		1		70			low
9241	**Power engineers and power systems operators**									high	moderate
	energy from waste plant operator	1		1		1		70			moderate
	energy recovery incinerator plant operator	1		1		1		70			low
9243	**Water and waste treatment plant operators**									high	high
	filtration plant controller – water treatment	1	1	1		1		80			low

	Green jobs: environmental criteria	1. Impact	2. Sustainable development						Note	Risk prioritization	
	NOC 2011	Minimizes impact of human activity	a) Health and quality of life	c) environmental protection	f) access to knowledge	i) prevention	j) precaution	%	(some jobs can only be considered green in a particular sector or specialization)	Chemical	Biological
	water filtration plant operator – water treatment	1	1	1		1		80			low
	wastewater collection operator	1	1	1		1		80			moderate
	water treatment operator	1	1	1		1		80			moderate
	wastewater treatment operator	1	1	1		1		80			moderate
	pumphouse operator – water treatment	1	1	1		1		80			moderate
	water treatment operator	1	1	1		1		80			moderate
	wastewater treatment plant operator	1	1	1		1		80			moderate
	water plant pump operator	1	1	1		1		80			moderate
	well-point pump operator	1	1	1		1		80			moderate
	liquid waste process operator	1	1	1		1		80			moderate
	wastewater collection systems operator	1	1	1		1		80			moderate
	water filtration plant operator	1	1	1		1		80			moderate
	pump station operator – water treatment	1	1	1		1		80			moderate
	water treatment plant operator	1	1	1		1		80			moderate
	wastewater treatment plant operator	1	1	1		1		80			moderate
	water treatment systems operator	1	1	1		1		80			moderate
	environmental systems operator – water treatment	1	1	1		1		80			moderate
	filter plant operator – water treatment	1	1	1		1		80			moderate
	water filtration plant operator	1	1	1		1		80			moderate
	operator, water purification plant	1	1	1		1		80			moderate
	water treatment plant operator	1	1	1		1		80			moderate
	industrial waste treatment plant operator	1	1	1		1		80			moderate
	sewage plant operator	1	1	1		1		80			high
	waste treatment plant operator	1	1	1		1		80			high
	liquid waste-processing plant operator	1	1	1		1		80			high
	wastewater treatment plant operator	1	1	1		1		80			moderate
	water treatment plant operator	1	1	1		1		80			moderate
	sewage-processing equipment tender	1	1	1		1		80			moderate
	wastewater treatment plant worker	1	1	1		1		80			moderate
	process technician, water treatment plant	1	1	1		1		80			moderate
	water treatment plant process technician	1	1	1		1		80			moderate
	water and wastewater technician	1	1	1		1		80			moderate
9411	**Machine operators, mineral and metal processing**									high	N/A
	cadmium recoverer	1		1		1		70	Recycling		N/A
	thallium recoverer	1		1		1		70	Recycling		N/A
9422	**Plastics processing machine operators**									low	low
	shredder operator – plastic recycling	1		1		1		70			low
	wash line operator – plastic recycling	1		1		1		70			low
9423	**Rubber processing machine operators and related workers**									moderate	low
	scrap rubber grinder – recycling	1		1		1		70			low
	scrap rubber grinder – recycling	1		1		1		70			low
9523	**Electronics assemblers, fabricators, inspectors and testers**									high	low
	salvage operator – electronic equipment manufacturing	1		1		1		70	Recycling		low
9613	**Labourers in chemical products processing and utilities**									moderate	moderate
	waterworks labourer	1		1		1		70			moderate
9614	**Labourers in wood, pulp and paper processing**									moderate	moderate
	recovery plant helper – pulp and paper	1		1		1		70	Recycling		moderate
9619	**Other labourers in processing, manufacturing and utilities**									moderate	moderate
	oil reclaimer	1		1		1		70			low
	sorter, recyclable materials	1		1		1		70			moderate

Totals

71	Number of green NOC jobs
63	Number of NOC jobs assessed for risks
433	Number of green jobs assessed for risks

score ≥ 80%	211
score ≥ 60%	466

Risk (occupation)		
high	13	2
moderate	30	11
low	20	45
N/A	–	5

N/A: Not applicable

APPENDIX C CHEMICAL CONTAMINANTS

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
1,1,1,2 tetrafluoroethane		REPTOX > 8,000 ppm no effects on humans	1		
1,1,1-trichloroethane	20-36/38-59	ACGIH 10 ppm AND R20	2		
abrasive dust		ACGIH 1 mg/m^3 alumina and 10 for silicon carbide	2		
abrasive dust (alumina, silicon carbide)		ACGIH 1 mg/m^3 alumina and 10 for silicon carbide	2		
acetic acid	10-35	ACGIH 10 ppm	2	+1	
acetone	11-36-66-67	ACGIH 500 ppm	1		
acetylene	ACGIH	simple asphyxiant	1		
acrylonitrile	45-11-23/24/25-37/38-41-43-51/53	ACGIH 2 ppm; A3	4	+1	carcinogen, Sigma retained
alcohol solvents	methanol(11-23/24/25-39/23/24/25), ethanol (11-20/21/22-68/20/21/22), propanol (11-41-67), isopropanol (11-36-67), butane-1-ol (10-22-37/38-41-67)	methanol (200 ppm), ethanol (1,000 ppm), propanol (100 ppm), isopropanol (200 ppm), butan-1-ol (20 ppm)	2	+1	methanol, ethanol, propanol, isopropanol, butan-1-ol
aliphatic aldehydes	11-12-20/22-36/37-37/38-40-41-43	ACGIH formaldehyde 0.3 ppm	4		C1–C4
aliphatic hydrocarbons	11-20-36/37/38-43-48/20-50/53-62-65	tox based on 62	4		
aliphatic solvents	pentane (12-51/53-65-66-67), cyclopentane (11-52/53), hexane (11-38-48/20-51/53-62-65-67), cyclohexane (11-38-50/53-65-67)	pentane (600 ppm), cyclopentane (600 ppm), hexane (50 ppm), cyclohexane (100 ppm)	2	+2	pentane, cyclopentane, hexane, cyclohexane
alkanes (C18+)	10-65		1	not ACGIH	
alkanes (C1–C4)	12	flammable: 12, simple asphyxiants	1		
alkanes (C5–C17)	10-11-12-38-48/20-50/53-51/53-62-65-66-67	tox based on 62	4	not ACGIH	C5–C11
alkanes (C7+)	10-11-12-38-48/20-50/53-51/53-62-65-66-67	tox based on 62	4	not ACGIH	C5–C17
alumina		ACGIH 1 mg/m^3	2		
aluminum		ACGIH 1 mg/m^3	2		
aluminum silicate (kaolinite)		ACGIH 1 mg/m^3	2		
ammonia	10-23-34-50	ACGIH 25 ppm	2	+1	
ammonium fluoride	23-24-25		3		
ammonium nitrate	8-36/37/38		3		
amphibole asbestos	carcinogen	ACGIH A1	5		
antifoaming agents	36/37/38		3		organosiloxane silicone oil
arc-welding fumes	ROHS (not elsewhere classified)		1		may vary a lot, depending on composition
aromatic amines	21/22-34; 23/24/25-40-41-43-48/23/24/25-50-68	some carcinogenic	5		benzylamine, aniline
aromatic solvents	benzene, toluene	benzene (0.5 ppm; A1), toluene (20 ppm)	5		benzene, toluene
arsenic	23/25-50/53	ACGIH 0.01 mg/m^3; A1	5	-2	
asbestos	carcinogen	ACGIH A1	5		
asphalt (fumes)		ACGIH 0.5 mg/m^3	2		
barium titanate	R20, R22	ACGIH 0.5 mg/m^3; Ba	2		
benzene	53-45	ACGIH A1	5		
benzo[a]pyrene	45-46-60-61-43-50/53	ACGIH A2	5		
beryllium	49-25-26-36/37/38-43-48/23	ACGIH A1	5		
biocides		ozone: 0.08 ppm Cl: 0.5 ppm ClO_2:0.1 ppm	4		ozone, chlorine, hypochlorite, chlorine dioxide

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
bleaching agents	22-41		3		hydrogen peroxide
brick dust	aluminum silicate		2		
cadmium (chloride)	45-46-60-61-25-26-48/23/25-50/53	ACGIH 0.01 mg/m^3; A2	5		
cadmium (telluride)	20/21/22-50/53	ACGIH 0.01 mg/m^3; A2	5	-3	
cadmium (telluride, dioxide, sulphide, chloride)	45-63-26-48/23/25-50/53-62-68	ACGIH 0.01 mg/m^3; A2	5		
calcium bisulphite	22, 31, 41		3		http://www.chemicalland21.com/industrialchem/inorganic/Sodium%20metabisulfite.htm
calcium carbonate		ACGIH sulphate at 10 mg/m^3	1		
calcium oxide (lime)	37/38-41	ACGIH 2 mg/m^3	1	+2	
calcium oxides	37/38-41	ACGIH 2 mg/m^3	1	+2	tox based on R 37, R 41
carbon black	40	ACGIH 3 mg/m^3; A3	4		
carbon dioxide	asphyxiant		1		
carbon disulphide	63-11-36/38-48/23-62	ACGIH 1 ppm	3	+1	Sigma 4
carbon fibres	36/38, 43, 51/53 (from SPGurit)		3		
carbon monoxide	61-12-23-48/23	ACGIH 25 ppm	2	+2	
cellulose		ACGIH 10 mg/m^3	1		
cement dust (Portland cement)		ACGIH 1 mg/m^3	2		
chlorinated aliphatic solvents	chloroform (22-38-40-48/20/22), dichloromethane (23-24/25-36/37)	chloroform (10 ppm), dichloromethane (50 ppm)	2	+2	chloroform, dichloromethane
chlorinated alkanes	11-20/21/22-50-53-40-50/53-66	tox based on 40	4	not ACGIH	pentane-octane-decane
chlorinated alkenes	12-36/37 -11-22-52 -11-43	tox based on 43	3	not ACGIH	chloropropene-butene-pentene
chlorine	23-36/37/38-50	ACGIH 0.5 ppm	4	-1	
chlorine (dioxide)	21-26-32-34	0.1 ppm ACGIH	4	-1	
chlorine gas	23-36/37/38-50	0.5 ppm ACGIH and R37	4	-1	
chlorofluorocarbons: chlorodifluoromethane	11-36-59-66-67	ACGIH 1,000 ppm	1		Freon mixture in Sigma
chloroform	22-38-40-48/20/22	ACGIH 10 ppm	2	+2	4 in Sigma and 2 in ACGIH
chrome (Cr^{+3} sulphate)	26-27-28-36/37/39-45	ACGIH 0.5 mg/m^3 Cr	2	+3	
chrome (Cr^{+6} sulphate)	20-21-32-34; 45-46-9-24/25-26-35-42/43-48/23-50/53-63	ACGIH 0.05 mg/m^3 chromate and A1	5		
chromium, iron, copper, nickel, manganese fumes		ACGIH Cu and Ni: 0.2 mg/m^3; Mn: 0.02	3		strictest ACGIH
chrysotile asbestos	23-45-46-49	ACGIH A1	5		
coagulant-flocculent	22-36-38; Al:41	iron salts: 1 mg/m^3	2	+1	aluminum or iron sulphate
cobalt	42/43-53	ACGIH 0.2 mg/m^3 and A3	4	+1	level 4 because A3
concrete and cement dust		ACGIH1 mg/m^3 – Portland cement	2		
concrete dust		ACGIH 1 mg/m^3 – Portland cement	2		
copper (chloride)	22-36/37/38-50/53	ACGIH 1 mg/m^3	2		
copper (sulphate)	22-36/38-50/53	ACGIH 1 mg/m^3	2		
copper chromate		ACGIH 0.05 mg/m^3 chromate and A1	5		
copper oxychloride	22-50/53	ACGIH 0.2 mg/m^3 of Cu	2		
cotton dust		DNOC	1		
creosote	23/24/25-34-37-48/20/21/22-52/53-68	tox based on 68: potentially irreversible effects	5		
crystalline silica	48-20	ACGIH 0.025 mg/m^3; A2	5	-2	
cutting oils	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
diesel engine emissions (CO)	61-12-23-48/23	ACGIH CO 25 ppm	2	+2	Sigma 4, ACGIH 2, based on CO only

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
electrical insulating oils	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
epoxy resins	36/38-43-51/53		3		
ethanol	11	ACGIH 1,000 ppm	1		
ethylene glycol	22	ACGIH 100 mg/m^3	1		
fibreglass	A3-ACGIH; German 49		4	+1	http://ec.europa.eu/environment/archives/dansub/pdfs/mmmftech.pdf
fluorochemicals	11-23/24/25-39/23/24/25-59	1,000 ppm	1	+2	dichlorodifluoro methane, used by firefighters
formaldehyde	23-24-25-34-39-40-43; NICNAS [National Industrial Chemicals Notification and Assessment Scheme] 49, 23/24/25, 34, 43	ACGIH A2; 0.3 ppm STEL	5	-2	http://www.nicnas.gov.au/chemical-information/pec-assessments [assessment no. PEC/28]
gallium	34		3		
gasoline engine emissions (CO)	61-12-23-48/23	ACGIH CO 25 ppm	2	+2	Sigma 4, ACGIH 2, based on CO only
gypsum (calcium sulphate)	ROHS: 10 mg/m^3; not ACGIH	DNOC	1		
heating oil	heavy hydrocarbons		1		alkanes C18+
helium (simple asphyxiant)	simple asphyxiant		1		
herbicides (EPA 508 mix)	11-20-36-51/53-66		1		
hydraulic oils	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
hydrochloric acid	10-35	ACGIH 2 ppm	3		
hydrogen chloride	34-37	ACGIH 2 ppm	3		
hydrogen fluoride	26/27/28-35	ACGIH 0.5 ppm	4		
hydrogen sulphide	12-26-50	ACGIH 1 ppm	3	+1	
hypochlorites	31-34-50		3		sodium hypochlorite
indium	20/21/22-36/37/38	ACGIH 0.1 mg/m^3	3		ACGIH 3 upper limit
inorganic acid fumes	8-10-34-35		3		
inorganic insulation dust	asbestos	A1	5		
inorganic pigments	Pb, Cd, Cr, Co, Ti oxides, Pb chromate	ACGIH 0.05 mg/m^3; A2	5		
insecticides (EPA 608 mixture)	63-38-48/20-51/53-62-65-67		4		
insulation dust	38		1		
iron (metal)	DNOC		1		
iron oxides	36-37-38		3		
iron phosphate	36/37/38		3		
isocyanates	asthma	asthma sensitizer	5		
isopropanol	11-36-67		1		
kerosene	23-24-62	ACGIH 200 mg/m^3	1	+3	ACGIH = 1, Sigma = 4
lead	61-33-40-48/20/22-50/53-62	ACGIH 0.05 mg/m^3; A3	4		
lead chromate	45-61-33-50/53-62	ACGIH 0.05 mg/m^3 lead, 0.012 Cr and A2	5		
lignin	DNOC		1		
lithium (chloride)	26, 36/37/39		3		
lubricating mineral oils and greases	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
lubricating oils	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
magnesium	15-17	DNOC	1		
manganese (chloride)	22-52	ACGIH 0.02 mg/m^3	3	-2	
mercaptan	12-23-50/53	ACGIH 0.5 ppm	4	-1	methyl mercaptan
mercury (chloride)	26-36/37/39-45-60-61; 61-26-48/23-50/53	ACGIH 0.1 mg/m^3; A4	3	+1	R 45 = 5; 0.1 mg/m^3 = 3
mercury (metal)	26-36/37/39-45-60-61; 61-26-48/23-50/54	ACGIH 0.1 mg/m^3; A4	3	+1	R 45 = 5; 0.1 mg/m^3 = 3
metal oxides (copper)	22, 50/53	ACGIH nil	1		
metal oxides (iron) Fe_3O_4	no risk noted	ACGIH 5 mg/m^3	1		
metal oxides (tin)	no risk noted	ACGIH 2 mg/m^3	1		

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
metal oxides (zinc)	50/53	ACGIH 2 mg/m^3	1		tox of each oxide depends on metal composition
metal oxides [iron, bronze (Cu-Sn), copper, brass (Cu-Zn)]		in comparison with others	1		
metallic dust (copper, iron, manganese)		ACGIH Cu: 0.2 mg/m^3; Mn: 0.02	3		
metallic dust (manganese, molybdenum)		ACGIH Mo: 0.5 mg/m^3; Mn: 0.02	3		
methane	12	simple asphyxiant	1		
methanol	11-23-24-25-39	ACGIH 200 ppm, skin	1	+2	
mica		ACGIH 3 mg/m^3	1		
mica (potassium)		ACGIH 3 mg/m^3	1		
mineral oil combustion fumes	PAH		5		
mineral oils and greases	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
mineral wool	38	ACGIH: A3	4	-3	A3
mineral wool fibres	A3 - ACGIH; 36/ 37/ 38 (from Strikotherm); German 49	tox based on R 49	4	+1	http://ec.europa.eu/environment/archives/dansub/pdfs/mmmftech.pdf
molybdenum		ACGIH 10 mg/m^3	1		
natural gas	simple asphyxiant		1		
natural gas combustion products		nitrous oxide: 25 ppm; nitrogen dioxide 0.2 ppm; nitric oxide: 25 ppm	4		
natural rubber (dust)	latex	DNOC	1		
neodymium	36-38		1		
n-hexane	11-38-48/20-51/53-62-65-67	ACGIH 50 ppm	2	+2	
nickel (chloride)	49-61-23/25-38-42/43-48/23-50/53-68	ACGIH 0.1 mg/m^3; A4	3	+1	Sigma: 5
nitrates (potassium, ammonium)	8-36/37/38		3		
nitric acid	8-35	ACGIH 2 ppm	3		
nitroarenes			5		mutagenic, carcinogenic
nitrogen oxides (nitrogen dioxide)		ACGIH 0.2 ppm	4		
nitrous oxides	8	ACGIH 50 ppm	2	-1	
oil soot		PAH	5		
organic fertilizers	no risk	no recommendation	1		nitrate, phosphate, potassium (containing no heavy metals; traces below acceptable levels)
organic solvents (other)	1.4-dioxane (11-19-36/37-40-66), diethyl ether (12-19-22-66-67), THF (11-19-36/37-40), ethyl acetate (11-36-66-67), acetone, DMSO (–), propylene carbonate (36), formic acid (10-35)	1.4-dioxane (20 ppm), diethyl ether (—), THF (50 ppm), ethyl acetate (400 ppm), acetone (500 ppm), DMSO (—), propylene carbonate (—), formic acid (5 ppm)	3	+1	1.4-dioxane, diethyl ether, THF, ethyl acetate, acetone, DMSO, propylene carbonate, formic acid
ozone	ACGIH	ACGIH 0.08 ppm; moderate work	4		
PAH			5		some carcinogenic
PCB	some carcinogenic		5		
pentachlorophenol	24/25-26-36/37/38-40-50/53	ACGIH 0.5 mg/m^3; A3	4		
perchloroethylene	40-51/53	ACGIH 25 ppm; A3	4		
petroleum distillate	10-11-12-38-48/20-50/53-51/53-62-65-66-67	based on R 62	4		C9–C16 according to REPTOX
phenols	23/24/25-34-48/20/21/22-68	ACGIH 5 ppm; A4	3	+2	R 68 = 5
phosgene	26-34	ACGIH 0.1 ppm	4		

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
phthalates	61-50-62; 60-61	ACGIH 5 mg/m^3 for dibutyl	4		dibutyl-p; dioctyl-p; tox based on R 60, R 61
plastic dust		DNOC	1		
plastic dust (polyacrylates)	36	DNOC	1		
plastic pyrolysis products		PAH	5		
platinum		ACGIH 1 mg/m^3	2		
polychloroprene	no phrase in Sigma-Aldrich; no risk REPTOX		1		
polystyrene	DNOC		1		
polyurethane foam	26-36/37/38-40-42/43-52/53; 20-36/37/38-40-42/43-48/20	asthma sensitizer	5		isocyanate for production: TDI, MDI
polyurethane resins	26-36/37/38-40-42/43-52/53; 20-36/37/38-40-42/43-48/20	asthma sensitizers	5		isocyanate for production: TDI, MDI
polyvinylchloride	36/37/38	ACGIH 1 mg/m^3	2	+1	
potassium cyanide	26-27-28-32-50-53	ACGIH 5 mg/m^3	1	+3	Sigma 4, ACGIH
potassium hydroxide	22-35	ACGIH 2 mg/m^3	1	+2	corrosive
propane combustion products (CO)	61-12-23-48/23	ACGIH 25 ppm, tox based on R 61	2	+2	Sigma 4, ACGIH 2, based on CO only
propane engine emissions	61-12-23-48/23	ACGIH CO 25 ppm	2	+2	Sigma 4, ACGIH 2, based on CO only
rubber pyrolysis products		nitroamines + carbon disulphide + PAH	5		
seed dust (rapeseed, canola)		ACGIH 4 mg/m^3	1		
selenium	23/25-33-53	ACGIH 0.2 mg/m^3 + pulmonary edema	2	+1	
silane	flammable gas	ACGIH 5 ppm	3		
silicon dioxide (diatomite		ROHS 6 mg/m^3	1		
silver (nitrate)	8-34-50/53	ACGIH 0.01 mg/m^3 Ag	3		
sodium hydroxide	35	ACGIH 2 mg/m^3	1	+2	corrosive
sodium sulphate	DNOC		1		
soil dust		DNOC	1		
soil dust (cement, earth, brick)		ACGIH 1 mg/m^3 – Portland cement	2		
soil dust (earth, brick, concrete, cement)		Portland cement	2		
soil dust (earth, cement, concrete)		Portland cement	2		
soil dust (earth, concrete)		Portland cement	2		
soil dust (earth, concrete, stone)		Portland cement	2		
soil dust (earth, seeds, concrete)		Portland cement	2		
soil dust (earth, stone)		DNOC	1		
steel		iron oxide 5 mg/m^3 ACGIH	1		
strong inorganic acid aerosols	34-37, 35, 26/27, 28-35	retain ACGIH classif.	3	+1	
strong inorganic acid fumes	8-10-34-35		3		
styrene	10-20-36/38	ACGIH 20 ppm	2		
sulphur	38		1		
sulphur dioxide	23-34	ACGIH 0.25 ppm STEL	4	-1	
sulphur dioxide	23-34	ACGIH 0.25 ppm STEL	4	-1	
sulphuric acid	35	ACGIH 0.2 mg/m^3	2	+1	Sigma says level 3, because no dust
synthetic adhesives (silicones)		silicone oils: irritation according to REPTOX	1		
synthetic glues		A1	5		benzene, xylene, toluene, formaldehyde
synthetic oils and greases	ROHS and ACGIH: 5 mg/m^3	mineral oil mist	1		
synthetic pigments	phthalocyanine pigments		4		zinc: nil; cobalt R 40

Contaminant	R-phrase	Proposal	Potential toxicity (ACGIH) (1=min; 5=max)	Sigma vs. ACGIH	Note
synthetic surfactants	triethanolamine lauryl sulphate (R 38/41); dioctyl sodium (—) sulphsuccinate	ACGIH no reference	3		triethanolamine lauryl sulphate; dioctyl sodium sulphosuccinate
talc	20-37	ACGIH 2 mg/m^3; A4	1	+2	
tar (coal-tar pitch)	ROHS 0.2 mg/m^3; Koppers, Australia: 22, 36, 37, 38, 40, 45	classified 2 in Quebec and ACGIH, but 5 in Australia and Europe	2	+3	http://echa.europa.eu/documents/10162/13630/trd_rar_hh_netherlands_pitch_en.pdf
textile dust (cotton, wool, silk)		DNOC	1		
textile fibres (polyester, nylon)		DNOC**	1		
thallium	26/28-33-53	ACGIH 0.02 mg/m^3	3	+1	
tin	36-37	ACGIH 0.1 mg/m^3	3		Sigma 3, ACGIH: limits 2 and 3
toluene	63-11-38-48/20-65-67	ACGIH 20 ppm; A4	2	+1	
trichloroethylene	45-36/38-52/53-67	ACGIH 10 ppm; A2	5		
turpentine	10-20/21/22-36/38-43-51/53-65	ACGIH 20 ppm	2	+1	Sigma 2, ACGIH 2
vinyl chloride	12-45	ACGIH A1	5		
welding fumes	ROHS (not elsewhere classified)		1		may vary a lot, depending on composition
welding fumes (nickel, chromium, manganese)		ACGIH Mn: 0.02 mg/m^3	3		
wood combustion products (smoke)		CO, PAH	5		
wood dust (including cedar)		ACGIH A1 at 1 mg/m^3	5		
xylenes	10-20/21-38	ACGIH 100 ppm	1	+1	
yttrium	20/21/22	ACGIH 1 mg/m^3	2		
zinc	50-53		1		
zinc fumes		ACGIH 1 mg/m^3; chloride fumes	2		

**DNOC: Dust not otherwise classified

Note: Classification based on ACGIH, Sigma-Aldrich MSDS data and REPTOX info. Priority was given to ACGIH if a recommended standard exists, even though Sigma is stricter.

The proposal column provides information on a number of classification decisions.

When ACGIH = borderline value, the higher level was chosen.

Agents that are known carcinogens or probable carcinogens in humans (IARC groups 1 and 2A), as well as asthmagens or substances that might cause genetic damage, automatically score 5.

APPENDIX D WEBSITES ON CONTROL BANDING

Useful Control Banding Websites (accessed June 4, 2014):

1. American Conference of Governmental Industrial Hygienists (ACGIH): *http://www.acgih.org/ControlBand/*

2. American Industrial Hygiene Association Control Banding Working Group: *http://www.aiha.org*

3. International Occupational Hygiene Association (IOHA): *http://www.ioha.net/controlbanding.html*

4. BAuA. (2006) Easy-to-use workplace control scheme for hazardous substances: *http://www.baua.de/nn_37642/en/Topics-from-A-to-Z/Hazardous-Substances/workplace-control-scheme.pdf*

5. British Occupational Hygiene Society: *http://www.bohs.org/StandardCopyPage.aspx?id=915*

6. International Labour Organization – International Chemical Control Toolkit: *http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/index.htm*

7. International Labour Organization – Chemical Control Banding Toolkit: *http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/index.htm*

8. COSHH essentials: *www.coshh-essentials.org.uk.*

9. COSHH, Control Guidance Sheets, strategy to link to many e-COSHH Essentials control guidance fact sheets (insert sheet number from index): *http://www.coshh-essentials.org.uk/assets/live (INSERT Sheet No.).pdf*

10. COSHH, The remaining fact sheets can be found at COSHH Essentials publications site: *http://www.hse.gov.uk/pubns/guidance/index.htm*

11. European Chemicals Bureau → Search Classlab → Search Annex 1: *http://ecb.jrc.it/classification-labelling/*

12. International Chemical Safety Cards: *http://www.cdc.gov/niosh/ipcs/*

13. International Occupational Hygiene Association (IOHA): *http://www.saioh.org/ioha2005/proceedings/SSI.htm*

14. NIOSH Control Banding Topic Page: *http://www.cdc.gov/niosh/topics/ctrlbanding/*

15. OSHA, A Guide to the Globally Harmonized System of Classification and Labeling of Chemicals (GHS): *https://www.osha.gov/dsg/hazcom/ghsguideoct05.pdf*

16. Stoffenmanager: *https://www.stoffenmanager.nl/Default.aspx*

17. HSE, The technical basis for *COSHH essentials*: easy steps to control chemicals: *http://www.coshh-essentials.org.uk/assets/live/CETB.pdf*

18. International Labour Organization (ILO) – International Chemical Control Toolkit: *http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/index.htm*

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20. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 2002. Chemical Management Guide: Improve Chemical Management to Gain Cost Savings, Reduce Hazards and Improve Safety: *http://www2.unitar.org/cwm/publications/cbl/ghs/Documents_2ed/F_Guidance_Awareness_Raising_and_Training_Materials/91_Germany_GTZ_Chemguide.pdf*

21. KjemiRisk, A tool for chemical health risk assessment, Norway: *http://www.ohs.no/english/KjemiRisk_ver_1_0.pdf*
Hans Thore Smedbold, ChemiRisk, A Man, Technology and Organization (MTO) Perspective in Control Banding: *http://www.ioha.net/assets/files/ICOH%202009%205ICBW%20Smedbold.pdf*

22. Regetox, Belgium: *http://www.regetox.be/accueil,* with a risk-management strategy, *http://www.toxpro.be/toxprofr/07outilsdegestionfr.htm*

23. SIGMA Aldrich: *http://www.sigmaaldrich.com/catalog/AdvancedSearchPage.do*

APPENDIX E RISK PHRASES (R-PHRASES)

According to European directive 2001/59/CE [61]

Safety

R 1 Explosive when dry
R 2 Risk of explosion by shock, friction, fire or other sources of ignition
R 3 Extreme risk of explosion by shock, friction, fire or other sources of ignition
R 4 Forms very sensitive explosive metallic compounds
R 5 Heating may cause an explosion
R 6 Explosive with or without contact with air
R 7 May cause fire
R 8 Contact with combustible material may cause fire
R 9 Explosive when mixed with combustible material
R 10 Flammable
R 11 Highly flammable
R 12 Extremely flammable
R 14 Reacts violently with water
R 15 Contact with water liberates extremely flammable gases
R 16 Explosive when mixed with oxidising substances
R 17 Spontaneously flammable in air
R 18 In use, may form flammable/explosive vapour-air mixture
R 19 May form explosive peroxides

Health

R 20 Harmful by inhalation
R 21 Harmful in contact with skin
R 22 Harmful if swallowed
R 23 Toxic by inhalation
R 24 Toxic in contact with skin
R 25 Toxic if swallowed
R 26 Very toxic by inhalation
R 27 Very toxic in contact with skin
R 28 Very toxic if swallowed
R 29 Contact with water liberates toxic gas
R 30 Can become highly flammable in use
R 31 Contact with acids liberates toxic gas
R 32 Contact with acids liberates very toxic gas
R 33 Danger of cumulative effects
R 34 Causes burns
R 35 Causes severe burns
R 36 Irritating to eyes
R 37 Irritating to respiratory system
R 38 Irritating to skin
R 39 Danger of very serious irreversible effects
R 40 Limited evidence of a carcinogenic effect
R 41 Risk of serious damage to eyes

R 42 May cause sensitization by inhalation
R 43 May cause sensitization by skin contact
R 44 Risk of explosion if heated under confinement
R 45 May cause cancer
R 46 May cause inheritable genetic damage
R 48 Danger of serious damage to health by prolonged exposure
R 49 May cause cancer by inhalation
R 50 Very toxic to aquatic organisms
R 51 Toxic to aquatic organisms
R 52 Harmful to aquatic organisms
R 53 May cause long-term adverse effects in the aquatic environment
R 54 Toxic to flora
R 55 Toxic to fauna
R 56 Toxic to soil organisms
R 57 Toxic to bees
R 58 May cause long-term adverse effects in the environment
R 59 Dangerous for the ozone layer
R 60 May impair fertility
R 61 May cause harm to the unborn child
R 62 Possible risk of impaired fertility
R 63 Possible risk of harm to the unborn child
R 64 May cause harm to breast-fed babies
R 65 Harmful: may cause lung damage if swallowed
R 66 Repeated exposure may cause skin dryness or cracking
R 67 Vapours may cause drowsiness and dizziness
R 68 Possible risk of irreversible effects

R-phrase combinations

R 14/15	Reacts violently with water, liberating extremely flammable gases
R 15/29	Contact with water liberates toxic, extremely flammable gas
R 20/21	Harmful by inhalation and in contact with skin
R 20/22	Harmful by inhalation and if swallowed
R 20/21	Harmful by inhalation, in contact with skin and if swallowed
R 21/22	Harmful in contact with skin and if swallowed
R 23/24	Toxic by inhalation and in contact with skin
R 23/24/25	Toxic by inhalation, in contact with skin and if swallowed
R 23/25	Toxic by inhalation and if swallowed
R 24/25	Toxic in contact with skin and if swallowed
R 26/27	Very toxic by inhalation and in contact with skin
R 26/27/28	Very toxic by inhalation, in contact with skin and if swallowed
R 26/28	Very toxic by inhalation and if swallowed
R 27/28	Very toxic in contact with skin and if swallowed R 36/37 Irritating to eyes and respiratory system
R 36/37/38	Irritating to eyes, respiratory system and skin
R 36/38	Irritating to eyes and skin
R 37/38	Irritating to respiratory system and skin

R 39/23	Toxic: danger of very serious irreversible effects through inhalation
R 39/23/24	Toxic: danger of very serious irreversible effects through inhalation and in contact with skin
R 39/23/24/25	Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed
R 39/23/25	Toxic: danger of very serious irreversible effects through inhalation and if swallowed
R 39/24	Toxic: danger of very serious irreversible effects in contact with skin
R 39/24/25	Toxic: danger of very serious irreversible effects in contact with skin and if swallowed
R 39/25	Toxic: danger of very serious irreversible effects if swallowed
R 39/26	Very toxic: danger of very serious irreversible effects through inhalation
R 39/26/27	Very toxic: danger of very serious irreversible effects through inhalation and in contact with skin
R 39/26/27/28	Very toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed
R 39/26/28	Very toxic: danger of very serious irreversible effects through inhalation and if swallowed
R 39/27	Very toxic: danger of very serious irreversible effects in contact with skin
R 39/27/28	Very toxic: danger of very serious irreversible effects in contact with skin and if swallowed
R 40/20	Harmful: possible risk of irreversible effects through inhalation
R 40/20/21	Harmful: possible risk of irreversible effects through inhalation and in contact with skin
R 40/20/21/22	Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed
R 40/20/22	Harmful: possible risk of irreversible effects through inhalation and if swallowed
R 40/21	Harmful: possible risk of irreversible effects in contact with skin
R 40/21/22	Harmful: possible risk of irreversible effects in contact with skin and if swallowed
R 40/22	Harmful: possible risk of irreversible effects if swallowed
R 42/43	May cause sensitization by inhalation and skin contact
R 48/20	Harmful: danger of serious damage to health by prolonged exposure through inhalation
R 48/20/21	Harmful: danger of serious damage to health by prolonged exposure through inhalation and in contact with skin
R 48/20/21/22	Harmful: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed
R 48/20/22	Harmful: danger of serious damage to health by prolonged exposure through inhalation and if swallowed
R 48/21	Harmful: danger of serious damage to health by prolonged exposure in contact with skin
R 48/21/22	Harmful: danger of serious damage to health by prolonged exposure in contact with skin and if swallowed
R 48/22	Harmful: danger of serious damage to health by prolonged exposure if swallowed

R 48/23	Toxic: danger of serious damage to health by prolonged exposure through inhalation
R 48/23/24	Toxic: danger of serious damage to health by prolonged exposure through inhalation and in contact with skin
R 48/23/24/25	Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed
R 48/23/25	Toxic: danger of serious damage to health by prolonged exposure through inhalation and if swallowed
R 48/24	Toxic: danger of serious damage to health by prolonged exposure in contact with skin
R 48/24/25	Toxic: danger of serious damage to health by prolonged exposure in contact with skin and if swallowed
R 48/25	Toxic: danger of serious damage to health by prolonged exposure if swallowed
R 50/53	Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment
R 51/53	Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment
R 52/53	Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment
R 68/20	Harmful: possible risk of irreversible effects through inhalation
R 68/21	Harmful: possible risk of irreversible effects in contact with skin
R 68/22	Harmful: possible risk of irreversible effects if swallowed
R 68/20/21	Harmful: possible risk of irreversible effects through inhalation and in contact with skin
R 68/20/22	Harmful: possible risk of irreversible effects through inhalation and if swallowed
R 68/21/22	Harmful: possible risk of irreversible effects in contact with skin and if swallowed
R 68/20/21/22	Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed

APPENDIX F BIOLOGICAL AGENTS

From the Human Pathogens and Toxins Act (S.C. 2009, c. 24) [62]

RISK GROUP 2 HUMAN PATHOGENS

Bacteria

Actinobacillus pleuropneumoniae
Actinobacillus ureae
Actinomyces israelii
Aerococcus ureinae
Aeromonas hydrophila
Aggregatibacter actinomycetemcomitans
Arcanobacterium bernardiae
Bordetella bronchiseptica
Bordetella parapertussis
Bordetella pertussis
Borrelia burgdorferi
Campylobacter jejuni
Chlamydia trachomatis
Chlamydophila pneumoniae
Citrobacter freundii
Clostridium botulinum
Clostridium difficile
Clostridium perfringens
Clostridium tetani
Corynebacterium diphtheriae
Enterococcus faecium
Escherichia coli
Francisella novicida
Haemophilus influenzae
Haemophilus parainfluenzae
Helicobacter pylori
Klebsiella pneumoniae
Legionella pneumophila
Leptospira interrogans
Listeria monocytogenes
Moraxella catarrhalis
Mycobacterium avium
Mycobacterium leprae
Mycobacterium smegmatis
Mycoplasma genitalium
Mycoplasma pneumoniae
Neisseria gonorrhoeae
Neisseria meningitidis
Pasteurella multocida
Porphyromonas gingivalis
Proteus mirabilis
Proteus vulgaris
Pseudomonas aeruginosa
Salmonella
Serratia marcescens
Shigella dysenteriae
Shigella flexneri
Shigella sonnei
Sphingobacterium faecium
Staphylococcus aureus
Staphylococcus saprophyticus
Streptococcus agalactiae
Streptococcus pyogenes
Streptococcus salivarius
Treponema pallidum
Ureaplasma urealyticum
Vibrio cholerae
Yersinia pseudotuberculosis

Viruses

Adenovirus
Human coronavirus (excluding SARS-CoV)
Coxsackievirus
Human herpesvirus 5 (cytomegalovirus)
Human herpesvirus 6 (roseolovirus)
Human herpesvirus 8 (Kaposi's sarcoma-associated herpesvirus)
Papillomaviruses
Human parvovirus
Reoviruses
Rhinovirus
Human rotavirus

Simian virus 40
Cowpox virus
Colorado tick fever viruses
Semliki Forest virus
Avian influenza virus (excluding highly pathogenic strains)
Influenza virus, types A-C (excluding Type A 1918 Spanish Flu and H2N2 strains)
Newcastle disease virus
Measles virus
Vaccinia virus
Hepatitis A virus
Hepatitis B virus
Hepatitis C virus
Hepatitis D virus
Hepatitis E virus
Norwalk virus
Epstein-Barr virus
Molluscum contagiosum virus
Herpes simplex viruses
Mumps virus
Parainfluenza virus (types 1–4)
Respiratory syncytial virus
Sendai virus

Fungi

Aspergillus fumigatus
Aspergillus niger
Aspergillus oryzae
Candida albicans
Cryptococcus neoformans
Microsporum audouinii
Microsporum ferrugineum
Sporothrix schenkii
Trichophyton concentricum
Trichophyton rubrum
Trichophyton schoenleinii
Trichophyton tonsurans

Protozoa

Acanthamoeba castellanii
Leishmania aethiopica
Leishmania braziliensis
Leishmania chagasi
Leishmania donovani
Leishmania guyanensis
Leishmania infantum
Leishmania panamensis
Plasmodium falciparum
Trypanosoma brucei gambiense
Trypanosoma brucei rhodiense
Trypanosoma cruzi

Prions

Chronic wasting disease agent

RISK GROUP 3 HUMAN PATHOGENS

Bacteria

Bacillus anthracis
Brucella abortus
Brucella canis
Brucella melitensis
Brucella ovis
Brucella suis
Burkholderia mallei
Burkholderia pseudomallei
Chlamydia psittaci
Coxiella burnetii
Francisella tularensis
Mycobacterium africanum
Mycobacterium bovis
Mycobacterium canettii

Mycobacterium microti
Mycobacterium tuberculosis
Neorickettsia sennetsu
Rickettsia akari
Rickettsia australis
Rickettsia conorii
Rickettsia japonicum
Rickettsia prowazekii
Rickettsia rickettsii
Rickettsia siberica
Rickettsia typhi
Yersinia pestis

Viruses

Herpesvirus ateles
Herpesvirus saimiri
Água Preta virus
Akabane virus
Allpahuayo virus
Andes virus
Araguari virus
Batken virus
Bermejo virus
Bhanja virus
Bijou Bridge virus
Black Creek Canal virus
Cabassou virus
Caño Delgadito virus
Chikungunya virus
Lymphocytic choriomeningitis virus
Rift Valley fever virus
Yellow fever virus
Highly pathogenic avian influenza virus
Influenza A H2N2
African Horse Sickness virus
Vesicular stomatitis virus
Murray Valley encephalitis virus
St. Louis encephalitis
Eastern equine encephalitis virus
Western equine encephalitis virus
Venezuelan equine encephalitis virus
Japanese encephalitis virus
Human immunodeficiency virus
Monkeypox virus
Dhori virus
Dobrava-Belgrade virus
Douglas virus
Bayou virus
Bear Canyon virus
Dugbe virus
West Nile virus fever
SARS coronavirus (SARS-CoV)
Duvenhage virus
Enseada virus
Everglades virus
Flexal virus
Garissa virus
Germiston virus
Hantaan virus
Israel turkey meningoencephalitis virus
Issyk-Kul virus
Juquitiba virus
Khabarovsk virus
Koutango virus
Kunjin virus
Laguna Negra virus
Lechiguanas virus
Louping ill virus
Maporal virus
Mapuera virus
Mayaro virus
Mobola virus
Monongahela virus
Mopeia virus
Mucambo virus
Negishi virus
New York virus
Ngari virus
Oliveros virus
O'nyong-nyong virus
Oran virus
Oropouche virus
Pergamino virus
Pirital virus
Piry virus
Powassan virus
Puumala virus
Rabies virus

Rocio virus
Saaremaa virus
Sakpa virus
Seoul virus
Sin nombre virus
Slovakia virus
Somone virus
Sripur virus
Thogoto virus
Human T-cell lymphotropic virus (HTLV)
Tonate virus
Topografov virus
Wesselsbron virus
Whitewater Arroyo virus
Xingu virus

Fungi

Blastomyces dermatitidis
Cladophialophora bantiana
Coccidioides immitis
Coccidioides posadasii
Histoplasma capsulatum
Paracoccidioides brasiliensis
Penicillium marneffei

Prions

Fatal familial insomnia agent
Bovine spongiform encephalopathy (BSE) agent and other related transmissible spongiform encephalopathies agents
Kuru agent
Creutzfeldt-Jakob disease agent
Gerstmann-Sträussler-Scheinker syndrome agent
Variant Creutzfeldt-Jakob disease agent

RISK GROUP 4 HUMAN PATHOGENS

Viruses

Herpes B virus
Absettarov virus
Alkhumra virus
Crimean-Congo hemorrhagic fever virus
Kyasanur Forest virus
Lassa fever virus
Russian spring-summer encephalitis virus
Ebola virus
Guanarito virus
Hanzalova virus
Hendra virus
Hypr virus
Junin virus
Kumlinge virus
Machupo virus
Marburg virus
Nipah virus
Omsk hemorrhagic fever virus
Sabia virus
Variola virus