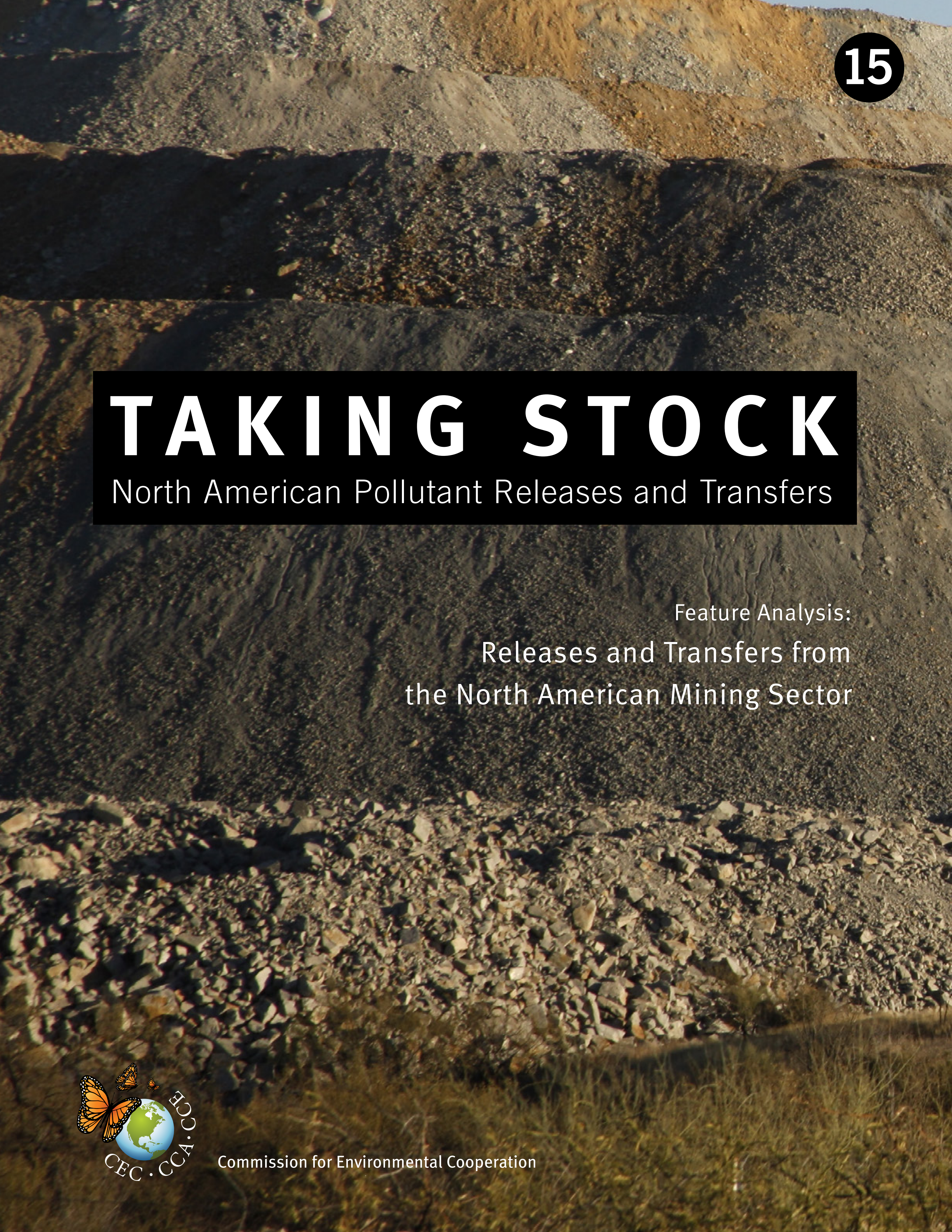


15

TAKING STOCK

North American Pollutant Releases and Transfers

Feature Analysis:

Releases and Transfers from the North American Mining Sector

CEC · CCA · CCE

Commission for Environmental Cooperation

Please cite as:

> *Taking Stock: North American Pollutant Releases and Transfers*, *Vol. 15*. Montreal, Canada: Commission for Environmental Cooperation. 154 pp.

This publication was prepared, in part, by SLR Consulting (Canada) Ltd., for the Secretariat of the Commission for Environmental Cooperation. The information contained herein does not necessarily reflect the views of the governments of Canada, Mexico or the United States of America.

ISBN: 978-2-89700-218-3

Disponible en français – ISBN: 978-2-89700-220-6
Disponible en español – ISBN: 978-2-89700-219-0

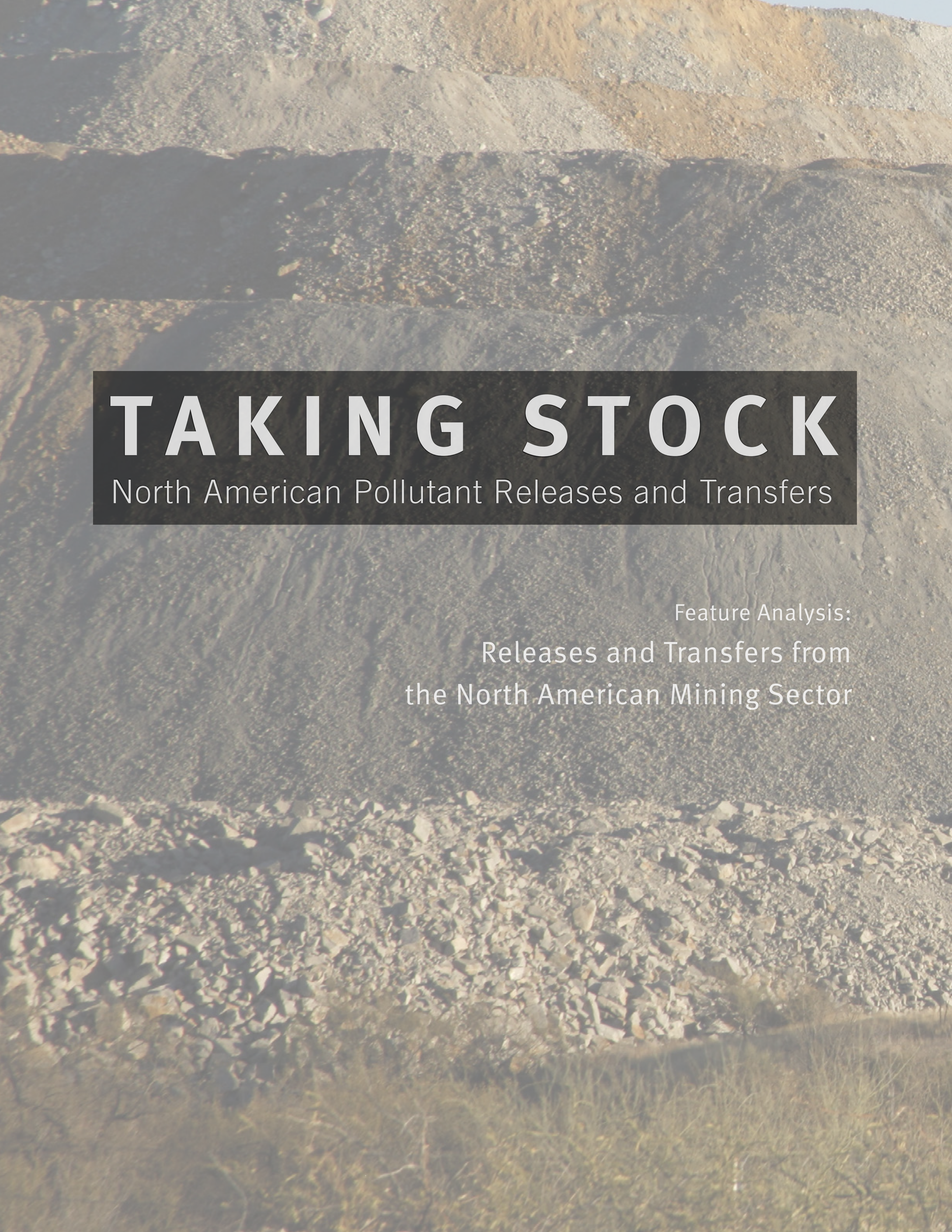
Legal deposit – Bibliothèque et Archives nationales du Québec, 2018
Legal deposit – Library and Archives Canada, 2018

Publication Details
Document category: Taking Stock
Publication date: April 2018
Original language: English
Review and quality assurance procedures:
Final Party review: September 2017
QA17.290
Project: North American PRTR initiative, 2017. *Taking Stock: North American Pollutant Releases and Transfers, Vol. 15*

For more information:

Commission for Environmental Cooperation

393, rue St-Jacques Ouest, bureau 200
Montreal (Quebec)
H2Y 1N9 Canada
t 514.350.4300 f 514.350.4314
info@cec.org / www.cec.org



TAKING STOCK

North American Pollutant Releases and Transfers

Feature Analysis:

Releases and Transfers from the North American Mining Sector

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

CAC	criteria air contaminant
CAS	Chemical Abstracts Service
CEC	Commission for Environmental Cooperation
ECCC	Environment and Climate Change Canada (formerly Environment Canada)
GHG	greenhouse gas
kg	kilogram
MPO	manufacture, process, or otherwise use
NAICS	North American Industry Classification System
NGO	nongovernmental organization
NOM	*Norma Oficial Mexicana* (Mexican Official Standard)
NPRI	National Pollutant Release Inventory (Canada's PRTR)
PBT	persistent, bioaccumulative and toxic substance
POTW	publicly owned treatment works (U.S. public wastewater treatment facilities)
PRTR	pollutant release and transfer register
RETC	*Registro de Emisiones y Transferencia de Contaminantes* (Mexico's PRTR)
Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales* (Ministry of the Environment and Natural Resources [Mexico])
TEP	toxicity equivalency potential
TRI	Toxics Release Inventory (U.S. PRTR)
TRS	total reduced sulfur
U.S. EPA	United States Environmental Protection Agency

Abstract

This edition of *Taking Stock* examines the 2013 pollutant data reported by industrial facilities in Canada, Mexico and the United States to their national pollutant release and transfer registers (PRTRs). The goal of the publication is to enhance the understanding of the sources, locations and handling of industrial substances to promote pollution prevention and support the integration of PRTR data into an overarching framework for managing pollutants in North America.

This year's report also features a special analysis of reporting from the North American mining industry. It describes the processes involved in the extraction of a variety of minerals, as well as the potential risks associated with the substances generated during these activities. The analyses of facility data from the three countries also reveal important gaps in reporting across the region and provide suggestions for how these discrepancies can be addressed.

Through the presentation of data analyses and information to help readers better understand the context of facility releases and transfers, *Taking Stock* supports enhancements of the North American PRTR programs and promotes informed decision-making, at all levels, relative to industrial pollution and environmental sustainability.

Preface

I am pleased to present the fifteenth edition of the *Taking Stock* report, a flagship series of the Commission for Environmental Cooperation (CEC) dedicated to the presentation of data and information on the pollutant releases and transfers reported by Canadian, Mexican and US industrial facilities to their respective PRTR programs. In the spirit of the public's right-to-know, this effort fosters greater awareness and understanding of the amounts, sources, and types of industrial pollutants in North America and supports informed decisions, at all levels, relative to pollution prevention and reductions.

This year's *Taking Stock* special feature, with analyses of reporting by the North American mining sector, is a significant achievement in that it embodies meaningful collaboration among a wide range of stakeholders—including the private sector, governmental and nongovernmental organizations, and academia—on the topic of environmental sustainability in this important industry sector. The decision to explore PRTR data from mining facilities resulted from discussions held during the CEC's public meeting in Mexico City in November 2014, during which stakeholders expressed concerns about uneven levels of reporting from this sector across the region. The CEC then convened a two-day workshop in December 2015 with North American PRTR officials, mining industry representatives and technical experts, where sector data and information were examined in the context of national PRTR reporting requirements. Finally, the draft report sections were reviewed by a number of individuals representing different stakeholder groups and viewpoints. The resulting document is thus the product of a truly collaborative and constructive effort.

As described in the report, a closer examination of the mining sector data reveals some important discrepancies that can be associated with inconsistencies among the national PRTR programs in relation to key areas of reporting. The analyses also yield insights into the limitations of existing PRTR reporting requirements with respect to the issue of legacy contamination, and related potential enhancements to the national programs to enable better tracking of pollutants in the case of an accident or spill. Sharing information and ideas on how to improve the completeness, quality, and comparability of PRTR data across the region is central to the North American PRTR initiative, as described in the *Action Plan to Enhance the Comparability of PRTRs in North America.*

Through the *Taking Stock* effort and ongoing engagement of stakeholders, the CEC maintains its commitment to promoting dialogue and collaboration on the subject of industrial pollution, and to enhance the public's access to North American PRTR data through the Taking Stock Online website and searchable database. In order to improve the utility and interpretation of the data, we recently added functionality to Taking Stock Online that enables queries according to North American watershed, and are planning more enhancements for the coming year. As always, we welcome your suggestions on how *Taking Stock* and the North American PRTR initiative can evolve to support your needs and do more to help ensure a healthy, shared environment.

César Rafael Chávez

CEC Executive Director

Executive Summary

This edition of *Taking Stock* examines the data on pollutant releases and transfers from North American industrial facilities for 2013, the latest data available from all three countries at the time of writing. These data are reported to the three national pollutant release and transfer registers (PRTRs) of the region, namely:

- Canada's National Pollutant Release Inventory (NPRI);
- *Mexico's Registro de Emisiones y Transferencia de Contaminantes* (RETC);
- The United States' Toxics Release Inventory (TRI).

The report shows that industrial facilities reported almost 5.23 billion kg in releases and transfers, with a few major industry sectors, and a relatively small number of pollutants, accounting for important proportions of the total. In order to provide some context for the data, *Taking Stock* addresses the topic of risk, providing additional information about the factors that need to be considered to assess the potential for harm to human health or the environment from the release of a given pollutant; and through the incorporation of available pollutant toxicity equivalency potentials (TEPs) for air and water releases.

A consistent theme throughout this report is that of differences among the national PRTR programs relating to reporting requirements for key industry sectors and pollutants. A closer look at reported releases to water by the wastewater treatment sector reveals the impacts of these inconsistencies on the picture of pollutant discharges to a shared watershed. *Taking Stock* also provides information relating to releases to air from North American electric utilities, and the initiatives that have contributed to decreases in these emissions over time.

The special feature analysis on reporting by the mining sector reveals wide variations in data across the region – relating to the amounts and types of pollutants reported, and the types of mines reporting the largest releases and transfers. The report shows that Canadian and U.S. mines accounted for the vast majority of reporting, with this discrepancy being due, in large part, to the inconsistencies among national PRTR reporting requirements. The insights gained from this in-depth analysis are intended to inform future improvements to the PRTR programs relative to this important sector.

Through the presentation and analysis of PRTR data, *Taking Stock* seeks to enhance awareness and understanding of the sources, locations and types of pollutant releases and transfers across the region, and promote greater data comparability and increased dialogue across borders and industrial sectors. In this way, the report furthers the CEC objectives of providing information for decision-making and facilitating collaboration and public participation to foster conservation, protection and enhancement of the North American environment.

Acknowledgments

This report was brought to fruition by the efforts of members of the CEC Secretariat and in particular, the Environmental Quality Unit: Orlando Cabrera-Rivera, Head of Unit; Danielle Vallée, Project Lead; and Zakir Jafry, Tools and GIS Coordinator. The publications staff of Douglas Kirk, Jacqueline Fortson, Johanne David and Marilou Nichols undertook the editing, translation and publishing of the report in three languages. Layout and graphic design were done by Gray Fraser.

The report's feature analysis of releases and transfers from the mining sector would not have been possible without the expert contribution of the SLR Consulting team of Joan Eamer, Principal Consultant and lead author, and Christina Brow, Project Engineer, whose hard work, dedication and insights resulted in an accessible and understandable presentation of information on this important but complex industry sector.

The CEC also wishes to acknowledge the time and expertise contributed by the following individuals and organizations to review the data and information at various stages in the development of this report:

- Tawny Bridgeford – U.S. National Mining Association
- Olga Briseño – Grupo México
- Roussos Dimitrakopoulos – McGill University
- Erik Edgar – Abt Associates
- Paloma García – Cámara Minera de México – CAMIMEX (Mexican Mining Association)
- Marisa Jacott – Fronteras Comunes (Mexican NGO)
- Justyna Laurie-Lean – Mining Association of Canada
- Kelly Payne – Rio Tinto
- Gerald Roose – Freeport McMoRan Inc.
- Fred Turatti – Rio Tinto
- Else Wolff – Colorado School of Mines
- Ugo Lapointe – Mining Watch Canada (NGO)
- Steve DeVito, Sandra Gaona, and Diana Wahler – U.S. EPA
- Jody Rosenberger, Paulo Costa, Cynthia Tremblay, Sarah Bennett, and Dylan Morgan – Environment and Climate Change Canada
- Ernesto Navarro – Secretaría de Medio Ambiente y Recursos Naturales (Semarnat)

Finally, the CEC wishes to recognize the invaluable support provided by Pangaea Information Technologies, Ltd, along with the CEC's Information Technology staff of Jean-Sébastien Goulet, Cezar Anghel, and Mireille Pasos, for the development of the Taking Stock Online website, <**www.cec.org/takingstock/**>. In the spirit of right-to-know, the searchable North American PRTR database provides access to data and information to support decisions at all levels to protect our shared environment.

	Total Reduced Sulfur (TRS)	107-21-1
	Ethylene glycol	108-88-3
	Toluene D	7647-01-0
	Hydrochloric acid	--
	Xylene (all isomers)	--
	Vanadium (and its compounds) M C	7789-75-5
	Calcium Fluoride	1332-21-4
	Asbestos (friable form) C	110-54-3
	n-Hexane	7429-90-5
	Aluminum (fume or dust) M	100-42-5
	Styrene C	7664-39-3
	Hydrogen fluoride	--
	Certain Glycol Ethers	75-05-8
	Acetonitrile	--
	Cobalt (and its compounds) M C	872-50-4
	N-Methyl-2-pyrrolidone D	100-41-4
31	Ethylbenzene C	108-10-1
32	Methyl isobutyl ketone	74-85-1
33	Ethylene	75-09-2
34	Dichloromethane C	95-63-6
35	1,2,4-Trimethylbenzene	68-12-2
36	N,N-Dimethylformamide	115-07-1
37	Propylene	50-00-0
38	Formaldehyde C	71-36-3

Introduction

This edition of the *Taking Stock* report presents data and information on the sources, types and amounts of pollutants released and transferred by industrial facilities in North America for 2013, the latest data available for all three countries at the time of writing. The data are taken from the national PRTR programs, which are:

- Canada's National Pollutant Release Inventory (NPRI);
- *Mexico's Registro de Emisiones y Transferencia de Contaminantes* (RETC);
- The United States' Toxics Release Inventory (TRI).

What Is a Pollutant Release and Transfer Register?

Pollutant Release and Transfer Registers (PRTRs) provide annual data on the amounts of pollutants released from a facility on site to air, water, land, underground injection, or disposal; or transferred off-site for disposal, recycling, treatment, or other management. PRTRs are an innovative tool that can be used for a variety of purposes—that is, they track specific chemicals, thereby helping industry, governments and citizens identify ways to reduce the release and transfer of these substances, increase responsibility for chemical use, prevent pollution and cut back on waste generation.

Corporations use the data to report on their environmental performance and to identify opportunities for reducing or preventing pollution. Governments use the data to guide program priorities and evaluate results. And communities, nongovernmental organizations and citizens use the data to gain an understanding of the sources and management of pollutants and to support dialogue with facilities and governments.

PRTRs collect data on individual pollutants rather than on the volume of waste streams containing mixtures of substances, because this approach allows the tracking of releases and transfers of specific substances. Reporting by facility is central to locating where releases occur and who or what generated them. Much of the power of a PRTR lies in public disclosure of the data and their dissemination in both raw and summarized form to a wide range of users. The public availability of pollutant- and facility-specific data allows interested persons and groups to identify local industrial sources of releases and support regional and other geographically-based analyses.

More than 5 billion kilograms in pollutant releases and transfers, representing reporting from approximately 27,000 facilities and almost 200 industry sectors, are analyzed in this report. The data show, however, that a relatively small number of sectors and pollutants accounted for a majority of releases and transfers in 2013, and that reporting was by no means uniform across the region. While this is certainly due, in part, to each country's industrial composition and size, it is also the result of other factors, not the least of which are differences among the three PRTR programs.

This year's report includes a special feature analysis of reporting by the mining industry. This important economic sector—including coal mining, metal ore mining, and nonmetallic mineral mining and quarrying— has consistently been among the top reporting sectors in North America for releases and transfers. A key objective of this special feature analysis is to provide additional information about specific mining activities and waste management practices across the region, the pollutants they generate, and the potential issues that can arise when these substances enter the environment.

The information presented about North American mining activities and processes highlights the fact that the potential risks to human health or ecosystems from the extraction of minerals are not necessarily those usually associated with manufacturing or other industry sectors, but are often related to the accumulation over time of large quantities of pollutants that must be properly managed on site.

The report examines the data for the mining industry by specific mining type and sheds light on the factors contributing to the wide variations seen across the region, including key differences among national PRTR reporting requirements relating to a specific waste management practice common to the sector, and to certain pollutants associated with mining activities in North America.

Through the presentation and analysis of data and information for this important sector, the *Taking Stock* report supports the central purpose of the national PRTRs and the CEC's North American PRTR initiative—which is to make information on pollutant releases and transfers publicly accessible to support pollution prevention and promote environmental sustainability within industry.

This report is organized as follows:

Chapter 1 presents an **overview of releases and transfers reported to the three PRTR programs for 2013,** including additional information regarding reported releases to air and water.

Chapter 2 the **first chapter in the feature analysis on the North American mining sector,** provides information about the industry, including its geographic and economic presence in the region, the minerals extracted and the processes used to extract them, and the pollutants associated with various mining types. This chapter also presents information about the environmental laws and regulations governing the mining sector in each country, as well as sustainable mining concepts and examples.

Chapter 3 presents the **data reported by mining facilities in the three countries**, as well as a more detailed look at the data by mining type. It also provides information about the potential toxicity of pollutants associated with these activities, and explores the data gaps created by inconsistent reporting requirements and ways in which these gaps can be addressed.

In addition, two appendices provide useful information for understanding the data presented in this report:

Appendix 1: Using and Understanding *Taking Stock* presents the key features of the three North American PRTR programs, as well as the scope and limitations of PRTR data.

Appendix 2: Main Pollutants Reported by the North American Mining Sector (2009–2013): Summary of On-site Release and Disposal Data, Sources and Potential Effects. This appendix presents information on the potential effects of pollutants typically released or disposed of on site at mining facilities.

For more information about the pollutants reported in the three countries and comprising the latest *Taking Stock* dataset, readers can consult the List of Pollutants Reported to the North American PRTRs at <**PRTR Reporting Requirements**>.

Comparing PRTR data from Canada, Mexico and the United States

Taking Stock presents PRTR data from facilities in Canada, Mexico and the United States, thereby providing the most complete picture currently available of industrial releases and transfers of pollutants in North America. This picture includes data that might be reported differently in each country because of variations among national reporting requirements, as well as differences in the methods used by facilities to estimate their releases. The features unique to each PRTR are described in appendix 1, and this information provides context for a better understanding of the reported pollutant releases and transfers across the region.

Accessing North American PRTR Data through Taking Stock Online

In addition to the analyses found in this report, you can use Taking Stock Online, the integrated, North American PRTR database (www.cec.org/takingstock), to answer your questions about pollutant releases and transfers by year, facility, location, pollutant, or industry sector. For instance:

Do you want to know the industries reporting the largest air releases in your state, province, or territory?

Step 1: Under "Report Type," select "Industry Report"

Step 2: Under "Year," select one or more years

Step 3: Under "Location," select your state, province, or territory

Step 4: Under "Release and Transfer Types," select "On-site air releases"

Step 5: Click on "Submit"

Note: On this page, you also have the option of selecting a pollutant, or category of pollutants, and a specific industry sector.

Once on the Results Page, click on an industry name to get a breakdown of air releases by facility, pollutant and pollutant type. You have the following options:

- Add or change the release or transfer type by clicking the "Show/Hide Column" button above the results table
- Ungroup your results by pollutant or country
- Sort the data in order of decreasing amounts reported
- View the facility locations on the map inset
- Click the "Export" button below the results table to download the data from this page in an Excel spreadsheet, or as a .kml or .kmz file to be displayed in Google Earth

Do you want to know which pollutants were released to water in the Columbia River Watershed?

Step 1: Under "Report Type," select "Pollutant Report"

Step 2: Under "Year," select one or more years

Step 3: Under "Location," select "Columbia River" as the "Level II" watershed

Step 4: Under "Release and Transfer Types," select "On-site surface water discharges"

Step 5: Click on "Submit"

Note: On this page, you also have the option of selecting a category of pollutant (e.g., "known or suspected carcinogens"), or only those pollutants that are common to the countries selected. You can also select a specific industry sector.

Once on the Results Page, you have the following options:

- Add or change the release or transfer type by clicking the "Show/Hide Column" button above the results table
- For releases to air or water only, you can also check the "TEP score" box to obtain calculated risk scores for cancer and non-cancer effects (e.g., developmental or reproductive toxicity)
- Sort the data in order of decreasing amounts reported, or by TEP score
- Click on a pollutant name to get a breakdown of reported releases to that medium by facility, state/province/territory, and industry sector
- View the facility location on the map inset
- Click the "Export" button below the results table to download the data from this page in an Excel spreadsheet, or as a .kml or .kmz file to be displayed in Google Earth

Other queries that may be of interest:

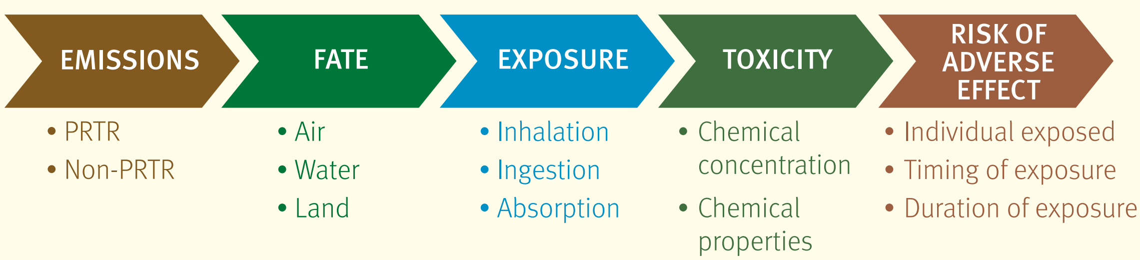
- Do a Facility search for one or more countries, then export the query results as kml or kmz file, to view the data in Google Earth
- Use the "Summary Charts" tool in the side bar to get an overview of reporting in one or more country by top pollutants or sectors
- Use the "Cross-border Transfers" tool in the side bar to see details of the pollutants transferred among the three countries.

Factors to Consider When Using PRTR Data to Evaluate Risk

Evaluating risk from the pollutants reported by facilities is a complex task. On their own, PRTR data provide insufficient information to determine human exposure to pollutants, or to calculate potential risks to human and environmental health. However, the data, in conjunction with other information, can be used as a starting point to evaluate risk. Other factors to consider include:

- **Toxicity and form of the substance**: Substances reported to PRTRs vary widely in toxicity and therefore, large quantities do not necessarily represent a greater risk (if any) to human and environmental health than small releases of highly toxic chemicals. The potential for exposure also depends on the form a substance takes in the environment and whether it changes over time. For instance, sunlight, heat or microorganisms can degrade some chemicals and render them less toxic, whereas metals are persistent and will not degrade in the environment.
- **Bioconcentration of the substance in the food chain**: Chemicals can either concentrate or disperse as they are incorporated into the food chain. For a substance, such as mercury, that bioaccumulates (accumulates and magnifies in concentration in organisms as it moves up the food chain), small releases may result in significant exposure to humans—e.g., through consuming contaminated fish.
- **Type of release and effectiveness of pollution prevention or waste management practices**: The potential for exposure to a substance depends on the environmental medium (air, water, land) to which it is released, which determines the types of exposures possible (e.g., inhalation, dermal exposure, ingestion). The amount of a substance that ultimately enters the environment depends on whether a facility engages in pollution prevention and how the substance was used and managed.

The following graphic provides an overview of the factors that influence risk from substance releases (from sources and pollutants covered by PRTRs, as well as other sources and substances):[1]



Source: Adapted from US EPA, Factors to Consider When Using Toxics Release Inventory Data.

1. Readers are reminded that sources and substances not covered by PRTRs also contribute to the pollution in the environment. More information about the scope and limitations of PRTR data is available in appendix 1.

Key Findings

- A total of 24,144 industrial facilities reported just under 5.23 billion kilograms in pollutant releases and transfers—to air, water, land and disposal, or for recycling or other treatment—to the three pollutant release and transfer registers (PRTRs) of the region for 2013. On-site disposals or land releases accounted for 40 percent of the total, followed by off-site transfers to recycling (24 percent), and transfers for other treatment (10 percent). Releases to air and water represented 9 percent and 4 percent, respectively, of the total.
- The report also reveals that a relatively small number of industry sectors (such as oil and gas extraction and metal ore mining) and approximately 25 pollutants (including metals and sulfur compounds), accounted for at least 90 percent of total reported North American releases and transfers. However, due to differences among national PRTR reporting requirements, reporting of some of these top sectors and pollutants is not consistent across the region. These discrepancies have impacts on our understanding of the types and amounts of pollutants manufactured, used, and potentially released to the North American environment.
- The report also underscores the importance of examining release and transfer data more closely, along with evaluating other key information, such as pollutant toxicity and route of exposure, when assessing the potential risk from a reported substance. *Taking Stock* incorporates available pollutant toxicity equivalency potentials (TEPs) to help readers better understand releases to air and water, and also mentions other sources of information that can be consulted.
- The data on releases and transfers from the mining sector, presented in the special feature analysis, show that the industry accounted for more than 1.67 billion kilograms, or almost one-third, of the total for 2013. On-site disposals or land releases accounted for almost 99 percent of the sector's total, with most of these reported by mines in Canada and the United States. Such discrepancies highlight the effects of important differences among the national PRTR programs – especially relating to reporting of on-site disposal or land releases, and certain mining pollutants –on our understanding of this sector's activities and potential impacts.
- The feature analysis further demonstrates that total releases and transfers are not a very useful measure of the mining industry's impacts and potential risk to human health or the environment. It points to the data and information that can be most useful, including details about spills or other unplanned releases occurring after mines have ceased to operate.
- The insights gained from the compilation and analysis of data reported in the three countries can serve to inform future enhancements to national PRTR reporting requirements, and support the environmental sustainability of North American industry.

1

Overview of North American Pollutant Releases and Transfers, 2013

Introduction

North American industrial facilities reported a total of almost 5.23 billion kilograms in pollutant releases and transfers—to air, water, land, disposal, or for recycling or other treatment—to the three pollutant release and transfer registers (PRTRs) of the region, for 2013 (table 1). The data presented in this chapter reflect the activities of many major industrial sectors and the wastes associated with the large number and quantities of substances that facilities manufacture, process, or use daily.

The data also reflect the impacts of differences among the three countries' PRTR programs in the pollutants and industry sectors and activities subject to reporting. These differences, which are explained more thoroughly in *Using and Understanding Taking Stock* (appendix 1), can complicate comparisons of the national PRTR datasets and create substantial gaps in our picture of North American industrial pollution.

1.1 Scope and Methodology

This chapter provides a brief overview of the data on pollutant releases and transfers reported for 2013 by North American industrial facilities to their respective PRTR programs. The data presented are the most recent available for all three countries at the time of writing, and can be accessed through the CEC's integrated North American PRTR (NA PRTR) database, Taking Stock Online at **www.cec.org/takingstoc**k.

Annual pollutant release and transfer data are often published with updates by the national programs, following quality assurance/quality control checks and industry revisions. Data are also periodically refreshed in Taking Stock Online to capture these revisions. Where data featured in the analyses in this report are recognized to be reporting errors that have yet to be revised, these are brought to the reader's attention. [2] The data used for the analyses in this report are from the NPRI, TRI and RETC datasets from September 2016, November 2016, and August 2014, respectively.

1.2 Top Industry Sectors and Pollutants for the Region

A total of 24,144 facilities reported pollutant releases and transfers to the three PRTR programs for 2013.[3] Compared with 2010 (the last year for which data were analyzed in *Taking* Stock) reported releases and transfers decreased by approximately 200 million kilograms.[4] The North American distribution of the data is shown in table 1. It reveals large variations among the three countries in the totals reported, as well as in the numbers of reported pollutants—with only 43 substances common to the three countries. In fact, just 60 pollutants overall are subject to reporting under all three PRTR programs.[5]

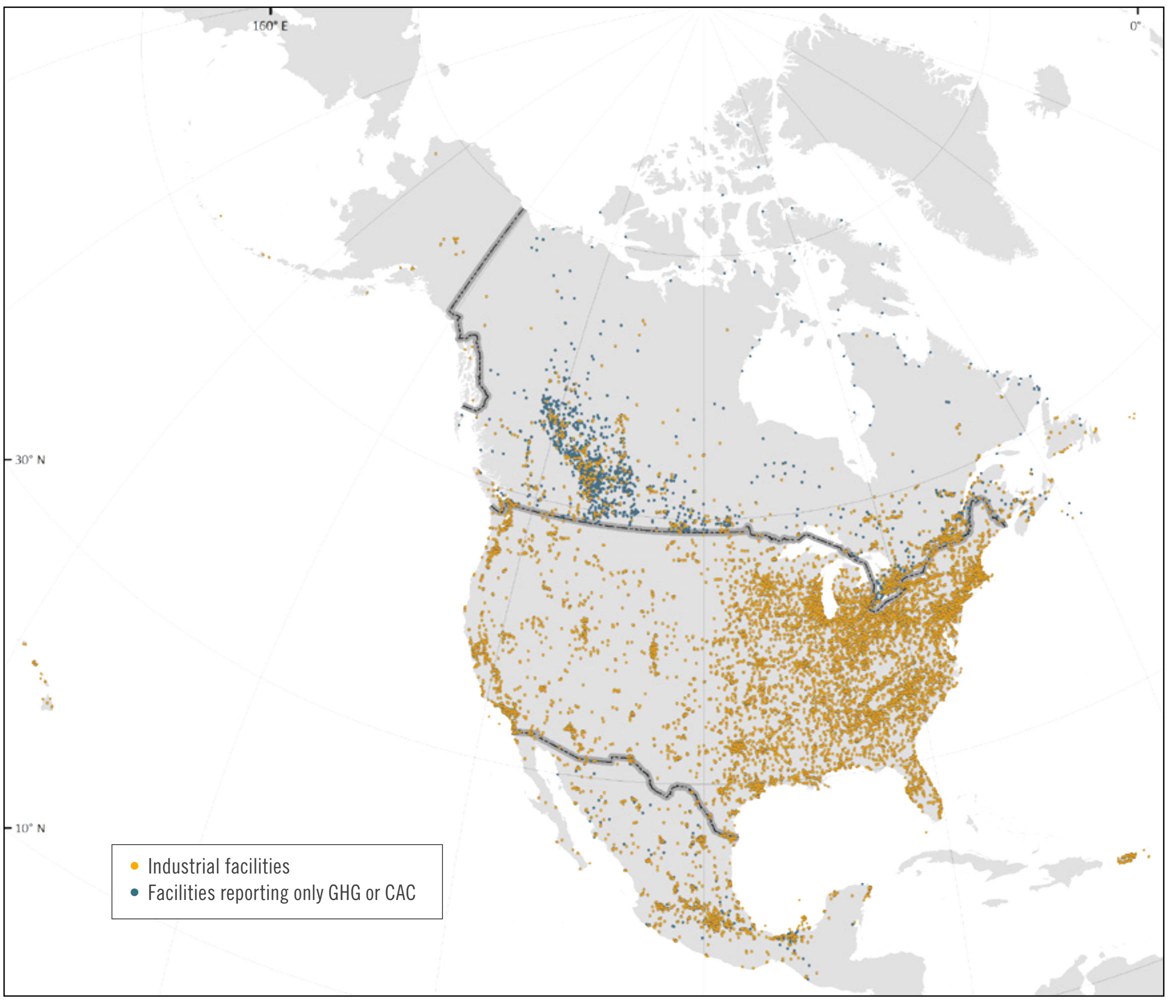
2. An important caveat relates to reporting of total reduced sulfur (TRS). This pollutant is subject only to Canada's NPRI and has been reported in large proportions by the oil and gas extraction sector, primarily as releases to underground injection or off-site disposal. Canadian reporting requirements changed as of the 2014 reporting year for TRS and its components (and especially hydrogen sulfide, the main constituent, which is also reported separately under NPRI), whereby only releases to air of TRS are required to be reported. However, the 2013 data still contain some facility records with duplicate amounts for TRS and hydrogen sulfide, and a note is included where such data are featured in this chapter. The issue of double-counting of TRS and carbon disulfide by Canadian mining facilities is also addressed in chapter 3.
3. Every year, a certain number of facilities report no releases or transfers (e.g., due to a slowdown, or no longer meeting reporting thresholds). In the analyses in Taking Stock, only those facilities and pollutants associated with reported amounts of at least 0.0001 kg are included (amounts are rounded to 2 decimal points).
4. To explore the data for 2013 or previous years, see Taking Stock Online at <**www.cec.org/takingstock**>. Readers are reminded that facilities sometimes revise their data for previous years and therefore, the data used in this report can vary somewhat from the national datasets.
5. "Pollutant" refers in some cases to a substance and its related compounds (e.g., "lead and its compounds"). For details about the pollutants reported to the PRTR programs and the countries in which they are subject to reporting, see the List of Pollutants Reported to the North American PRTRs at <**PRTR Reporting Requirements**>.

Table 1. **North American PRTR Data,** 2013

PRTR Program	Number of Facilities Reporting, 2013*	Substances Reported, 2013*	Total, 2013 (kg)	Total, 2010 (kg)
Canada NPRI	2,435	192	1,846,695,595	2,361,561,811
Mexico RETC	2,639	52	43,703,200	35,060,539
US TRI	19,070	459	3,336,621,309	3,031,187,854
North American Total	24,144	520 (43 pollutants common to the three countries)	5,227,020,104	5,427,810,204

* Refers to the number of facilities and substances contributing to the data analyzed in this report (i.e., with reported amounts of at least 0.0001 kg).
Note: Over half of the facilities reporting to Canada's NPRI and certain facilities reporting to Mexico's RETC are not included because they reported releases only of criteria air contaminants or greenhouse gases, two pollutant groups excluded from Taking Stock due to different national reporting requirements (see Box 1). Readers are reminded that differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

Figure 1. **Facilities Reporting to the North American PRTRs, 2013**



Notes: Among the Canadian and Mexican facilities shown on this map are 5,836 facilities (represented by blue dots) that reported releases only of criteria air contaminants or greenhouse gases, two pollutant groups that are excluded from the analyses in this report. Readers are reminded that differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. For more information, please see Using and Understanding *Taking Stock* (appendix 1).

Box 1. Facility Releases of Criteria Air Contaminants and Greenhouse Gases

The impacts of differences in the pollutants subject to reporting under each of the North American PRTRs can be seen in the map of reporting facilities (figure 1). The blue dots represent the Canadian facilities (the majority of them in the oil and gas sector) that reported only releases of criteria air contaminants (CACs) to the NPRI, as well as the Mexican facilities that reported only releases of greenhouse gases (GHGs) to the RETC. CACs (e.g., carbon monoxide, nitrogen oxides, particulate matter, sulfur oxides and volatile organic compounds) and GHGs (e.g., carbon dioxide, methane and fluorinated gases) are generated by a number of industrial activities such as oil and gas extraction and refining, production of cement, energy generation, and so on. These releases are associated with public health, ecosystem and climate impacts.

Because of the differences in national reporting requirements for these two groups of pollutants, they are excluded from *Taking Stock*. As a result, almost two-thirds of the facilities reporting to Canada's NPRI and about 900 facilities reporting to Mexico's RETC are excluded from the North American PRTR database (table 1). However, there are other sources of information on emissions of these pollutants in all three countries (see Using and Understanding *Taking Stock*, appendix 1).

The releases and transfers reported by North American facilities for 2013, along with the industry sectors and pollutants that accounted for the largest proportions, are illustrated in figure 2.[6] It shows, for example, that **metal mines** accounted for over three-quarters of all reported on-site disposals or releases to land for 2013, the category that made up 40 percent of the total that year.[7] These facilities reported large proportions of metals (and their compounds) such as lead, manganese and zinc, as well as phosphorous (total), nitric acid and nitrate compounds, and ammonia. The releases and transfers reported by the North American mining industry are examined in greater detail in the feature analysis of this report (chapters 2 and 3).

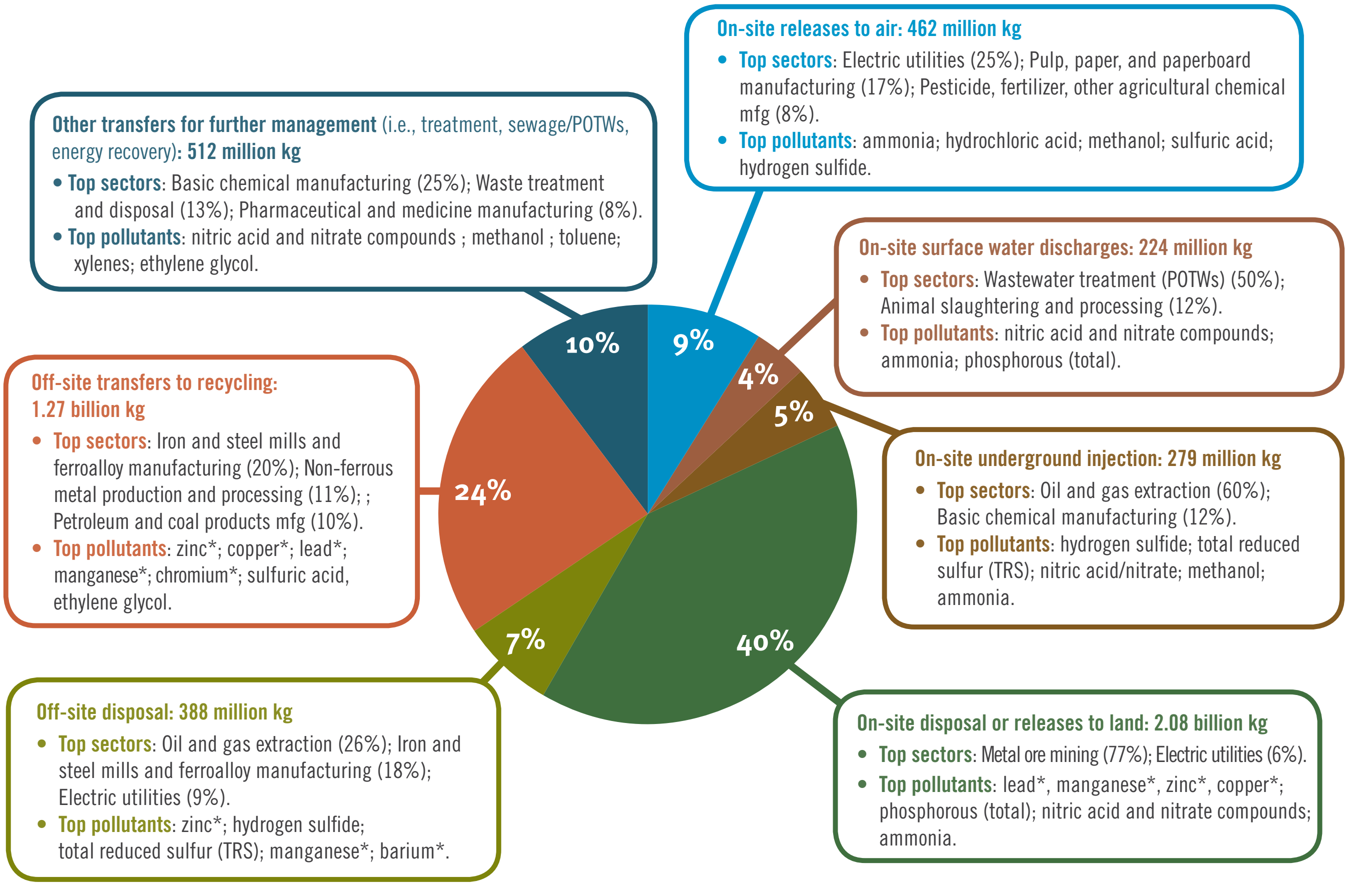
Off-site transfers to recycling represented the second-largest category for 2013, with 24 percent of the reported total. **Iron and steel mills and ferroalloy manufacturers** accounted for about 20 percent of this amount, followed by **non-ferrous metals producers and refiners** (e.g., smelters). These sectors reported transfers to recycling of valuable metals (and their compounds) such as zinc, manganese, and copper, as well as sulfuric acid and hydrochloric acid. The iron and steel mills/ferroalloy manufacturing sector also sent many of the same substances for off-site disposals, and was a top reporter in that category. The **petroleum and coal products manufacturing** industry ranked third for transfers to recycling, with 88 percent of the sector's total comprised of sulfuric acid.

Releases to air accounted for nine percent of the reported total for 2013, with **electric utilities** reporting 25 percent, followed by **pulp, paper and paperboard manufacturers.** Among the top substances released by both sectors were ammonia, hydrochloric acid, and hydrogen sulfide, sulfuric acid (especially from electric utilities), and methanol (with the largest emissions from the pulp and paper sector). The third-ranked sector, **pesticide, fertilizer and other agricultural chemical manufacturing**, reported very large proportions of ammonia, followed by methanol and hydrogen sulfide, and other pollutants.

Reported releases to water represented 4 percent of the total for 2013, with the **wastewater treatment sector**—also referred to as publicly-owned treatment works, or POTWs—contributing half of all such releases, followed by the **animal slaughtering and processing sector**, with 12 percent. These sectors reported large proportions of nitric acid

6. Unless otherwise specified, the data in this report relating to reporting sectors are presented at the level of 4-digit NAICS codes.
7. The category, "On-site disposal or land releases" includes pollutants released at the site of the facility directly onto land, land farming, pollutants injected underground, surface impoundments, spills/leaks, or disposals in landfills.

Figure 2. **Reported Releases and Transfers, North America,** 2013



* and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

and nitrate compounds, with POTWs also accounting for large releases of ammonia and phosphorous (total). Additional information relating to air and water releases is provided later in this chapter (section 1.3.2).

Two categories, off-site disposal and underground injection (with seven and five percent of the total, respectively), were dominated by the **oil and gas extraction sector**. Facilities in this sector reported very large proportions of hydrogen sulfide and total reduced sulfur (TRS).[8]

The **basic chemical manufacturing and pharmaceutical and medicine manufacturing** sectors together accounted for about one-third of reported off-site transfers for further management, followed by **waste treatment and disposal** facilities, with 13 percent. These sectors reported transfers of many of the same pollutants, including large proportions of nitric acid and nitrate compounds, methanol, toluene, xylenes, and ethylene glycol.

Large proportions of these substances were transferred to other facilities for energy recovery (e.g., toluene transferred from a waste management facility to a cement plant or hazardous waste disposal facility). Some of them were also transferred across national borders to be treated or disposed of at specialized reception facilities.

8. Readers are reminded that the 2013 NPRI data still contain some facility records with duplicate amounts for TRS and hydrogen sulfide.

Figure 3 illustrates the cross-border transfers that were reported within North America for 2013. In all, facilities reported more than 190 million kilograms, an increase of 24 million kilograms from 2010. The majority of these pollutant transfers were from Canadian facilities to the United States for recycling, with sulfuric acid from **petroleum refineries** accounting for 80 percent of that amount. Of the reported transfers from the United States to Canada, more than 40 percent consisted of copper sent by **fabricated metals manufacturers** to be recycled. As was the case in 2010,[9] U.S. transfers to Mexico were almost entirely driven by zinc (and its compounds) sent for recycling—with over 20 million kilograms going from U.S. **primary metals manufacturers** (e.g., steel plants) to the Zinc Nacional facility in Nuevo Leon. The majority (almost 2 million kilograms) of the transfers from Mexico to the United States consisted of lead and its compounds sent for recycling by one facility, TED de México, based in Ciudad Juarez, Chihuahua, which **manufactures electrical components** for vehicles. The data for North American cross-border transfers can be accessed through the Cross-Border Transfers tool in Taking Stock Online at **www.cec.org/takingstock**.

Figure 3. North American Cross-border Transfers of Pollutants, 2013

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

1.3 A Closer Look at the Data

The regional picture of pollutant releases and transfers, presented in the preceding section, is greatly influenced by differences among the three national PRTRs relating to the substances and industry sectors subject to reporting. As demonstrated throughout this report, these differences need to be considered when interpreting the reported PRTR information.

9. See *Taking Stock*, vol. 14.

Table 2 presents the top 25 pollutants, of a total of 520, that were reported by North American industrial facilities for 2013.[10] These 25 substances accounted for almost 4.8 billion kilograms, or 91 percent, of total reported releases and transfers that year. Ten of the top 25 pollutants were metals (and/or their compounds) and just four of them (zinc, manganese, lead and copper), together with nitric acid and nitrate compounds and hydrogen sulfide, accounted for more than half of all reported releases and transfers for 2013.

Table 2. Top 25 Reported Pollutants (by Total Releases and Transfers), North America, 2013

Pollutant	Total Releases and Transfers	On-site Air Emissions	On-site Surface Water Discharges	On-site Underground Injection	On-site Disposal/Land Releases	Off-site Disposal	Off-site Recycling Transfers	Other Off-site Transfers
Zinc* CA, US	722,361,910	2,685,595	663,213	1,380,842	379,837,547	86,169,664	251,621,878	--
Manganese* CA, US	573,382,586	699,219	4,012,921	4,577,370	412,957,850	37,732,797	113,400,858	--
Lead* CA, MX, US	564,531,821	1,428,695	152,283	97,861	388,627,028	18,832,508	155,393,445	--
Copper* CA, US	426,543,657	626,945	193,479	1,125,684	164,007,332	13,252,793	247,335,356	--
Nitric acid/nitrates CA, US	284,759,902	870,652	153,866,317	22,779,716	7,059,533	9,025,838	1,908,458	89,248,747
Hydrogen sulfide CA, MX, US	229,310,583	24,979,367	284,558	101,937,110	164,843	50,549,776	9,739,728	41,654,469
Methanol CA, US	210,890,156	63,587,115	3,554,506	21,740,343	1,637,849	21,078,931	10,925,935	88,361,876
Sulfuric acid CA, US	190,641,347	54,423,034	61,851	1	845	367,640	133,218,689	2,565,486
Phosphorus (total) CA	189,386,843	66,997	5,412,021	8,439	166,010,274	10,016,652	2,828,471	5,043,909
Ammonia CA, US	174,838,182	75,862,155	50,731,666	19,231,713	10,937,188	5,527,308	1,500,068	11,047,879
Nickel* CA, MX, US	154,958,337	1,150,407	196,125	134,685	60,466,010	9,011,716	83,998,738	--
Barium* US	152,575,185	602,511	473,055	60,542	128,866,095	20,980,393	1,592,589	--
Chromium* CA, MX, US	138,573,714	496,038	188,225	1,726,259	37,195,662	11,759,179	87,206,863	--
Arsenic* CA, MX, US	137,763,358	402,127	37,673	27,539	134,683,763	2,156,080	456,176	--
Total Reduced Sulfur (TRS) CA	104,464,638	7,614,798	324,902	57,937,269	2,359	38,548,343	34,735	1,949
Ethylene glycol CA, US	83,613,993	946,189	871,073	735,392	12,680,791	8,281,217	37,282,825	22,814,047
Toluene CA, US	77,438,934	13,267,195	100,763	709,984	2,014,345	2,083,442	13,293,172	45,961,628
Hydrochloric acid CA, US	73,087,760	64,626,230	0	157,600	4,766,952	115,507	2,860,445	559,203
Xylene (all isomers) CA, US	64,291,264	9,180,213	24,745	600,431	1,750,073	1,842,004	19,361,784	31,527,614
Vanadium* CA, US	49,606,498	278,911	258,275	654,120	33,759,260	4,667,182	9,988,399	--
Calcium Fluoride CA	45,401,949	28,816	26,770	--	43,566,181	564,374	1,211,180	4,627
Asbestos (friable form) CA, MX, US	41,316,994	907	0	0	39,259,037	1,937,196	27,096	92,759
n-Hexane CA, US	30,987,116	19,673,075	10,925	43,685	3,627,302	582,501	2,858,237	4,189,892
Aluminum (fume or dust) CA, US	30,759,660	685,181	3,264	0	9,452,400	7,868,839	12,749,976	--
Styrene CA, MX, US	21,941,402	14,054,928	830	97,077	371,860	866,483	239,848	6,307,669
Total, Top 25 Pollutants	4,773,427,790	358,237,302	221,449,442	235,763,661	2,043,702,379	363,818,362	1,201,034,947	349,381,755
Total (520 Pollutants)	5,227,020,104	462,828,876	224,380,028	278,600,117	2,084,158,040	387,700,445	1,276,850,558	512,428,952
Percentage, Top 25 / 520 Pollutants	91	77	98	85	98	94	94	68

"--" means not reported. * and its compounds. CA, MX, US = Canada, Mexico, United States.
Note: Readers are reminded that the 2013 NPRI data still contain some facility records with duplicate amounts for TRS and hydrogen sulfide.
Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data

10. Reported in quantities of at least 0.0001 kg.

This table also reveals that only seven of the top 25 substances are subject to reporting under all three PRTRs. Since 2006 (the first year for which data from the three countries is included in *Taking Stock*), facilities have reported releases or transfers of over 600 pollutants (or pollutant groups). However, as mentioned in the previous section, only 60 pollutants are common to the three programs.[11] The exclusion, from the PRTR of one or more country, of substances typically associated with certain industrial activities can lead to important gaps in reporting across the region. In the last edition of the *Taking Stock* report, for example, the feature analysis on the pulp and paper manufacturing sector highlighted the disparity in reporting of methanol (a substance often released as a by-product of pulping and bleaching operations), due to its exclusion from Mexico's RETC list. Such differences among national reporting requirements need to be taken into account when interpreting PRTR data for the region.

1.3.1 National Reporting Profiles

Figure 4 presents reported releases and transfers, by type, for each country for the 2013 data year. It reveals national profiles that differ significantly from one another, with unique distributions among reported releases and transfers and the sectors that contributed the largest proportions.

For example, in Canada and the United States, on-site disposals or releases to land accounted for the majority of each country's total for 2013, followed by off-site transfers to recycling. In the United States, transfers for further management (e.g., energy recovery) accounted for 14 percent of the total, compared with two percent in each of the other countries. In Mexico, transfers to recycling also represented a large proportion of the total. However, in comparison with Canada and the United States, releases to air (43 percent of the total) dominated reporting in that country.

These national release and transfer profiles paint a different picture than that presented in the previous section. For instance, figure 4 reveals that the vast majority of **on-site disposals or releases to land** (reported in large part by the mining sector and accounting for 40 percent of North American releases and transfers – figure 2), were reported almost entirely in Canada and the United States. As described in greater detail in chapters 2 and 3, important differences among national PRTR reporting requirements play a key role in the regional variations in data from the mining sector.

The inconsistencies among the national PRTRs also have impacts on reported **releases to underground injection** for the region. The practice of injecting production-related wastes underground is particular to a small number of industries such as the extraction and production of petroleum and gas and chemical manufacturing. Of the 279 million kilograms in releases to underground injection for 2013, figure 4 reveals that an important proportion of this total was reported by oil and gas extraction facilities in Canada, with a top reported substance, total reduced sulfur (TRS), subject to reporting only in that country.[12] In the United States, oil and gas extraction facilities are not subject to TRI reporting; and in Mexico, where reporting from that sector is mandatory, underground injection is not a separate category under the RETC program (rather, it is aggregated in the *on-site releases to land* category).

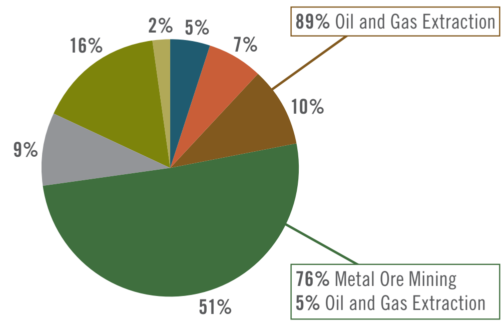
In terms of **transfers to recycling**, the industrial make-up of each country and the substances consequently manufactured, processed or otherwise used undisputedly play a role in the varying quantities and numbers of pollutants reported. As shown in table 2, however, many of the top reported pollutants transferred to recycling are not common to the three countries. When such substances are transferred across national borders (e.g., zinc to Mexico, where that pollutant is not subject to reporting), information relating to the pollutants' final fate and destination can be difficult to track.

11. As of the 2014 reporting year, Mexico's RETC pollutant list has been expanded from 104 pollutants to 200.
12. Readers are reminded that the 2013 NPRI data still contain some facility records with duplicate amounts for TRS and hydrogen sulfide.

Figure 4. Reported Releases and Transfers, 2013: National Profiles

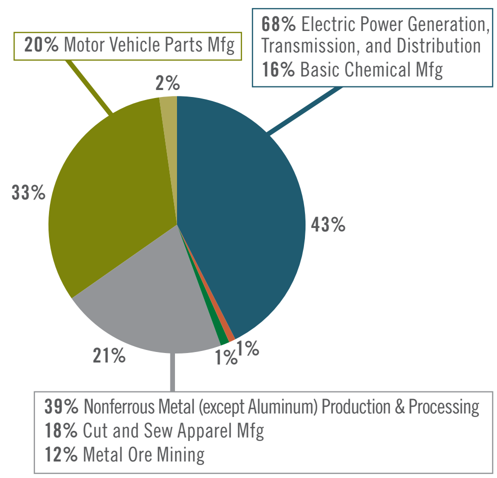
Reported Releases and Transfers, **Canada NPRI**, 2013

	Kilograms	Number of Pollutants	Number of Facilities
On-site Releases to Air	93,401,030	167	1,462
On-site Releases to Water	127,005,945	91	453
On-site Releases to Underground Injection	185,213,760	56	110
On-site Disposal or Land Releases	937,606,263	95	400
Off-site Disposal	165,883,545	116	934
Off-site Transfers to Recycling	294,919,169	95	913
Off-site Transfers for Further Management	42,592,795	132	549
National Total	**1,846,695,595**	**192**	**2,435**



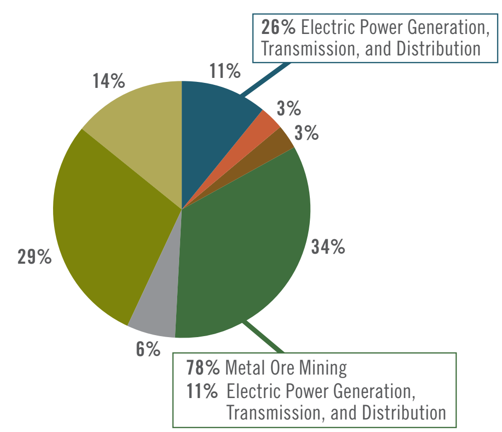
Reported Releases and Transfers, **Mexico RETC**, 2013

	Kilograms	Number of Pollutants	Number of Facilities
On-site Releases to Air	18,820,764	46	673
On-site Releases to Water	436,406	17	635
On-site Releases to Underground Injection	NA	NA	NA
On-site Disposal or Land Releases	242,619	17	637
Off-site Disposal	8,996,843	27	1,234
Off-site Transfers to Recycling	14,514,445	21	441
Off-site Transfers for Further Management	692,123	30	603
National Total	**43,703,200**	**52**	**2,639**



Reported Releases and Transfers, **United States TRI**, 2013

	Kilograms	Number of Pollutants	Number of Facilities
On-site Releases to Air	350,607,082	444	15,595
On-site Releases to Water	96,937,677	211	3,223
On-site Releases to Underground Injection	93,386,357	137	105
On-site Disposal or Land Releases	1,146,309,157	184	1,938
Off-site Disposal	212,820,057	324	7,988
Off-site Transfers to Recycling	967,416,945	166	7,680
Off-site Transfers for Further Management	469,144,034	393	5,716
National Total	**3,336,621,309**	**459**	**19,070**



*Reporting values above 0.0001 kg.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

1.3.2 Reported Releases to Air and Water

Pollutant releases to air and water are often viewed with greater interest than other industrial releases and transfers because they enter the environment directly. As mentioned in section 1.2, releases to air for 2013 accounted for 462,828,876 kilograms, or 9 percent, of total reported releases and transfers, while releases to water accounted for 224,380,028 kilograms (4 percent of the total). Additional information about some of the pollutants reported released to air and water, and two top reporting sectors, is provided herein.

Table 3 presents the top industry sectors and pollutants that accounted for almost two-thirds of all reported releases to air for 2013. It shows the electricity generation sector as the top reporter; as mentioned earlier, this sector accounted for about 25 percent of all reported releases to air that year. Of the total of 495 pollutants reported released to air by all North American facilities, the eight shown in this table made up almost half of the total. They include ammonia, methanol, and acidic gases such as hydrochloric acid and sulfuric acid. If inhaled, these pollutants can cause headaches and dizziness, irritate the respiratory track, and cause difficulty breathing. In the environment, acid gases can contribute to acidic deposition and the acidification of freshwater bodies.[13]

Table 3. **Top Reporting Industry Sectors for Releases to Air, and Top Reported Pollutants, North America,** 2013

Industry Sector (NAICS-4 Code)	**Releases to Air 2013** (kg)	**Pollutant**	**Releases to Air 2013** (kg)	**Canada NPRI (%)**	**Mexico RETC (%)**	**US TRI (%)**
Electric Power Generation, Transmission and Distribution (2211)	114,200,707	**Hydrochloric Acid** CA, US	44,125,817	18%	--	82%
		Sulfuric Acid CA, US	40,396,364	2%	--	98%
		Hydrogen Sulfide CA, MX, US	12,593,282	0%	99.98%	0.02%
Pulp, Paper, and Paperboard Mills (3221)	80,224,858	**Methanol** CA, US	47,249,839	19%	--	81%
		Ammonia CA, US	7,808,486	21%	--	79%
		Hydrochloric Acid CA, US	7,380,675	27%	--	73%
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (3253)	39,173,221	**Ammonia** CA, US	31,810,672	26%	--	74%
		Methanol CA, US	3,468,675	15%	--	85%
		Hydrogen Sulfide CA, MX, US	1,312,711	--	--	100%
Basic Chemical Manufacturing (3251)	35,223,021	**Ethylene** CA, US	5,668,308	9%	--	91%
		Ammonia CA, US	4,469,009	2%	--	98%
		Carbonyl Sulfide CA, US	3,833,241	0.5%	--	99.5%
Petroleum and Coal Products Manufacturing (3241)	20,866,144	**Sulfuric Acid** CA, US	3,609,800	23%	--	77%
		Ammonia CA, US	2,918,341	6%	--	94%
		Hydrogen Cyanide CA, US	2,610,134	2%	--	98%
Total, Top 5 Sectors	**289,687,951**	**Total, Top Pollutants**	**219,255,353**			
Total Releases to Air	**462,828,876**					
%, Top 5 Sectors, of Total Releases to Air	**63%**					

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.
"--" means not reported. CA, MX, US = Canada, Mexico, United States.

13. More information about the potential effects of some of these pollutants can also be found in appendix 2 of this report.

This table shows a very uneven distribution of reporting among the three countries, with the only data for Mexico being for releases of hydrogen sulfide from the electricity generation sector. As the table indicates, hydrogen sulfide is the only pollutant, among these top substances, that is subject to reporting under Mexico's RETC.

Table 4 shows the top industry sectors and pollutants that accounted for 81 percent of total reported releases to water for 2013. As mentioned earlier, the wastewater treatment (POTW) sector accounted for about half of the 224 million kilograms in reported releases to water that year (figure 2).[14] Of the 247 substances reported released to water by all North American facilities, the seven shown in this table accounted for close to 80 percent. By far, nitric acid and nitrate compounds comprised the largest proportions (almost 70 percent), followed by ammonia. As described in *Taking Stock*, volume 13, these pollutant discharges can contribute to nutrient loadings in freshwater systems and contribute to oxygen-poor environments for fish, or otherwise be toxic to aquatic life.[15]

As with reported releases to air, this table reveals a very uneven distribution of reported releases to water across the region, with no data for Mexico relative to the top reported pollutants, due to the fact that they are not subject to

Table 4. Top Reporting Industry Sectors for Releases to Water, and Top Reported Pollutants, North America, 2013

Industry Sector (NAICS-4 Code)	**Releases to Water 2013** (kg)	**Pollutant**	**Releases to Water 2013** (kg)	**Canada NPRI (%)**	**Mexico RETC (%)**	**US TRI (%)**
Water, Sewage and Other Systems (2213)	113,650,578	**Nitric Acid/Nitrates** CA, US	63,007,913	97%	--	3%
		Ammonia CA, US	45,864,955	100%	--	0%
		Phosphorus, Total CA	4,221,603	100%	--	--
Animal Slaughtering and Processing (3116)	26,147,730	**Nitric Acid/Nitrates** CA, US	25,777,765	1%	--	99%
		Sodium Nitrite CA, US	303,697	--	--	100%
		Sulfuric Acid CA, US	37,020	100%	--	0%
Iron and Steel Mills and Ferroalloy Manufacturing (3311)	16,283,131	**Nitric Acid/Nitrates** CA, US	15,453,963	3%	--	97%
		Sodium Nitrite CA, US	477,414	0%	--	100%
		Ammonia CA, US	109,366	67%	--	33%
Pulp, Paper, and Paperboard Mills (3221)	14,619,044	**Nitric Acid/Nitrates** CA, US	5,063,311	38%	--	62%
		Manganese* CA, US	3,057,024	33%	--	67%
		Ammonia CA, US	2,475,192	68%	--	32%
Petroleum and Coal Products Manufacturing (3241)	10,844,936	**Nitric Acid/Nitrates** CA, US	10,385,805	3%	--	97%
		Ammonia CA, US	255,984	31%	--	69%
		Ethylene Glycol CA, US	32,176	--	--	100%
Total, Top 5 Sectors	**181,545,418**	**Total, Top Pollutants**	**176,523,188**			
Total Releases to Water	**224,380,028**					
%, Top 5 Sectors, of Total Releases to Water	**81%**					

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. "--" means not reported.
* and its compounds. CA, MX, US = Canada, Mexico, United States.

14. In table 4, almost 100% of the data associated with the NAICS-4 level sector, "Water, Sewage and Other Systems (NAICS 2213)," can be attributed to sewage treatment facilities (NAICS 22132).
15. See *Taking Stock*, volume 13, available through the CEC's virtual library at: <**http://www3.cec.org/islandora/en**>.

PRTR reporting in that country. Another inconsistency among the national PRTRs that is particularly relevant to the reporting of releases to water is the fact that in the United States, POTWs are not subject to the TRI.

Toxicity Equivalency Potentials (TEPs)

As explained in text box in the introduction to this report, "Factors to Consider When Using PRTR Data to Evaluate Risk," using release and transfer data to assess risk to human health or the environment is a complex task and reported volumes alone cannot indicate what, if any, risk exists from the release of a pollutant. Important information such as the form and toxicity of the substance, its fate in the environment, and the potential for exposure is necessary for an accurate understanding of potential risk. Readers should also remember that PRTR data are limited in their coverage of pollutants and industrial sources (see appendix 1). In order to help address the issue of risk, *Taking Stock* incorporates available toxicity equivalency potentials (TEPs) into the assessment of pollutant releases to air and water. TEPs rank the risk posed by one unit of a pollutant in comparison with one unit of a reference chemical for which the risk to human health is well known. The reference chemical for carcinogens is benzene. Toluene is the reference chemical for other health risks, including developmental or reproductive impairment.[16]

A TEP score does not constitute a risk assessment but, as the term suggests, indicates the potential for risk based on the amount released and the inherent toxicity of a substance, without taking other risk factors into consideration. TEPs are useful because they draw attention to highly toxic substances that are often released in relatively small quantities and may not otherwise be recognized as pollutants of significance. The TEPs are based on available knowledge, so there will be gaps—some substances may, in fact, pose a risk to human health, but there is not enough information to estimate a TEP. An additional restriction is that, at the North American level, certain pollutants are reported as groups of related substances (e.g., a metal and its compounds) and thus the more toxic chemical forms are grouped with less toxic forms.

Table 5 presents the cancer and non-cancer TEP scores for selected pollutants reported released to air for 2013. It attests to the fact that certain substances released in relatively small proportions (e.g., dioxins and furans) can, potentially, pose a far greater risk to human health than those ranked by total release volumes.[17] And while six of the ten pollutants in this table are subject to reporting under all three North American PRTRs, the high TEP scores for others (e.g., thallium compounds) highlight the importance of having comparable data across the region for releases of pollutants of special concern.

Similarly, the selected pollutants – most of them metals – reported released to water and shown in table 6 have very high TEP scores, particularly in relation to non-cancer effects. Since only five of these ten pollutants are subject to reporting under all three PRTR programs, the result is a lack of comparable data across North America for releases of certain pollutants (e.g., barium, copper) that are of special concern.

The issue of comparable pollutant release and transfer data for the region also includes the thresholds at which pollutants must be reported. For example, among the substances in tables 5 and 6 that are common to the three PRTRs, only mercury compounds have comparable "activity" (MPO) reporting thresholds (i.e., approximately 5 kg).[18] More often, the national reporting thresholds vary widely—such as the wide discrepancy between the Canadian NPRI and Mexican RETC threshold for cadmium and its compounds (5 kg), compared with the U.S. TRI threshold (11,340 kg). For a number of substances known for their potential toxicity to human health or the environment, thresholds have been lowered to better track, and manage, their releases. For the 2014 reporting year, Mexico's RETC pollutant list has expanded from 104 to 200, and many of the original pollutant reporting thresholds have also been lowered.

16. "Non-cancer" can refer to various health impacts, such as developmental or reproductive effects. Not all pollutants have been evaluated for their potential toxicity. See Using and Understanding *Taking Stock* for more information (appendix 1).
17. Some information relating to the categories of PRTR substances (e.g., known or suspected carcinogens) is also available through Taking Stock Online. National PRTR reporting requirements for dioxins and furans vary. Readers should consult the national programs for more information.
18. The thresholds referred to in this section are for the manufacture, processing or otherwise use (MPO) of a pollutant. Mexico also has a release threshold, and facilities must report if they meet either threshold. To see the reporting thresholds for all pollutants reported to the North American PRTRs, see the List of Pollutants Reported to the North American PRTRs at : <**PRTR Reporting Requirements**>.

Table 5. **Selected Pollutants Released to Air,** 2013, and their TEP Scores

Pollutant	Air Emissions 2013 (kg)	Cancer Risk Score (TEP) 2013	Non-cancer Risk Score (TEP) 2013
Ammonia CA, US	75,862,155	0	288,276,190
Hydrochloric acid CA, US	64,626,230	0	775,514,761
Hydrogen sulfide CA, MX, US	24,979,367	0	849,298,494
Zinc* CA, US	2,685,595	0	510,263,119
Lead* CA, MX, US	1,428,695	40,003,468	828,643,272,965
Nickel* CA, MX, US	1,150,407	3,221,138	3,681,301,113
Arsenic* CA, MX, US	402,127	6,434,034,451	33,778,680,867
Mercury* CA, MX, US	297,022	0	4,158,306,504,373
Thallium* US	1,362	0	16,340,755,861
Dioxins and furans CA, MX, US	82	97,885,900,732	71,782,993,870,079

Notes: For certain pollutants (e.g., dioxins and furans), multiple thresholds or other criteria may apply. See national programs for details. CA = Canada's NPRI; MX = Mexico's RETC; US = US TRI. The TEP score is calculated by multiplying a pollutant's assigned toxicity equivalency potential (TEP) by the amount of the pollutant released to air or water. * and its compounds.

Table 6. **Selected Pollutants Released to Water,** 2013, and their TEP Scores

Pollutant	Surface Water Discharges 2013 (kg)	Cancer Risk Rcore (TEP) 2013	Non-cancer Risk Score (TEP) 2013
Manganese* CA, US	4,012,921	0	14,045,225
Zinc* CA, US	663,213	0	9,284,985
Barium* US	473,055	0	22,706,622
Vanadium* CA, US	258,275	0	183,375,363
Copper* CA, US	193,479	0	2,321,744,756
Lead* CA, MX, US	152,283	304,566	6,395,889,251
Arsenic* CA, MX, US	37,673	150,691,323	753,456,617
Cadmium* CA, MX, US	37,094	70,477,730	5,193,095,894
Mercury* CA, MX, US	5,861	0	76,194,288,031
Dioxins and furans CA, MX, US	1	826,593,718	587,001,336,096

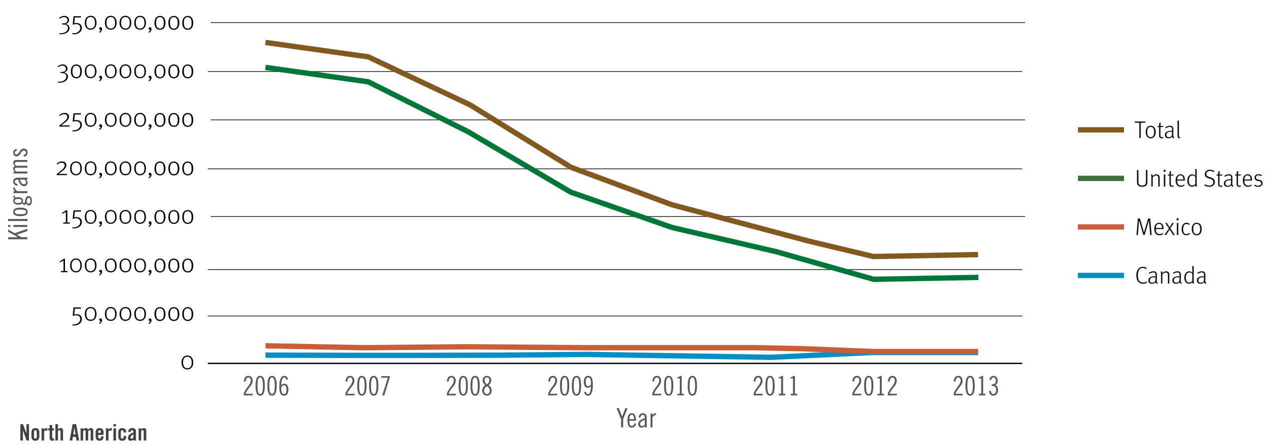
Notes: For certain pollutants (e.g., dioxins and furans), multiple thresholds or other criteria may apply. See national programs for details. CA = Canada NPRI; MX = Mexico RETC; US = US TRI. The TEP score is calculated by multiplying a pollutant's assigned toxicity equivalency potential (TEP) by the amount of the pollutant released to air or water. * and its compounds.

Releases to Air from Electric Utilities, 2006–2013

The data in table 3 showed that the electricity generation sector accounted for just over 114,000 million kilograms, or about one-quarter, of the air emissions reported by North American facilities for 2013, including large proportions of hydrochloric acid, sulfuric acid, and hydrogen sulfide. These data reflect a lack of comparability among the PRTR programs relative to certain pollutants, but they also reflect the unique characteristics of each country's industrial composition and size. In the United States and Mexico, electricity generation relies heavily on the combustion of fossil fuels such as coal, oil, and natural gas, but in differing mixes; and while these fuels are also used in Canada, more than half of that country's energy is supplied by hydroelectric power plants.

The last edition of the *Taking Stock* report presented data for releases to air from North American electric utilities between 2005 and 2010, revealing a substantial decrease over that period.[19] The 2006-2013 data, reflecting the current trilateral dataset in Taking Stock Online, are presented in figure 5. They show a continuation of this downward trend, driven mainly by U.S. facilities. In that country, important decreases in air emissions of pollutants such as hydrochloric

Figure 5. **Reported Releases to Air from North American Electric Utilities,** 2006-2013



North American Power Plants: Selected Pollutants	**2006** (kg)	**2007** (kg)	**2008** (kg)	**2009** (kg)	**2010** (kg)	**2011** (kg)	**2012** (kg)	**2013** (kg)
Hydrochloric acid CA, US	220,623,693	210,196,337	165,981,043	112,272,806	76,201,300	58,329,625	43,796,613	44,125,817
Sulfuric acid CA, US	57,671,646	54,185,933	50,931,324	47,938,596	49,128,529	45,121,165	38,721,642	40,396,364
Hydrogen sulfide CA, MX, US	17,852,484	16,167,903	18,323,708	15,908,515	16,254,130	15,664,782	13,308,825	12,593,282
Barium* US	739,250	791,025	744,841	640,180	617,208	546,432	472,908	428,024
Zinc* CA, US	568,777	583,407	663,545	376,090	352,407	349,076	148,385	148,641
Selenium* CA, US	237,172	241,429	194,605	125,989	113,498	97,337	69,735	69,172
Nickel* CA, MX, US	173,776	186,282	152,753	113,685	91,311	58,276	48,650	55,536
Lead* CA, MX, US	77,416	77,537	67,709	51,015	47,331	39,318	33,235	30,442
Mercury* CA, MX, US	44,325	44,665	42,219	33,889	31,548	27,088	22,687	22,946
Arsenic * CA, MX, US	39,644	40,587	37,275	29,879	29,868	25,465	18,751	18,832
Total, 138 pollutants	330,736,574	315,007,131	266,010,342	200,941,389	164,156,310	138,332,130	112,277,693	114,200,707

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. CA = Canada's NPRI; MX = Mexico's RETC; US = US TRI. * and its compounds.

19. See *Taking Stock*, volume 14, available through the CEC's virtual library, at: <**http://www3.cec.org/islandora/en**>.

acid can be attributed, in part, to greater awareness of the impacts of emissions from the combustion of fossil fuels on air quality and human health. Policy tools including the 1990 Clean Air Act amendments and the 2005 Clean Air Interstate Rule established regulations and economic incentives to address issues such as acid rain resulting from power plant emissions of sulfur oxides and nitrogen oxides. As a result, many utilities installed pollution controls, or switched to low-sulfur coal or natural gas.[20]

The data for Canada show relatively consistent power plant emissions throughout the period. However, a closer look at the data in Taking Stock Online reveals that in Ontario, emissions from this sector decreased dramatically, from approximately 4.5 million kilograms in 2007 to 644,000 kilograms in 2013.[21] The province's 2007 *Cessation of Coal Use Regulation* drove the transition to an energy mix of nuclear, natural gas and non-hydro renewables. It was followed by the *Ending Coal for Cleaner Air Act* of 2013, which resulted in a change in fuel or closure of the four remaining coal-fired utilities.[22] Ontario's shift away from the use of coal has led to a significant decrease in emissions of acid gases, particulate matter and sulfur oxides. The result has been fewer smog days, as well as an annual decrease of 17 percent in greenhouse gas emissions—with this initiative hailed as the single most important greenhouse gas reduction measure in North America.[23]

The data in figure 5 reveal that these efforts to reduce emissions of particulate matter and acid gases have also yielded co-benefits, in decreases in emissions of other air pollutants associated with the combustion of fossil fuels. As shown in the discussion on TEPs, some of these pollutants (e.g., mercury compounds) can have significant human health impacts.

Releases to Water by the Wastewater Treatment Sector

Wastewater (or sewage) treatment plants accounted for 113,650,157 kilograms, or half, of all reported releases to water for 2013 (table 4). These facilities constitute a sector that is distinct from the other industrial sectors reporting to the North American PRTRs. That is, they receive and treat releases from a wide range of residential, industrial, commercial and non-point (e.g., agricultural and stormwater run-off) sources. The complex nature and large volumes of the wastewater requiring treatment at these facilities present significant challenges for managing pollutant releases to surface waters.

Table 7 presents the top 10 pollutants, of 31 in all, reported discharged to water by the sewage treatment sector and making up almost 100 percent of the total. It also indicates where these substances are subject to PRTR reporting and further demonstrates the impacts of differences among the national programs – with the third-ranked pollutant, total phosphorous, subject to reporting only in Canada; and only one of the 10 substances, lead, subject to reporting in Mexico.

Table 7. **Pollutants Released to Water by SewageTreatment Plants,** 2013

Pollutant	**Surface Water Discharges 2013** (kg)
Nitric acid/nitrates CA, US	63,007,913
Ammonia CA, US	45,864,955
Phosphorus (total) CA	4,221,603
Zinc* CA, US	134,529
Ethylene glycol CA, US	95,590
Manganese* CA, US	90,584
Copper* CA, US	44,334
Total Reduced Sulfur (TRS) CA	31,260
Lead* CA, MX, US	27,111
Nonylphenol and ethoxylates CA	23,200
All other pollutants (21)	109,080
Total, 31 pollutants	113,650,157

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. * and its compounds. CA = Canada's NPRI; MX = Mexico's RETC; US = US TRI.

20. **https://www.eia.gov/todayinenergy/detail.php?id=10151**.
21. Search the data at : **www.cec.org/takingstock**.
22 Cessation of Coal Use Regulation No. 496/07: **https://www.ontario.ca/laws/regulation/070496**; and <**http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTIxMDQ3&statusId=MTk3MjEz**.
23. The End of Coal: Ontario's coal phase-out. IISD 2015: **https://www.iisd.org/sites/default/files/publications/end-of-coal-ontario-coal-phase-out.pdf**.

The fact that publicly-owned sewage treatment plants (POTWs) are not subject to the U.S. TRI program also results in a paucity of data for releases to water in that country. As shown in table 4, only relatively small discharges (just under 2 million kilograms, almost all of nitric acid and nitrate compounds) were reported by one private facility, a meat processing plant in Nebraska. In Mexico, pollutant releases to water are generally subject to the RETC, as the program covers discharges to national water bodies (which include most water bodies in the country); however, wastewater treatment facilities are under municipal jurisdiction and thus there is some ambiguity relative to the reporting requirements for this sector. Due to these inconsistencies, almost all of the data shown in this table were reported by Canadian facilities.

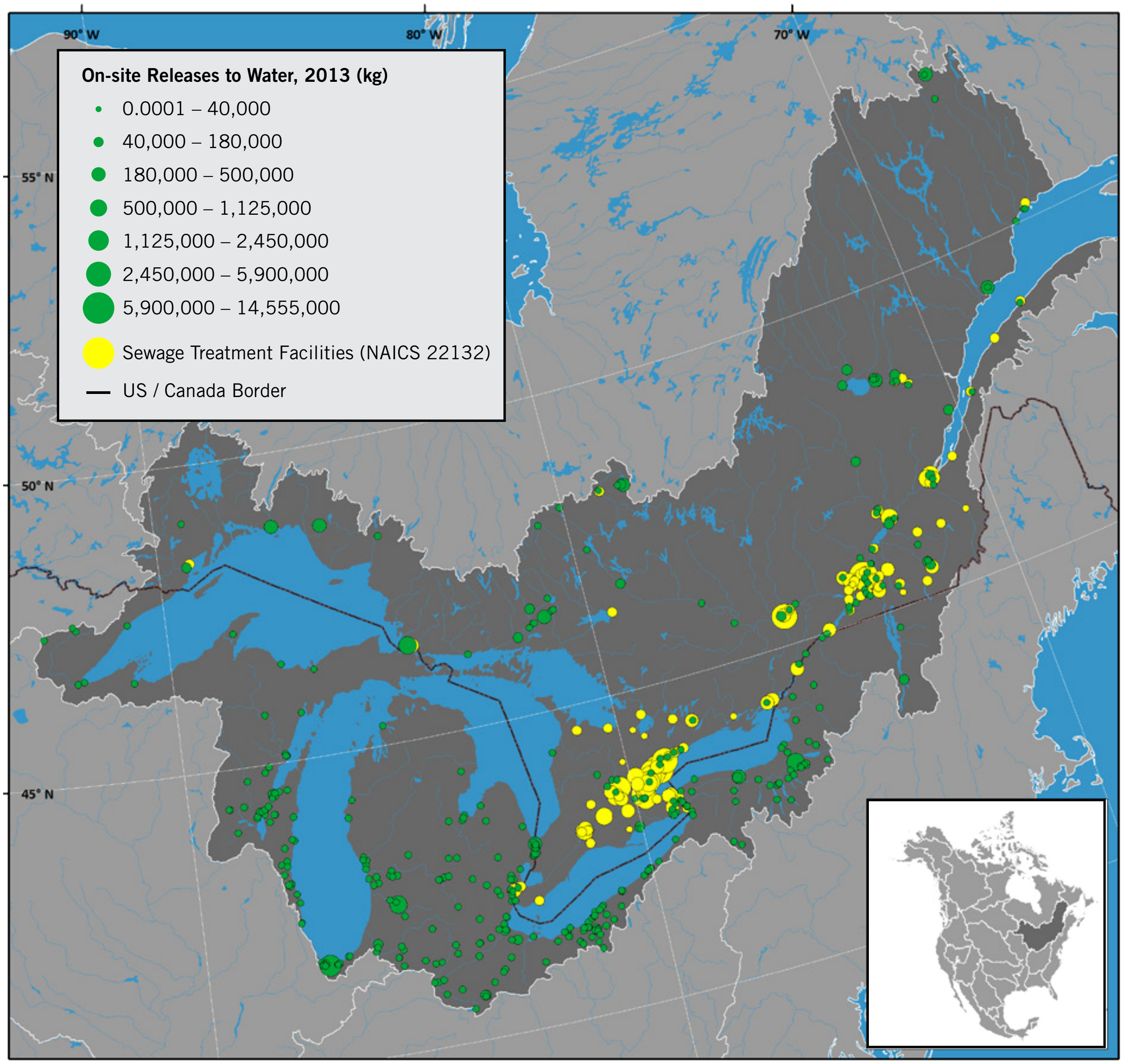
Figure 6 portrays releases to water from all reporting sectors within the St. Lawrence River watershed, which straddles the Canadian-U.S. border, for 2013.[24] The yellow proportional circles (scattered among the green ones) represent discharges from wastewater treatment plants, which reported more than 70 million kilograms of many of the pollutants shown in table 7. This figure clearly reveals that all of the reporting sewage treatment facilities are located on the Canadian side of the border. The lack of U.S. data for the sector therefore hinders our understanding of the pollutant loadings to this important shared watershed.

Enhancing the Integration and Comparability of Data

The example of the St. Lawrence River watershed highlights the value of having comparable data for pollutant releases to shared ecosystems in order to understand the potential impacts of these releases on human or environmental health. This theme was discussed during the public meeting of the CEC's North American PRTR initiative, held in October 2016 in Washington, DC. Presentations centered on the challenges of integrating data and information relating to shared ecosystems, and efforts undertaken to try to address these challenges. One such effort was

24. Using the newest function of Taking Stock Online, data for releases to North American watersheds can be queried using the watersheds ecosystem layer of the CEC's North American Environmental Atlas.

Figure 6. **Reported Releases to Water in the St. Lawrence River Watershed,** 2013



Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

the Great Lakes Basin Human Health and Environmental Databases Project, undertaken for the International Joint Commission (IJC), the agency responsible for protecting this shared ecosystem.[25] The project explored how existing environmental and human health datasets for the Great Lakes Basin could be integrated to inform decisions relating to concerns such as transboundary air pollution, harmful algal blooms, fish contamination, invasive species, and so on. It identified the Canadian NPRI and U.S. TRI programs as important sources of information on environmental stressors that, when combined with data on human exposure and health outcomes, could be used to support health-environment associations.

Through the CEC, the PRTR programs of the three countries regularly cooperate on the integration and harmonization of data, which are made accessible via the Taking Stock Online website. The countries have also committed to efforts to improve the completeness, quality and comparability of PRTR data and information, as described in the *Action Plan to Enhance the Comparability of PRTRs in North America* (box 2). In this way, pollutant release and transfer data can support research, policies and initiatives relative to issues and concerns in the region's shared ecosystems.

Box 2. *Action Plan to Enhance the Comparability of PRTRs in North America*

The *Action Plan for Enhancing the Comparability of Pollutant Release and Transfer Registers in North America* reflects the engagement of the three Parties over the past two decades, as expressed in a number of Council resolutions.[26] Updated and published in 2014, the *Action Plan* is the result of collaboration among the CEC, the three PRTR programs, and stakeholders including industry, nongovernmental organizations (NGOs), academia, citizens, and the media. It contains ten recommendations and related actions to increase the scope, quality, comparability, and understandability of data for the region. Progress has been made in a number of areas—e.g.:

- Exchanges of information among the PRTR programs relative to listing additional pollutants or industrial activities, and reducing reporting thresholds;
- Engagement of industry sector representatives, NGOs and academics in the review of information and data for special feature analyses in *Taking Stock* (e.g., pulp and paper, mining), and identification of data quality issues, gaps, and areas for improvement;
- Data quality efforts to address specific issues in facility reporting of cross-border transfers;
- Addition of contextual information and tools in Taking Stock Online to enhance user understanding (e.g., pollutant-based information; watersheds query option; informational videos);
- Meetings to explore the use of PRTR data and information to address environmental issues and to inform activities under the North American PRTR initiative.

Having complete, comparable and accurate PRTR data across North America has multiple benefits. These include reliable information for use by industry, governments and citizens as indicators to help improve human health and environmental outcomes; and public transparency in the management and use of pollutants by industrial facilities. In this way, PRTRs can promote accountability and sustainable environmental management practices at all levels.

25. Health and Environmental Data in the Great Lakes Basin - Integrating Data Collection and Analysis. Report to the International Joint Commission by the Health Professionals Advisory Board, September 25, 2013.
26. See the *Action Plan* at <**cec.org/takingstock**>.

2 The North American Mining Sector

Introduction

This first chapter of the feature analysis on the North American mining sector provides an overview of the industry, including its geographic and economic presence, the processes and technologies used, and regulations governing the activities of the industry. The goal of this chapter is to provide some background and context for interpreting the data, presented in chapter 3, on releases and transfers of pollutants from the mining sector for the 2013 reporting year. The reader should note, however, that this analysis is not restricted to mines that were active in 2013, and that discussions of the regulatory context, mineral processing, pollutant releases and sustainability of mining include consideration of past practices and recent advances.

For the purposes of this report, the activities covered in these two chapters include the mining of metals, non-metallic minerals and coal, but not oil and gas. "Mining" is the extraction of ore, often followed by crushing and separating processes to concentrate the valuable minerals. Underground mines, open-pit mines and quarries are included, as are activities associated with mines—the storage and handling of mineral products; waste treatment; on-site disposal of wastes; release of wastes to land, water and air; and transfer of wastes off-site for recycling, disposal or treatment. Smelting (melting ores to extract the metals) and other metal refining and manufacturing processes are not covered in this report.[27] While mining operations typically extend over life-cycle stages from prospecting and exploration through mine decommissioning, the focus of this overview is on mines at the production stage.

The role of mining in modern societies

There are few aspects of modern life that do not depend on metals and other minerals. Our roads, buildings, communications, water, energy, food, and much of the infrastructure that supports our cultural and leisure activities depend on the raw materials produced by mines (table 8). Population growth, rapid economic development of some nations, especially China, and advancements in technology all contribute to increased global consumption of minerals in recent decades. The demand for minerals to fertilize crops, for example, is rising steadily. Worldwide, 30 to 50 percent of crop yields are a result of fertilizers, the primary ingredients of which are phosphate rock and potash. World consumption of phosphate rock is estimated to increase 10 percent from 2013 to 2017 (Wellington and Mason 2014). Modern technologies make use of an increasingly diverse array of minerals, which has led to particularly rapid growth in demand for metals used in electronics and specialized alloys (Graedel et al. 2015).

Table 8. **Selected Minerals and Examples of Their Uses**

Aluminum	Ships, airplanes, doors, windows, roofing, insulation, packaging, food processing, domestic utensils, electrical conductors
Clay	Pottery; bricks, tiles; cement and concrete to build roads, buildings and housing foundations
Coal	Energy source for steel manufacturing and electrical production; reducing agent for smelting iron to produce steel
Copper	Electrical conductors, motors, appliances, piping, coins, metal alloys
Gold	Jewelry and decorative items, computers and electronics, medical equipment and scientific instruments, coins and bullion
Iron	Steel, magnets, medicines, biomedical research, paints, printing inks, plastics, cosmetics, dyes
Molybdenum	Stainless steel, cast iron, chemicals, lubricants, alloys
Phosphate rock	Fertilizers, feed additives for livestock, chemicals
Platinum group metals[1]	Computers, hybrid cars, flat-screen TVs, medical devices, jewelry
Rare earth elements[2]	Computers, televisions, rechargeable batteries, magnetic industry, metallurgical applications, ceramics, lighting, communications systems
Silver	Electrical conductors, jewelry and decorative items; chemical manufacturing, dental and medical uses
Zinc	Protective coatings for steel, alloys, medicines, paints, cosmetics, pharmaceuticals

1. Platinum group metals: six metals, including platinum, with similar properties and tending to occur in the same mineral deposit.
2. Rare earth elements: 17 metals with similar properties often found together in mineral deposits. Examples: yttrium, neodymium, europium, erbium and samarium.
Source: Adapted from Mine-Engineer.com (2016).

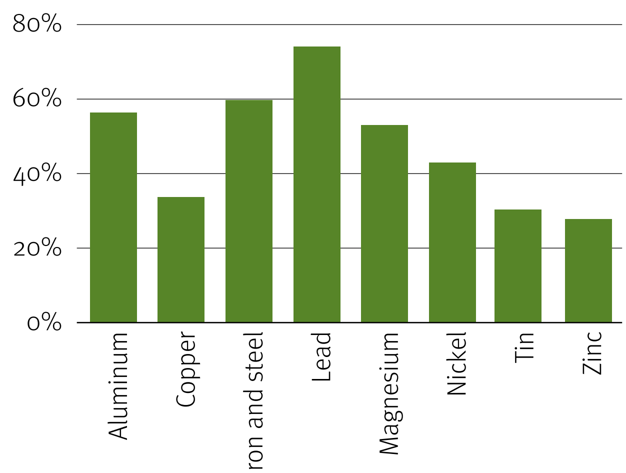
27. The exception is when a facility that also operates a smelter reports those activities under a NAICS code for mining.

One way to reduce demand for metals is to improve recycling. Recycling conserves metal reserves, reduces environmental impacts from mining and smelting, and diverts waste from landfills. It is an effective climate change mitigation measure. Maximizing metal recycling worldwide, especially for the metals in highest use—iron, steel and aluminum—has the potential to reduce greenhouse gas emissions from the metal industry by up to 13 to 23 percent, corresponding to one percent of global greenhouse gas emissions (Ciacci et al. 2016). Examples of per-unit savings in materials and energy (ISRI 2015) include:

- Recycling a tonne of steel, compared with producing a tonne of steel from primary sources, uses 56 percent less energy and conserves 1.1 tonnes of iron ore, 635 kilograms of coal and 54 kilograms of limestone.
- Recycling a tonne of aluminum uses 92 percent less energy and conserves over 4 tonnes of bauxite ore.

Recycling of common metals is long-established, with varying success in recycling for different elements (Figure 7). The bulk of recycling of these industrial metals, however, is recycling of scrap from manufacturing, not recovery of metals from post-consumer products. Recycling rates vary with types of metals and types of products, based on technology and other factors, such as differences in product lifespans. An aluminum pop can, for example, becomes available for recycling not long after it is manufactured, while a copper cable may remain in use for decades. Even greatly improved recycling will not provide sufficient metal to meet demand for some commodities.

Figure 7. **Recycling Rates for Common Metals in the United States** (2010–2014 average)



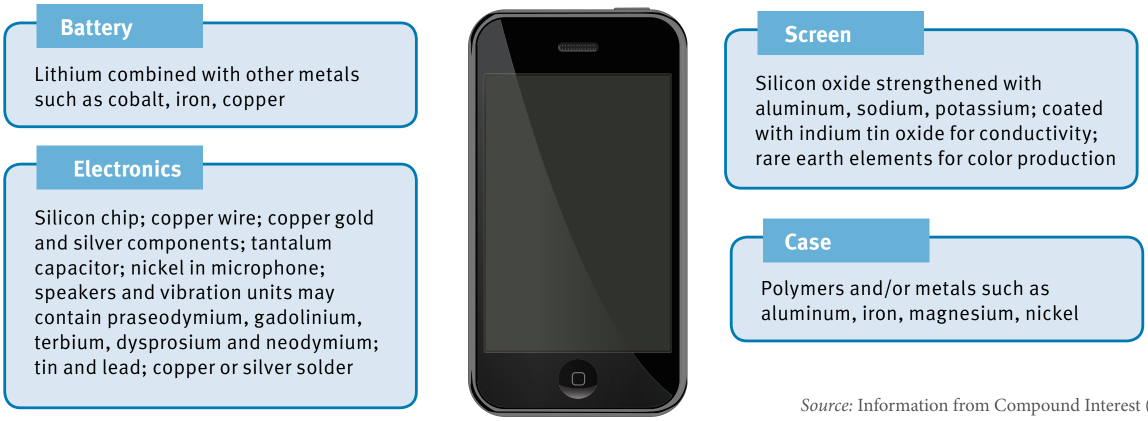
Note: The recycling rate is the amount recycled as a percent of the sum of mine production, net import and amount recycled. *Source:* Data from US Geological Survey (Papp 2016).

The last two to three decades have seen a huge rise in loss of metals through electronic waste (e-waste), which is now the fastest growing waste stream in the world, increasing at a rate of 4 to 5 percent per year (Williams 2016, Baldé et al. 2015), though it remains a relatively small proportion of overall metal waste. Per capita e-waste generation for 2014 was estimated at 20 kilograms for Canada, 22 kilograms for the United States and 8 kilograms for Mexico (Baldé et al. 2015).

Computers, cell phones and other high-tech products containing precious metals and rare minerals usually have short lifetimes and low recycling rates. Disposal is more likely to be through incineration, landfill, or informal recycling (in developing countries) for the most valuable metals, often using unsafe methods with adverse environmental impacts (Izatt et al. 2014). A typical recently-made smart phone contains up to 62 different metals (see figure 8) (Rohrig 2015). Recovering the small amounts of many types of metals from each unit is technologically challenging and expensive. Improving recycling rates in post-consumer goods involves changes in societal goals and priorities, improved systems for collection and reprocessing and, especially for e-waste, improved technology for metals recovery (Izatt et al. 2014).

While metals conservation through recycling holds promise for reducing the need for new metals, widespread use of metals and shifting needs due to technological innovation ensure that new mineral reserves will continue to be identified and new mines opened in North America. Pollution, the focus of this report, is only one of the issues associated with mines, and not always the major one. Assessments of proposed mines typically identify a range of concerns in addition to the human health and environmental risks from pollution. Use of lands and waterways for mining may conflict with other established uses, or reduce opportunities for future development. Communities may benefit from

Figure 8. Smartphone elements



Source: Information from Compound Interest (2014).

jobs and economic growth, but they also may suffer economic losses and damage to community health and well-being. Mining may disproportionately affect Indigenous Peoples because mineral deposits are often on their traditional lands. More generally, mining may affect the livelihoods and quality of life of rural communities through land changes such as deforestation, or through depletion of water resources. Habitat for fish and wildlife may be lost or degraded, landscapes altered, or terrain rendered unstable.

Modern mining policies and regulations, as well as industry standards and initiatives, aim to take the interests of local residents into account and to minimize the potential for adverse impacts of mining. National regulatory frameworks and sustainability initiatives, particularly as they relate to pollution, are summarized in this chapter.

2.1 Geographic and Economic Presence of the Mining Industry

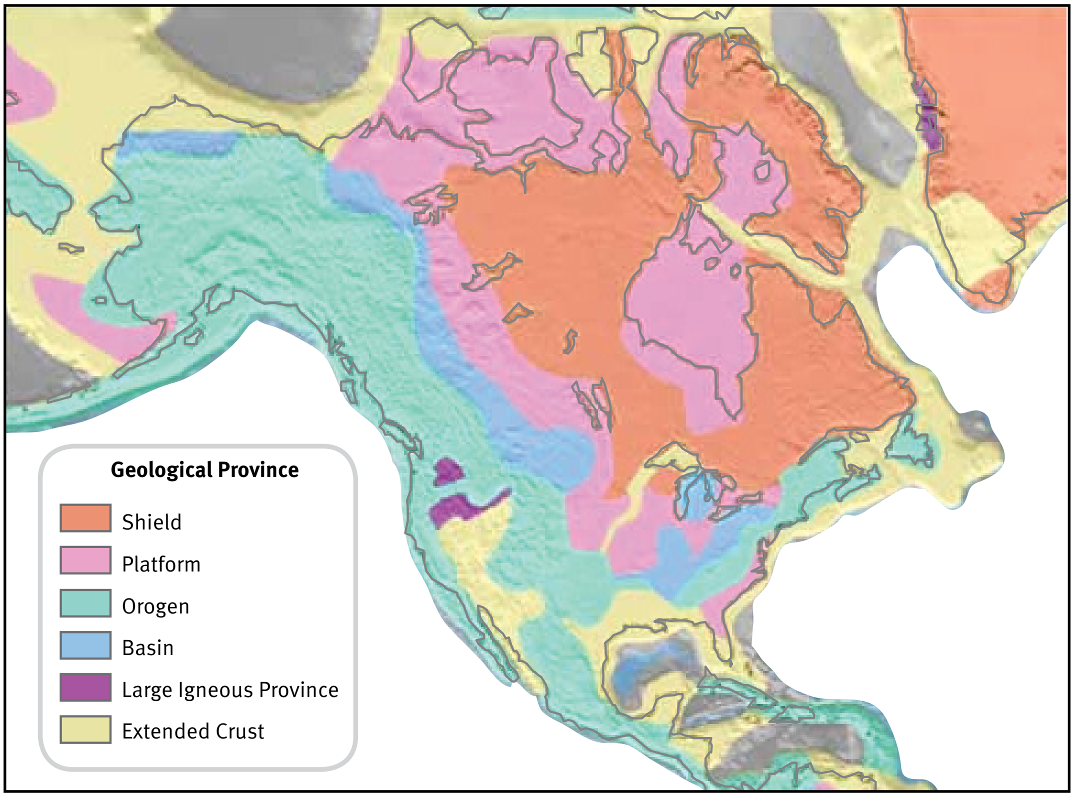
2.1.1 Overview of North American Mineral Deposits

The distribution, size and quality of mineral deposits in North America are directly linked to regional geological settings and geological processes that have occurred over millions of years. The North American craton (the geological core of the continent) has a complex history. It ranges from some of the oldest rocks in the world to relatively young rocks that host a variety of mineral deposit types. The geology of North America at a continental scale can be summarized into broad categories (shown on the map of geological provinces, figure 9):

- **Shield**—typically "basement" granitic rocks that are part of the oldest terranes in North America
- **Platform**—typically part of the stable North American craton, with younger sedimentary cover rocks over basement rocks
- **Orogen** (Orogenic Belts)—geological provinces that have been submitted to tectonic forces, including accretion (addition of part of one tectonic plate to a larger plate) and uplift, through crustal plate movements over millions of years
- **Basin**—rocks that have been deposited in a sedimentary basin environment
- **Large Igneous Province**—a unique geological province specific to the United States, with extensive volcanic-related deposits
- **Extended Crust**—regions where the continental crust has been extended and thinned.

Because most geological processes have been repeated many times, rocks of different ages and types may contain similar mineral deposit types (Eckstrand et al. 1996). As a result, it is difficult to link geological provinces or areas with common geological history to specific mineral deposit types or commodities—the formation of these deposits

Figure 9. **Geological Provinces of North America**



Note: The map shows features of about 150 km across and greater. Source: US Geological Survey (USGS 1997).

occurred over tens of millions of years and across a variety of geological settings. However, it is useful and important to classify mineral deposits to understand the geology, geochemistry and metallurgical properties that affect the type and extent of waste materials and potential pollutants that are generated from mining these deposits.

Mineral deposits are natural concentrations of mineral commodities formed by geological processes and conditions that include specific temperature and pressure ranges, structural conditions that favour fluid flow, and availability of sources of metals. **Mineral deposit types** share a set of geological attributes and contain a particular mineral commodity or combination of commodities (Eckstrand et al. 1996).

There are several classification systems used to describe mineral deposits in North America. The approach followed here covers the major categories for metallic mineral deposits (Eckstrand et al. 1996). Mineral deposit types are grouped into seven major classes:

1. Sediment-associated deposits (sedimentary host rocks);
2. Volcanic-associated deposits (volcanic host rocks);
3. Felsic and intermediate intrusion-associated deposits (granitic host rocks);
4. Alkaline intrusion-related deposits (granitic host rocks);
5. Mafic and ultramafic volcanic and intrusion-associated deposits (volcanic host rocks);
6. Vein and/or replacement deposits (volcanic, granitic and metamorphic rocks);
7. Placer deposits (sedimentary rocks and unconsolidated sand and gravel).

Canada

Canada has over 77 mineral deposit types of which 21 account for significant Canadian mining production (Eckstrand et al. 1996).

The Canadian Shield, which has some of the world's oldest rocks (dating back to the Precambrian era), is characterized by rolling terrain that was glaciated by the last ice advance across northern and southern Canada. Covering almost half of Canada, the Canadian Shield has extensive mineral occurrences and deposits, including base metals (copper, lead, zinc, nickel and cobalt), precious metals (gold and silver), uranium, iron ore and tungsten. The Canadian Shield is surrounded by platform sedimentary rocks that are host to large oil and gas deposits as well as coal, potash, salt, gypsum, limestone and other non-metallic mineral deposits.

The Orogenic Belts in Canada are highly favorable areas for the creation of mineral deposits due to tectonic activity and the deep migration of solutions that are rich in metals, as well as the prevalence of volcanic activity, which can also deposit metals in a variety of host rocks. An example is the highly complex Cordilleran Belt in western and northern Canada, which contains a variety of metallic minerals including gold, copper, iron, silver, lead, zinc, nickel, tungsten and molybdenum, and industrial minerals such sand and gravel, barite and limestone. Deposits in the Appalachian Belt in eastern Canada include industrial minerals such as asbestos, fluorite, potash, gypsum and salt, as well as metallic minerals such as copper, zinc, lead, iron, gold and silver.

Diamond deposits are also found in the Canadian Shield, particularly in the Northwest Territories and Nunavut. These deposits were formed some 50 million years ago by eruptions that carried diamonds (pure carbon in a crystal form) through the Earth's crust in volcanic pipes in a host rock called kimberlite.

Placer deposits are accumulations of heavy minerals such as gold, tin and platinum that have been eroded from bedrock sources and concentrated by sedimentation processes involving gravity, water, wind or glacial ice (McLeod and Morison 1995). Placer deposits are found across Canada in several geological provinces that host precious metal gold deposits. Economic placer gold deposits are in British Columbia and Yukon Territory.

United States

In the United States, there are hundreds of thousands of mineral deposits and well over a thousand that are considered to be significant (Long et al. 1998). Most of the mineral resources and mine production, however, are associated with a few large deposits (Zientek and Orris 2005). For example, Nevada is the largest producer of gold, with multiple active mines along a structure known as the "Carlin Trend." Alaska is also a significant mining jurisdiction, with several large operating mines including the Fort Knox gold mine near Fairbanks and, in northern Alaska, the Red Dog Mine, one of the world's largest producing lead-zinc mines.

Most U.S. coal production is in the eastern and central regions. Metallic minerals including gold, silver, copper, lead and zinc are found in the western part of the U.S. interior, while non-metallic mineral and coal deposits are more common in the central and eastern interior regions.

Accreted terranes: Terranes (areas with distinctive structure and geological history) that have become detached from one tectonic plate and attached to another as a result of tectonic processes.

The Orogenic Belts in Alaska, formed through tectonic and volcanic activity, host a range of mineral deposits. The geology of Alaska is largely an extension of accreted terranes from the Canadian Cordillera, as well as stable craton platform rocks that have metallic mineral deposits such as gold, silver, copper, lead and zinc. Non-metallic minerals include sand and gravel and coal. Placer gold and tin mining are found both offshore near Nome, Alaska, and in central Alaska near Fairbanks.

Hawaii is a chain of active to dormant volcanoes. The only mining that occurs in Hawaii is for industrial minerals such as sand and gravel.

Mexico

Mexico has a broad and diverse geological setting that hosts a number of commodities, including silver, bismuth, celestine, fluorite, cadmium, arsenic, gold, copper, zinc, lead, molybdenum, manganese, coal, salt, sulfur and iron (Camprubí 2009). The country is geologically complex, with mineral deposits that are largely related to tectonic activity in the Orogenic Belts along the Pacific coast and to mineral-rich fluid migration and geochemical processes in the sedimentary basins of central Mexico (Camprubí 2009, Clark and Fitch 2009). There are several accreted terranes along the west coast of Mexico that are extensions of similar terranes in the United States and Canada.

Major "metallogenic provinces" of Mexico are summarized below, based on the classification system of Camprubí (2009). Information is from Camprubí (2009) and Campa and Coney (1983). Figure 10 shows a simplified distribution of the major mineral commodities across Mexico.

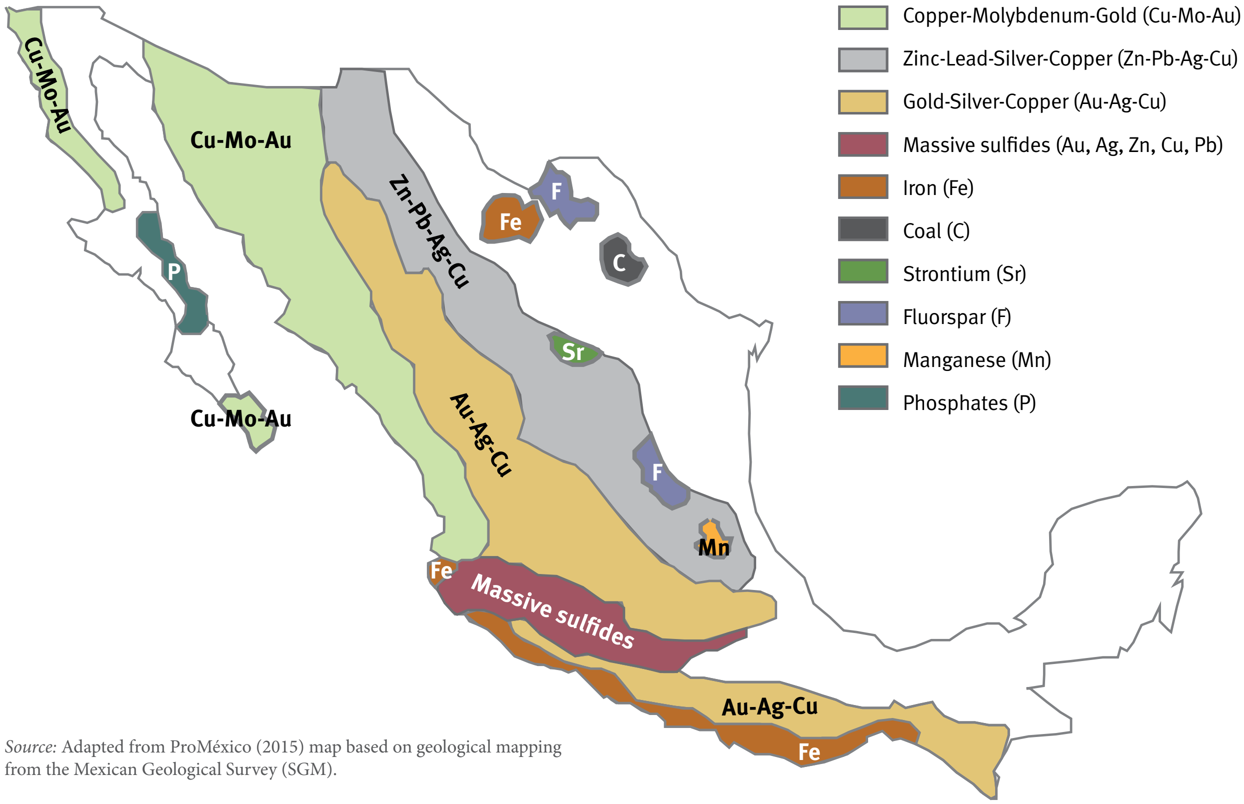
The Pacific Margin includes the western and southern Sierras Madre. Mineral deposit types include:

- polymetallic or gold-silver epithermal deposits that are typically hosted in relatively shallow hot springs-related geological environments;
- porphyry deposits that host copper-molybdenum-gold-tungsten mineralization;
- skarn replacement deposits that host minerals including gold, silver, lead and zinc;
- volcanogenic massive sulfide deposits that are related to hydrothermal venting in marine environments and host a variety of minerals including gold, silver, barite and iron;
- other granitic-related deposits that host tin, silver, gold and other minerals; and
- other volcanic-related settings that host veins containing uranium and gold.

The Gulf of California. Deposits in the southern half of Baja California include phosphate-rich sedimentary deposits that were formed in a shallow submarine environment, manganese veins and polymetallic deposits formed from hydrothermal vents. Northern Baja California has epithermal deposits.

The Gulf of Mexico Megabasin hosts hydrocarbon gas fields and a range of mineral deposits, including sedimentary iron and sulfur deposits and skarn deposits. The eastern Sierra Madre has the largest manganese deposit in North America. Fluorite, celestine and strontianite deposits are in central Mexico.

Figure 10. **Simplified Distribution of Major Mineral Deposits in Mexico**



Source: Adapted from ProMéxico (2015) map based on geological mapping from the Mexican Geological Survey (SGM).

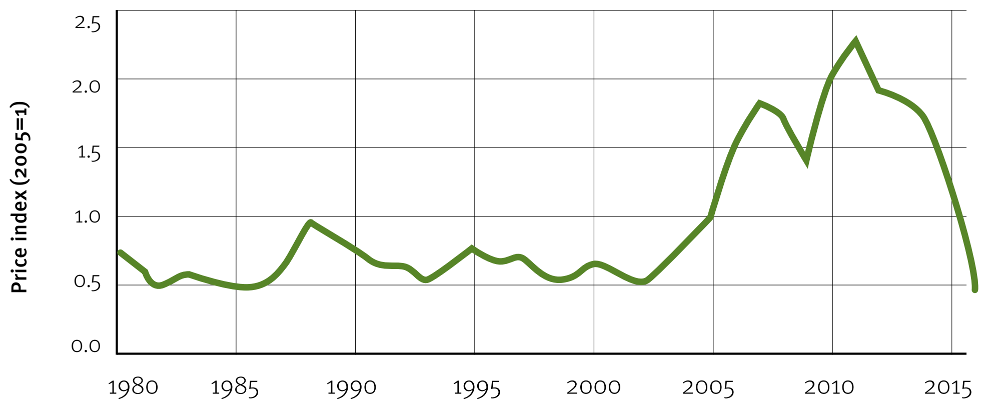
2.1.2 Economics of the Mining Industry

The mining sector economy is a blend of interrelated factors, which include mineral reserves (both quantity and grade), commodity prices, financing mechanisms, exploration programs and capital investment. Commodity prices and overall investor confidence influence the economic health of the mining industry. In addition, government investment for geoscientific programs in support of mineral exploration and the regulatory environment for project approvals can affect financing and long-term mine development proposals.

> **Mineral resource**: a concentration or occurrence of a mineral or minerals of economic interest with reasonable prospects for eventual economic extraction.
>
> **Mineral reserve**: the economically mineable part of a mineral resource, as defined by studies. Mineral reserves are classified as probable or proven. (adapted from CIM Council 2014)

Commodity prices are affected by global economic events and they can fluctuate daily. The long-term trend of the International Monetary Fund's metals price index indicates that prices tend to be cyclical over periods of a few years and, more recently, subject to longer-term trends. This is shown by the marked increase in commodity prices that started in the early 2000s and was dramatically interrupted by a sharp decline related to the financial crisis of 2008, followed by a robust recovery, then a steady decline after 2011 (figure 11). On average, metals prices declined by almost 60 percent from 2011 to 2015 (IMF 2016b) and continued to decline into 2016. Prices of major industrial minerals (non-metallic products such as sand and gravel) are more influenced by regional supply and demand and trends vary considerably by commodity (Kogel et al. 2006). Many non-metallic minerals have not been subject to the same marked decline that has been seen for metals in recent years (Marshall 2015).

Figure 11. **World Metals Price Index,** 1980 to 2016

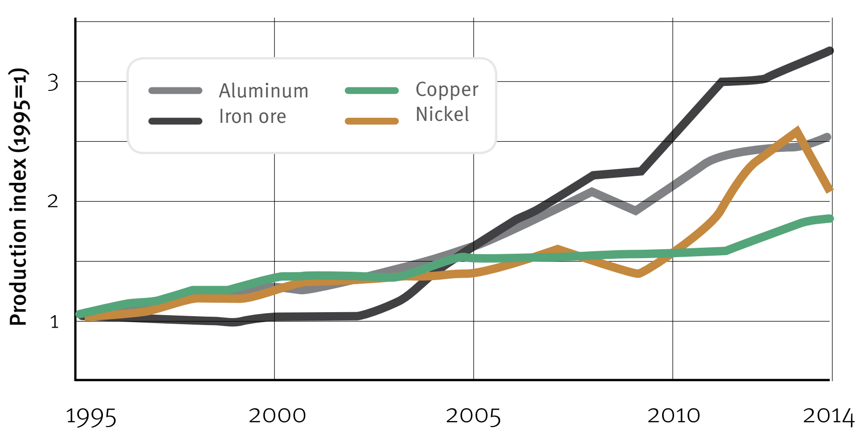


Note: The index is based on international price data for copper, aluminum, iron ore, tin, nickel, zinc, lead and uranium. Only the first 5 months of 2016 are included. *Source:* Data from International Monetary Fund (IMF 2016a).

Prices of recycled metals are also subject to global market forces and the strength of the recycling industry is influenced by trends in world metals prices. In 2015, the index used by the U.S. Institute of Scrap Recycling Industries to track scrap metal prices reached its lowest point since the 2008 recession (ISRI 2016).

China, as the world's biggest importer of metals, has a dominant influence on metal markets. China's economy grew rapidly through the 2000s to 2011, and its consumption of base metals (abundant, relatively low-value metals such as copper, lead and zinc) increased from 10 to 20 percent of global consumption in the early 2000s to over 50 percent in 2015 (IMF 2015). This growth fueled investment in mining, mine production and a steady increase in metals prices. The slowdown of economic growth in China since 2011 has been and continues to be a major influence on North American mining industry investment trends. The decline in demand for metals since 2011 has led to progressively less investment in mine development due to soft commodity prices, high capital costs for new developments and an overall lack of investor confidence. At the same time, however, the supply of metals has increased (figure 12) and global stockpiles of many commodities have risen. At the country level, currency fluctuations also affect mineral prices.

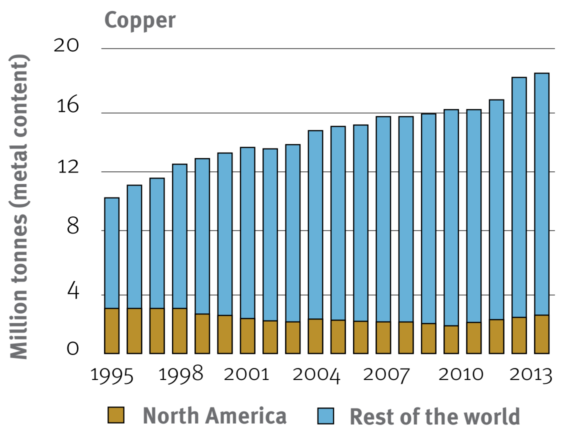
Figure 12. **World Production of Aluminum, Copper, Iron Ore and Nickel,** 1995 to 2014

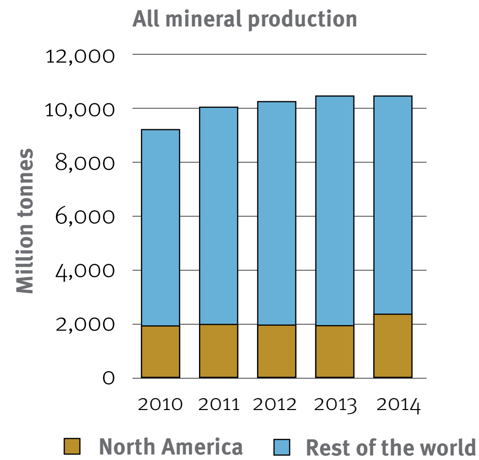


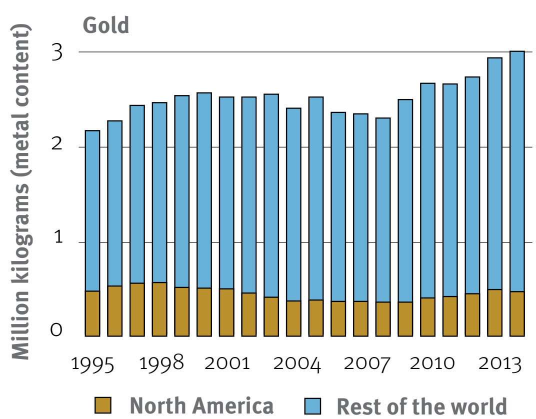
Note: As iron ore production in China is reported with low precision, world production statistics for iron ore have a higher degree of uncertainty than for other commodities. *Source:* Arezki and Matsumoto (2015).

The North American share of world production of all minerals and of selected mineral commodities is shown in figure 13. Trends since 1995 for copper and gold indicate that North American production has fluctuated less than global production for these two commodities.

Figure 13. North American Mineral Production as a Proportion of World Production





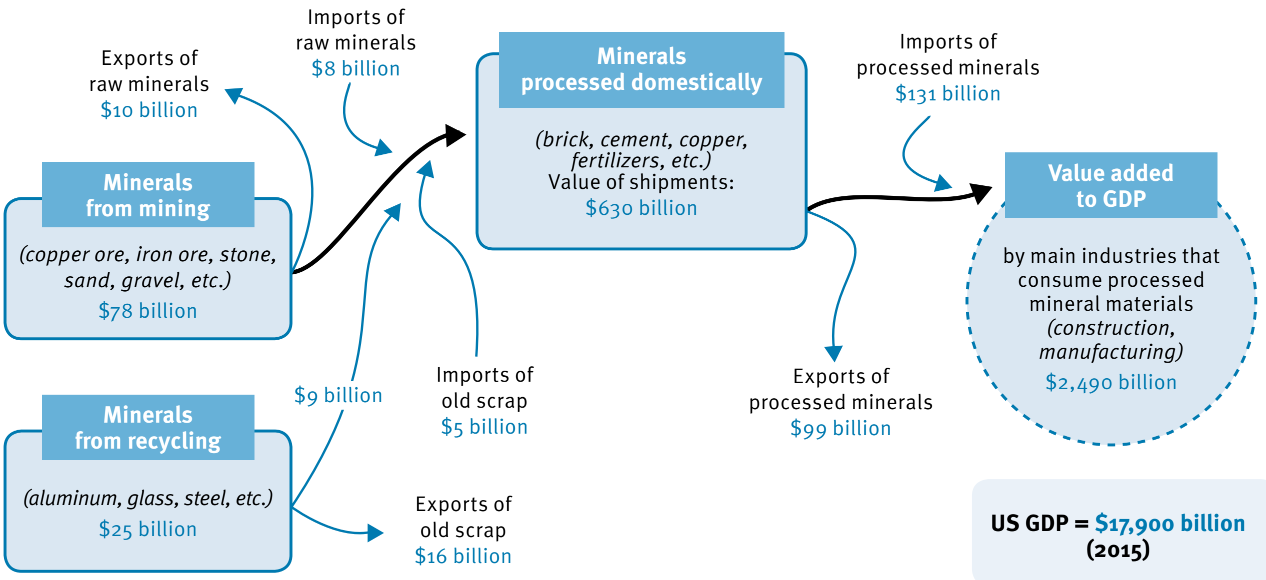


North American share of world production of selected commodities (2014)	
Coal	13%
Copper	14%
Gold	16%
Iron ore	4%
Lead	11%
Molybdenum	32%
Nickel	12%
Potash	30%
Salt	25%
Silver	27%
Uranium	19%
Zinc	13%

Source: Data from Minerals UK Centre for Sustainable Mineral Development (2016) and Reichl et al. (2016).

Mining contributes to national and regional economies directly, but also indirectly through support businesses that supply the industry with goods and services (Marshall 2015). Because minerals are major inputs to construction and manufacturing, their production, recycling and processing are intertwined with many aspects of national economies, including imports and exports of scrap, raw and processed minerals (USGS 2016) (figure 14).

Figure 14. **Role of Minerals in the U.S. Economy** (2015)

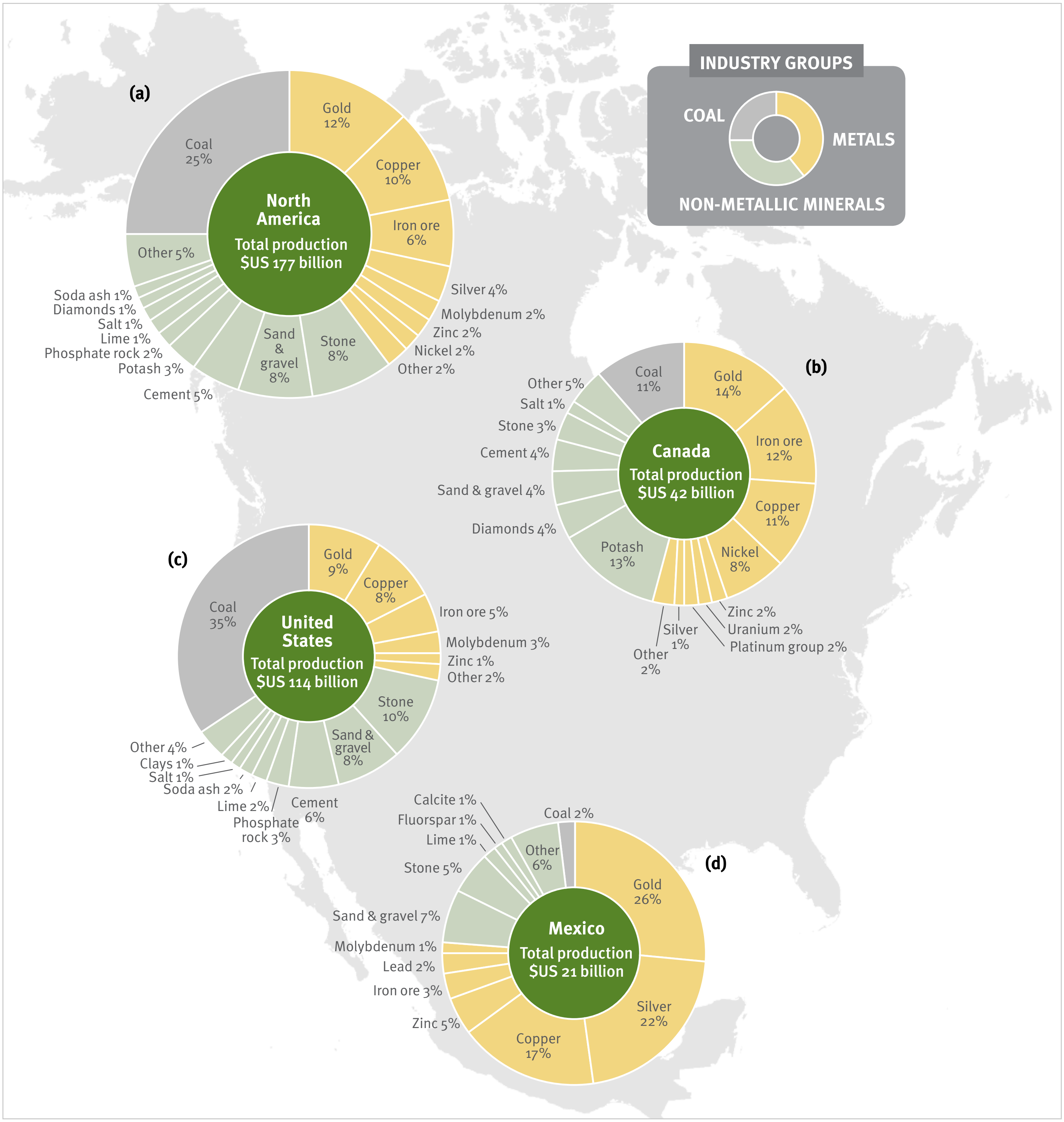


Note: Coal is not included. The majority of "minerals from recycling" is scrap from metals manufacturing. *Source:* Based on estimated 2015 values from the U.S. Geological Survey and Department of Commerce. Adapted from USGS (2016).

This picture of the economic contribution of the mining industry is incomplete as it does not include environmental and socio-economic costs and liabilities, which may be spread over several years. Some costs can have dollar figures attached over specific time periods—for example, costs associated with remediation of abandoned mines in Canada (Story and Yalkin 2014). Other economic costs are harder to define, such as the loss of recreational opportunities when a new mine is developed, or the ongoing costs of degradation of water in areas with chronic pollution from past mining operations. Impacts on health and well-being of people in affected areas can have broad and poorly defined economic implications, including for domestic water supplies, health care and food security. The costs may be indirect and long-term, often affecting the region's potential for future economic development (Eamer et al. 2015, Tetreault 2015, Damigos 2006). When assessing these costs and liabilities and looking at responsibility and solutions, it is important to distinguish societal costs associated with current and recently active mines from those associated with the legacy of mining conducted in the past under very different conditions, both in terms of mining methods and regulation.

2.1.3 Economic Overview by Country

Figure 15. **Value of Mineral Production for North America and for Each Country (2013)**



Notes: Only commodities that make up at least 1 percent of continental or national mineral production are shown. The many additional minerals mined are grouped together as "other." Crushed rock is included in "stone." Cement is not reported as a separate commodity in Mexico. Currencies are standardized to 2013 $US. *Source:* Data from Government of Canada, (NRCAN 2016b), US Geological Survey (USGS 2014) and Servicio Geológico Méxicano (SGM 2014).

Continental overview

Mineral production is presented in figure 15 as individual commodities, with amounts and dollar values based on the content of each chemical element (such as gold) or marketable mineral product (such as gravel). These commodities, however, are produced by mines in various combinations and in various chemical forms. Most metals occur in nature in several chemical compounds, many in combination with oxygen (as oxides) or sulfur (as sulfides). Mineral deposits often contain more than one metal in economic concentrations. For example, zinc mines often also produce lead, and some also may produce copper, silver, nickel or other metals.

Gold, copper and iron ore were the most economically important metals produced in North America in 2013 (figure 15a). Stone, sand and gravel, and cement were the most important non-metallic (industrial) minerals, and coal made up a quarter of the value of all mineral production. The dominance of coal was primarily due to its importance in U.S. mining (figure 15c), though it also accounted for 11 percent of Canadian mine production (figure 15b). Industrial minerals mainly used for construction, including for building and maintaining infrastructure, made up about a quarter of U.S. production, but only about an eighth of production for Canada and for Mexico.

Metals, especially gold, silver and copper, dominated mineral production in Mexico (figure 15d). Silver, which made up 1 percent or less of Canadian and U.S. production, was second only to gold in Mexico in total value. Metals formed over half the value of mine production in Canada, but with a more diverse industry: 8 metals each made up from 1 to 14 percent of production (figure 15b) and an additional 14 metals, including cobalt, molybdenum, lead and tungsten, made up the rest of 2013 production (NRCan 2016b). Two non-metallic minerals that are very different from one another, potash and diamonds, formed significant portions of mine production for Canada, but not for Mexico or the United States (figure 15b,c,d).

What figure 15 does not show is the wide range of metals and non-metal minerals produced by all three countries. As an example, the 31 commodities lumped as "other" in the non-metallic minerals industry group for Mexico, accounting for 6 percent of total production, include fluorspar, salt, phosphate rock, sodium sulfate, kaolin, bentonite, diatomite, magnesite, wollastonite, celestite, graphite, perlite and vermiculite (SGM 2014). Some of these commodities, while making up a low percentage of total Mexican mine production, are important exports.

Some metals that are important components in electronics are mined in North America, notably platinum group metals, which were mined in Canada in 2013 (forming 2 percent of total mine production value) and, in smaller quantities, in the United States. There was very little production of rare earth metals—one metal in this category was produced by one mine in the United States. Most rare earth metals are mined in China.

Canada

Economic overview. In 2014, mining made up 1.5 percent of Canada's GDP. Adding in related mineral processing and metals manufacturing raises the contribution that year to 3.5 percent. There were 77 facilities related to metal mining operating in 2014 and 1,132 non-metallic mineral facilities, the majority of which were sand, gravel and stone quarries. Mineral extraction employed 63,590 people, with an additional 312,410 people working in processing and related metals manufacturing (Marshall 2015).

Trade. Exports of domestically produced raw mineral products (including coal) were valued at C$26.1 billion in 2015, while imports were valued at $7.9 billion. When processed mineral materials and fabricated metal products are added in, total exports for the year, at $96.2 billion, exceeded imports by $16.2 billion. Canada's main trade partners for these mining-related products are the United States and the European Union, accounting for 56 percent and 20 percent of the 2015 export value, respectively (NRCan 2016d). Mineral materials, products and fabricated metals accounted for 18 percent of Canada's total export value in 2015 (Statistics Canada 2016a).

Globally significant commodities. Canada is the world leader in production of potash and among the top five producers for an additional 13 commodities: uranium, niobium, cobalt, aluminum, tungsten, platinum group metals, nickel, salt, sulfur, titanium, diamonds, cadmium and gold (based on 2014 data; Marshall 2015).

Investment trends. Proven and probable reserves of most base metals have declined over the past 30 years, while gold, silver and copper reserves have fluctuated, partly driven by exploration spurred on by high prices. Canada is a top destination for exploration investment from other countries, including China and European nations, but both the dollar value of investment and the country's share in global mineral exploration investment have declined since about 2013. In 2015, direct foreign investment in the mining industry was C$10.4 billion, 50 percent less than the previous year (Statistics Canada 2016b).

In 2014, there were 1,573 companies with headquarters in Canada that owned mining assets (NRCan 2016c). Many of these were small companies engaged in exploration and development. Relatively few were producing mines—only 10 percent had operating revenues that year. Half of these companies held interests outside Canada, with 37 percent holding mining assets in at least two countries (NRCan 2016c). Canadian mining and exploration companies accounted for 30 percent of 2014 global investment in exploration for metals (excluding iron) and Canadian annual direct investment in mining abroad averaged C$69.5 billion from 2012 to 2015 (Marshall 2015).

Production trends. Trends in annual value of production of the three mining industry groups (figure 16) show the influence of commodity prices (figure 11). The production of most metal commodities increased from 2004 to 2014, but by much less than the increase in value (figure 17). Production of coal and main non-metallic minerals either declined or changed little over this period. Increases in value for these minerals reflect trends in price, not in production.

Figure 16. **Trend in Annual Value of Canadian Mineral Production,** 1999–2014

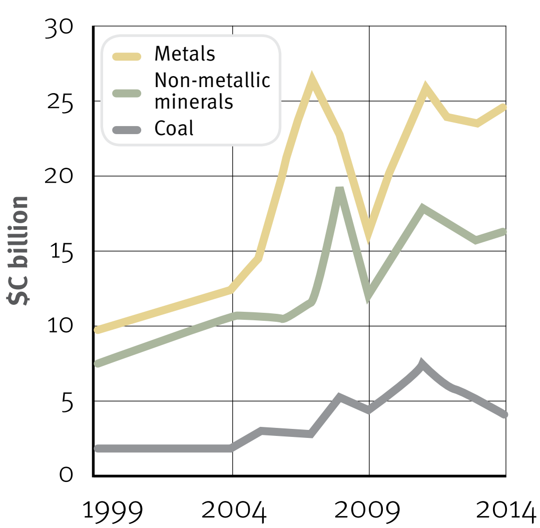
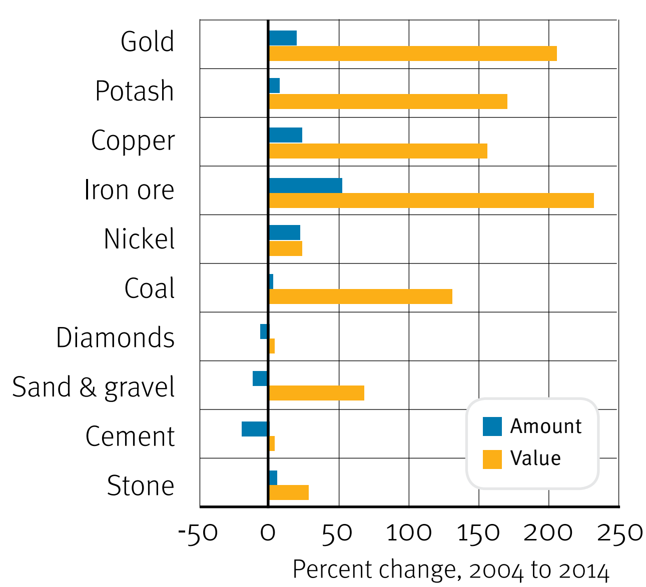


Figure 17. **Percent Change from 2004 to 2014 in Amount and Value of Production of Top 10 Mineral Commodities for Canada**



Source: Based on Canadian Government data compiled in Marshall (2015).

Mexico

Economic overview. The mining sector (including processing) represented 5.5 percent of GDP in 2015 and employed about 345,000 people (ProMéxico 2016). Precious metals make up the largest share of the industry, by value, but a wide range of commodities is produced. These official figures do not include unregulated mining that forms part of the informal economy, in particular, artisanal and small scale mining for gold and mercury (see section on types of mining, below).

Trade. Mineral exports (mainly metals) are an important source of foreign currency for Mexico. The trade surplus in 2013 was US$10.35 billion, with the most important destinations for exports being the United States, Canada and Spain (Perez 2016).

Globally significant commodities. Mexico leads in silver production, accounting for 19 percent of the world's silver production in 2013. Mexico is among the top five producers of fluorspar, bismuth, wollastonite, cadmium, lead and molybdenum (Perez 2016).

Investment. A few large domestic companies produce 60 percent of mineral output, but foreign investment is important for the remaining 40 percent of production (Brasdefer et al. 2016). In 2015, 267 mining companies operated in Mexico with foreign capital (ProMéxico 2016). Of these companies, 65 percent are based in Canada, 16 percent in the United States and 5 percent in China. Over one-third of projects undertaken with foreign capital were at the exploration stage in 2015. The majority (64 percent) of projects with foreign capital are gold and silver prospects (ProMéxico 2016). As elsewhere, Mexico has experienced a decline in mining investment in recent years (MMR 2016).

Production trends. The combined value of metals production increased more than 400 percent from 2005 to 2013, with the value of gold and silver production increasing by 1,500 and 800 percent respectively (figures 18 and 19). The value of non-metallic minerals and coal also rose over this period, but by much less. Copper production volume changed little, but the value increased by 200 percent. The opposite is true for coal, where lower prices were offset by increased production (figure 19).

Figure 18. **Trend in Annual Value of Mexican Mineral Production,** 2005–2013

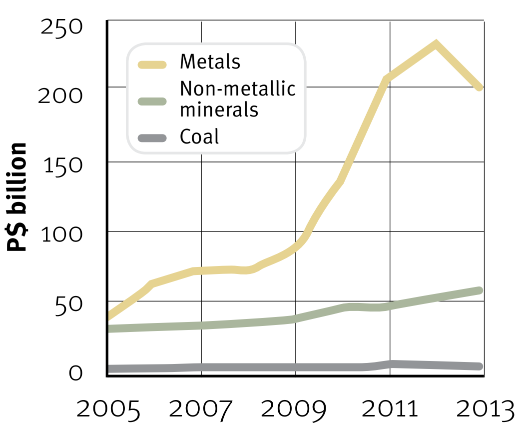
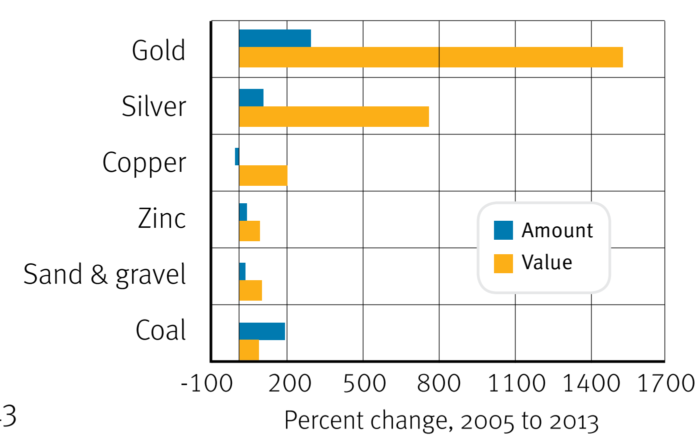


Figure 19. **Percent Change from 2005 to 2013 in Amount and Value of Production of Selected Mineral Commodities for Mexico**



Source: Data from Mexican mining statistical yearbooks (SGM 2014, Secretaría de Economía 2010).

United States

Economic overview. The role of mining and minerals in the U.S. economy, from extraction to industrial use, is summarized in figure 14. Value added by the mining industry to U.S. GDP, which ranges from 0.3 to 0.5 percent, has increased since the mid-2000s despite reductions in production of most main mineral products. The industry employed an average of 199,000 people during 2015 (BLS 2016). Employment numbers fluctuate but have generally declined since the early 2000s, especially in the coal mining industry, due to increased mechanization coupled with decreased production.

Trade. In 2015, the United States imported over half of the raw mineral products consumed and was a net exporter of 19 mineral commodities (excluding coal). Overall, the U.S. nonfuel mineral trade had a relatively small net export value of $3 billion that year (USGS 2016).

Globally significant commodities. In 2013, the United States was among the top five producing countries for several metals, including gold, molybdenum, lead, copper and zinc. U.S. coal production ranked among the top three countries for all types of coal. The United States was among the top three producers for several non-metallic minerals, including phosphate rock, salt, sulfur, kaolin, boron, bentonite and gypsum (Reichl et al. 2016).

Investment trends. In 2012, over 14,000 operations mined coal, metals and non-metallic minerals in the United States (NMA 2014). Annual investment in mining and exploration (including coal and natural gas, because the data are combined in the investment statistics) fluctuated from over $US60 billion to over $120 billion from 1999 to 2015, with a decline of 35 percent from 2014 to 2015, influenced by lower commodity prices (U.S. EIA 2016b). Cumulative foreign direct investment in the U.S. mining sector (not including oil and gas) was $105 billion in 2015, about the same value as in 2010 (Organization for International Investment 2016). This is in contrast with an increase in cumulative foreign direct investment in most U.S. sectors over the same period.

Production trends. The value of production for all three mineral industry groups rose steadily starting in the early 2000s, but the groups show divergent trends in recent years (figure 20). In contrast with Canada and Mexico, mine production in the United States decreased for most commodities between 2004 and 2014, with the exception of iron ore production, which did not change significantly (figure 21).

Figure 20. **Trend in Annual Value of U.S. Mineral Production,** 2000–2014

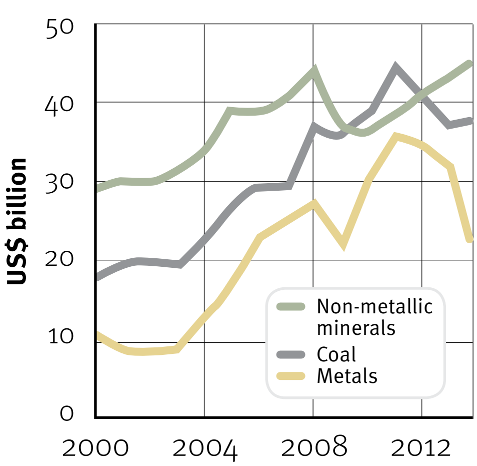
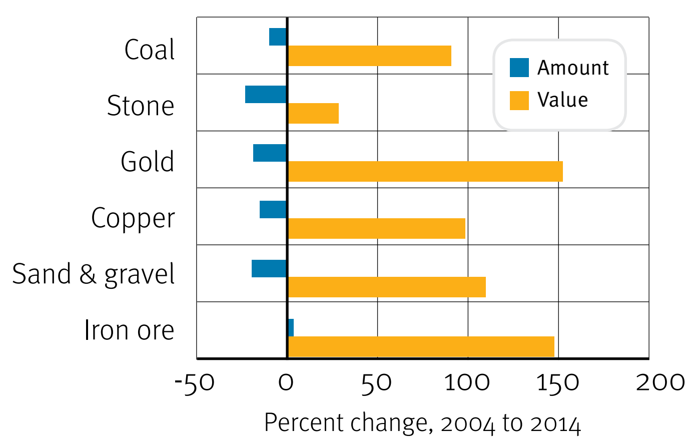


Figure 21. **Percent Change from 2004 to 2014 in Amount and Value of Production of Six Leading Mineral Commodities for the United States**



Source: Data from US Geological Survey Mineral commodity summaries (USGS 2016, USGS 2014, USGS 2005, USGS 2008a), Kelly and Matos (2016) and US Energy Information Administration (US EIA 2016a).

2.2 Processes and Technologies

> **Ore**: Material that can be processed to recover mineral commodities for economic or strategic gain (Eckstrand et al. 1996).
>
> **Tailings**: Ground rock and effluents produced by a mine processing plant and often transported by pipe to a tailings pond.
>
> **Waste rock**: Low-grade ore and other rock that has been excavated, but not processed, during mining.

2.2.1 Types of Mining and Processing Techniques

Most rock deposits contain metals or other minerals. When the concentration of valuable minerals is too low to economically justify mining, rock is considered a waste (or gangue material). Within an ore body, valuable minerals are surrounded by gangue. The primary function of mineral processing (or beneficiation) is to liberate and concentrate the minerals of value (Grewal 2016).

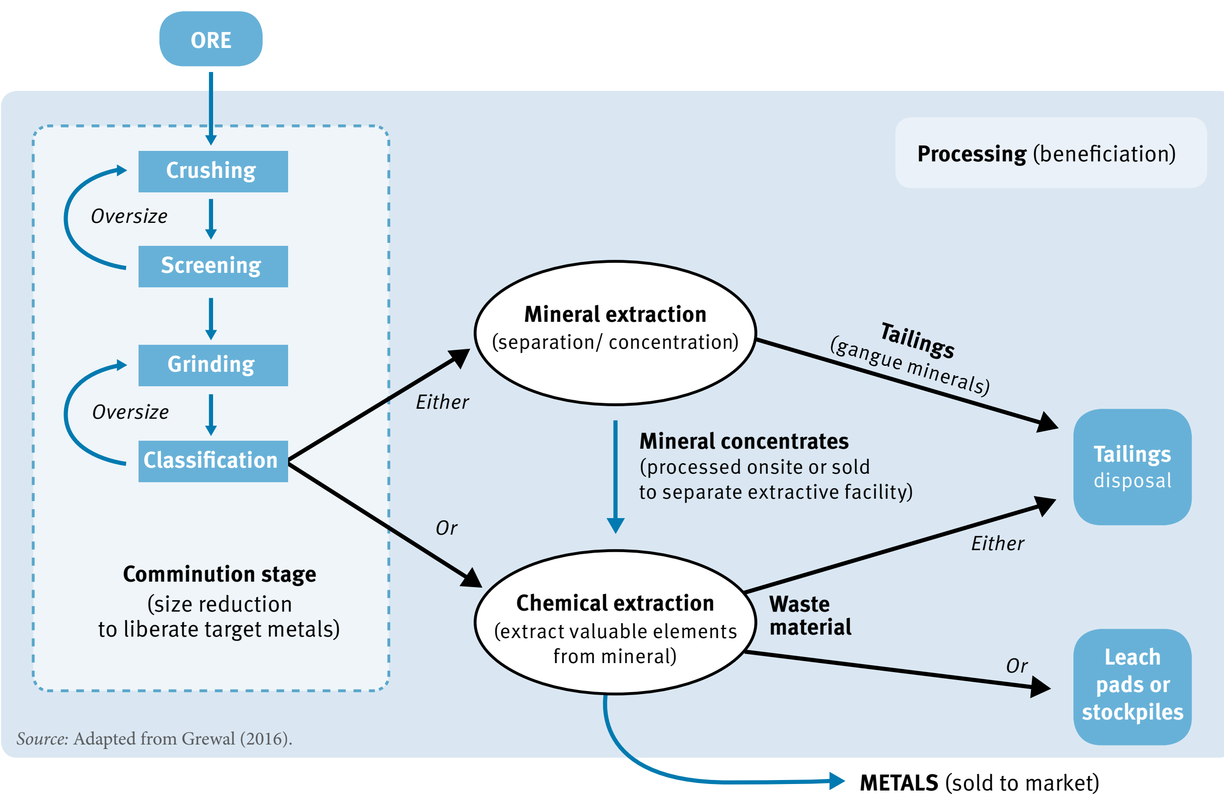
Metals

Processing metallic minerals from ore commonly involves several stages (figure 22) (modified from Grewal 2016):

Comminution—the separation of ore from gangue through crushing and grinding, reducing the size of the rock particles. This process partially or fully exposes valuable minerals within the ore for further extractive processing.

Classification or sizing. This is required for three purposes: to provide an optimum particle size distribution for mineral recovery techniques, to further reduce the size of larger particles, and to produce a product that meets particle size specifications for the market. Coarse materials are usually screened mechanically. Classification techniques, which rely on differential settling rates of different sized particles in fluids, are used for more finely divided materials.

Figure 22. Typical Metallic Mineral Ore Processing Flowsheet



Source: Adapted from Grewal (2016).

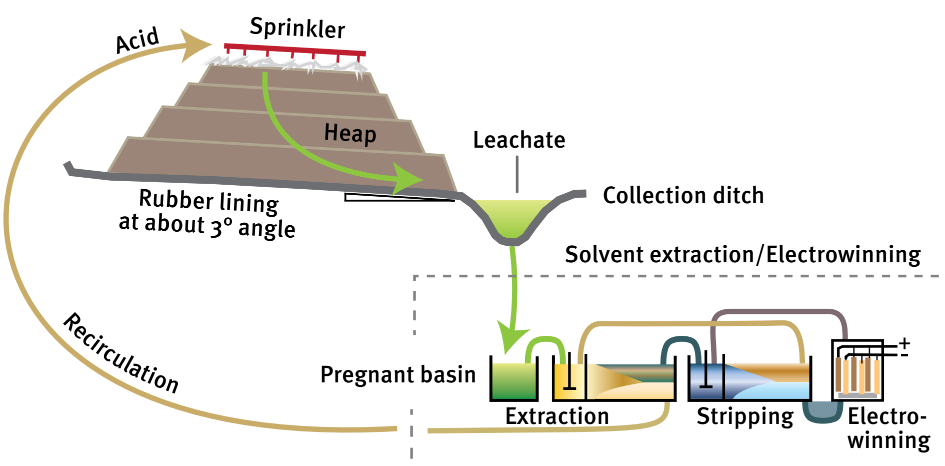
Separation and concentration. This stage occurs after the ore has gone through grinding, crushing, and classification into the required particle size distribution. The goal is to produce a mineral product (concentrate) that can be transported to market for further refinement, such as through smelting. There are several physical and chemical separation and concentration techniques. Froth flotation in a slurry medium, one of the most widely used, selectively separates minerals through air bubbling and addition of chemical reagents that affect the surface properties of the minerals.

An additional step in mineral processing is the dewatering of mineral concentrates and waste streams, which is critical to the management of water supply and pollutant releases. Dewatering includes decanting and recycling of water back to the mill for reuse as process water, as well as discharge of excess water to a tailings pond. Excess water can also be treated, if required, and released. Dewatering reduces the mine's water use through recycling and minimizes the volume of wastes that require treatment and disposal.

In all processing stages, the characteristics of the ore and of the targeted mineral(s) drive the selection of approaches and techniques to liberate economic minerals from ore.

Specific techniques have been developed for extracting metallic minerals from some types of ore, particularly for precious metals such as gold and silver. Heap leaching, a type of hydrometallurgy, for example, uses passive migration of a dilute leaching solvent such as cyanide through ore that has been crushed and stacked on a pad on top of an impermeable liner. Collection ditches carry the ore-bearing fluids to a "pregnant" basin where the metals are extracted from solution (figure 23). Heap leaching is particularly efficient for the processing of low-grade and large-tonnage ores, and recovery can exceed 90 percent of the total metals in the ore. Microbes can be used to extract metals in a similar manner (bioleaching).

Figure 23. Heap Leaching



Source: Adapted from an illustration by Anna Bauer (2007).

In tank and vat leaching, the ore is crushed and ground into a fine pulp or slurry, then put into large containers (tanks or vats) with a leaching solution to extract the precious metals. The efficiency of this process depends on retention times in the tanks or vats, the particle size of the crushed ore, the grade and the characteristics of the ore, the slurry density and the degree of agitation in the tank.

Placer gold (gold in sand and gravel deposits), tin and some other minerals are recovered using gravity separation techniques. Sluice boxes, trommels, jigs and other equipment are used with water to separate these heavy minerals from the less dense host rock.

Non-metallic minerals

In contrast to the metal mining industry, non-metallic (industrial) minerals are often marketed and used in the form in which they leave the beneficiation plant, without further processing or manufacturing. Their market value depends on the characteristics of the deposit and specifications of the final project, such as grade, moisture content and particle size (Kogel et al. 2006).

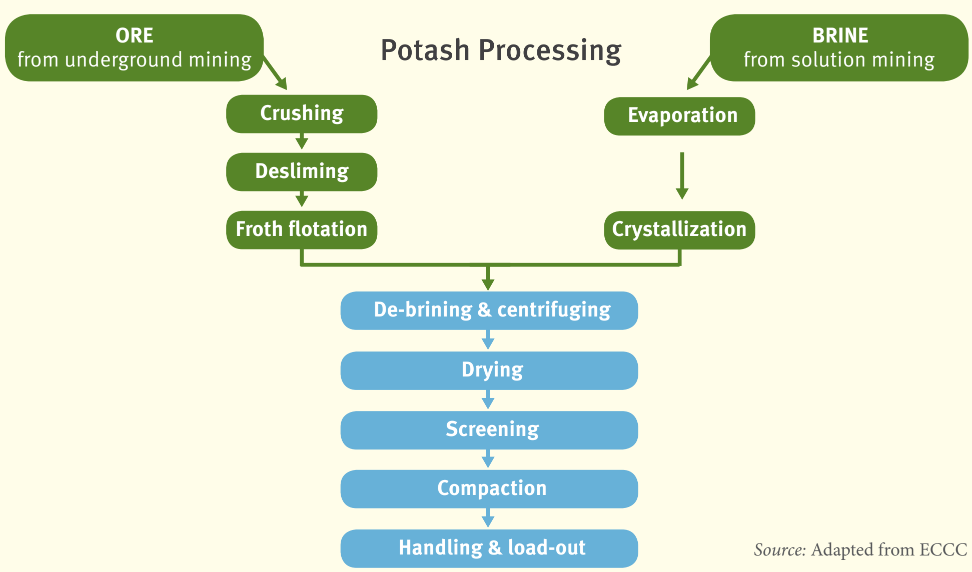
The same stages and many of the same techniques that are used to process metals may also be applied to non-metallic minerals. Industrial mineral processing almost always involves comminution, sizing and some form of packaging for shipment. In addition, washing and dewatering are often required. Commodity-specific processing techniques from the range of mechanical, chemical and other methods used in metal processing may also be employed (see the examples outlined in box 3).

Box 3. Industrial mineral processing examples: potash and phosphate rock

Potash (potassium salts) and phosphate rock are used mainly as fertilizers. Potash is an important commodity and export for Canada; the United States is a top producer of phosphate rock (figure 15).

Potash is mined either through conventional underground mining methods or (less frequently) by solution mining, in which brine is injected into the ore body and pumped back to the surface. The solution mining technique and much of potash processing (see figure below) takes advantage of the solubility of potash salts in heated brine. After crushing, desliming removes clay, sand and dolomite by scrubbing and/or flotation. Following further treatment and drying, screening separates the product into standard size ranges for marketing. Fine material is compacted into boards that are broken up to form granular potash.

Phosphate rock, which is usually extracted by surface mining, frequently needs processing to remove impurities and barren material. Clay is removed through crushing, grinding, scrubbing and washing with water. The fines may be screened out and deposited on land or separated with water and released to settling ponds. Flocculants are often added to the ponds to aid with settling. Depending on the characteristics of the ore, further processing may be required, such as froth flotation to remove sand or further scrubbing and magnetic separation to remove iron-bearing minerals.



Source: Adapted from ECCC (2016a).

Sources: Environment and Climate Change Canada (ECCC 2016a), Perucca (2003) and United Nations Environment Programme (UNEP) and International Fertilizer Industry Association (IFIA) (2001).

Coal

Coal is either shipped unprocessed or it is processed to different degrees, depending on the type and quality of the raw coal, the intended use of the coal, and other factors such as transportation costs and the availability of water (NAS 2007). In the United States, brown coal (see definition box) is rarely processed before shipment and use.

Coal processing may involve crushing, screening into size groups, gravity separation in water or another fluid medium, and washing (often using froth flotation) to remove non-organic waste rock ("ash"). The last stage is dewatering, which may include thermal drying using coal- or gas-fired burners (NAS 2007). The processed coal is then stockpiled for transport to market.

Types of coal

Anthracite (metallurgical coal): used in steel production

Bituminous coal: mainly used in power generation (thermal coal)

Brown coal (subbituminous and lignite, which is lower grade): produces fuel and steam for industry and is used in coal gasification and liquefaction

Coarse waste material is trucked to a solids disposal area and tailings are usually piped to a tailings pond. After the solids have settled out, the water in the tailings pond is recycled to the processing plant (NAS 2007).

2.2.2 Main Pollutants Associated with the Mining Sector

The mix of pollutants treated, stored and, in some cases, released from mines is site-specific, influenced by the geochemistry and physical properties of the ore body and the mining and beneficiation processes used to concentrate the minerals. The pathways that the pollutants follow and their effects on the environment depend on local conditions such as climate, topography, and rock, soil and water characteristics. The effects from releases of substances also depend on human use of the area and on what aquatic and terrestrial species are in the vicinity. Evaluating the risk associated with releases and transfers of substances can be complex and requires consideration of a number of factors (see chapter 3 and appendix 1—Using and Understanding *Taking Stock*). Nonetheless, pollutants or groups of pollutants with known environmental and health impacts tend to be associated with specific types of mining.

The general discussion below on releases of pollutants to air, land and water is augmented by examples of pollutants and pollution issues associated with certain mineral commodities produced by the mining sector. Note that the pathways of potential pollutant release discussed in this section are not limited to those that are reported through the North American PRTRs. This section looks more broadly at mine pollution from current and historical mining. Section 2.4 and chapter 3 distinguish the pollutant releases that are reported through each country's PRTR.

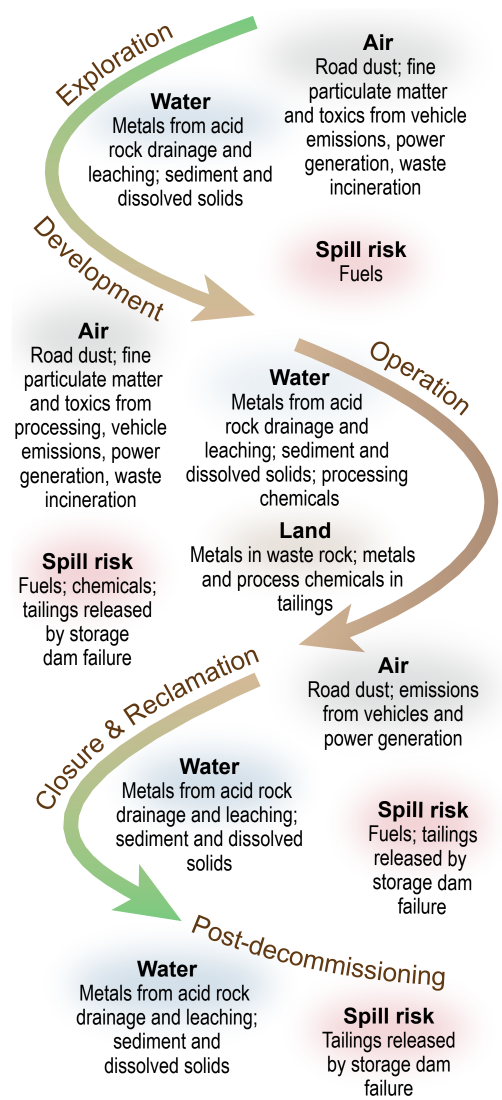
Pollutants may be released throughout the mining life cycle as emissions (to air), effluents (to water) or releases or deposits to land. Pollutants may leave the mine site from diffuse sources such as erosion or due to spills or equipment malfunctions (figure 24).

Dust and vehicle exhaust are released throughout a mine's life cycle, especially at quarrying operations and open-pit and surface mines. Dust and vehicle emissions may also be due to associated activities such as shipment of concentrate or transport of materials to the mine site along roads. Dust can be a health problem for humans and for wildlife and it can also harm vegetation and aquatic habitat when it settles. The mining industry manages dust through a variety of methods such as watering or covering potential dust sources.

During mine operations, beneficiation processes emit substances that can be harmful to humans or the environment, especially from drying stages that involve heat. These stack emissions may contain metals; gases such as sulfur dioxide, nitrogen oxides and volatile organic compounds; and fine particulate matter.

Pollutant releases to water and land are often interlinked. Releases to water from mining include effluent ("end-of-pipe" discharges) from mine workings and mineral processing, usually from a treatment facility or a settling or tailings pond. Releases also include water that has run over or percolated through disturbed land and waste rock that was deposited to land, perhaps many years previously. Water can transport pollutants downstream, with some settling into river and lake sediments (where

Figure 24. **Some Potential Pollutant Releases over a Mine's Life Cycle**



the pollutants may only be temporarily stored and later re-mobilized), some being taken up by aquatic plants and animals and transferred through food chains, and some entering groundwater and polluting aquifers. This process of moving pollutants from their sources on land into the aquatic environment can continue for a very long time after the mine has been decommissioned.

The severity and longevity of water pollution from mine sites is often related to the ore body type. Sulfur-bearing ore bodies, including some coal fields, are prone to acid rock generation—the formation of acidic water that leaches metals from rocks through oxidation. This is a natural process that is accelerated by exposing sulfur-rich rock to water and oxygen. When not properly treated, acid rock drainage (ARD) can carry metals into streams and contaminate water-bodies after mine closure. It is a problem particularly for abandoned mines and requires very expensive maintenance and rehabilitation that is generally borne by governments.

Waste rock and tailings are the main sources of pollutant disposals or releases to land. Waste rock is placed in piles or as backfill in open pits or underground workings. Tailings can be disposed of in ponds (the most common method), dewatered and disposed of as dry tailings, or thickened and used as backfill in underground mine workings. The water in tailings ponds that is not reused in processing evaporates and/or is discharged as effluent. The remaining solids accumulate in the pond, confined by a dam. Pollutants initially disposed of or released to land can later enter streams, lakes or the ocean through the seepage of surface water and shallow groundwater from waste rock piles and tailings facilities. Pollutants released to land can also later be spread to surrounding areas through windblown dust.

In addition to the planned and managed releases of regulated substances to air, water and land described above, pollutants may be released through malfunctions and spills. Solids or toxic liquids may be spilled, including concentrates, fuels and mine reagents. Malfunctions include equipment failure, causing leaks, releases of untreated effluent or emissions, and catastrophic malfunctions, such as the failure of a tailings pond dam.

Pollution associated with mining may also be a result of past mining practices or of commodities that were mined in the past. For example, asbestos, which is no longer mined in North America, remains an issue for health protection and waste disposal due to the widespread past use of asbestos in construction and consumer goods. Asbestos use is still permitted in North America—although it will be phased out in Canada by 2018. Mining of asbestos ceased in the United States in 2002 and the last two Canadian asbestos mines shut down in 2011 (USGS 2014, SSHRC). Asbestos has not been mined in Mexico.

Past mercury mining and past use of mercury in gold and silver mining continue to be sources of pollutant release to the environment. For example, the dispersal of mercury from tailings produced by past silver ore beneficiation plants in the town of Cedral, State of San Luis Potosí, Mexico, continues to be a concern for public health (Morton-Bermea et al. 2015). Mercury accumulation in lake and stream sediments in the western United States is strongly influenced by past and current mercury releases from mercury and gold mines that have not operated for many years. In some areas, mercury is elevated well downstream of past mining activity, such as in the Sacramento-San Joaquin River Estuary in California (Eagles-Smith et al. 2016).

Pollution may also be associated with ongoing mining that is not included in national mineral production and pollutant release statistics. In Mexico, artisanal and small-scale gold mining and “informal” mining of mercury constitute a health and safety risk and a source of environmental pollution (see box 4).

Some examples of pollutants associated with mining are presented in table 9.

Box 4. Artisanal and small-scale gold mining and informal mercury mining in Mexico

"Artisanal" refers to rudimentary methods used and "small-scale" to the size of the mining operation. Artisanal and small-scale gold mining (ASGM) operations generally operate outside the law and lack measures to protect health, safety and the environment (Seccatore et al. 2014). Artisanal and small scale mines of various types provide livelihood and income for poverty-affected populations in many countries in Africa, Asia, and Latin American and the Caribbean (The World Bank 2013). An estimated 16 million ASGM workers produce 379 to 449 t of gold annually through ASGM (Seccatore et al. 2014). This is about 17 to 20 percent of official global gold production. Production is particularly high in several South American countries: for example, an estimated 25 t produced annually by Bolivia, 40 t by Peru, and 41 to 51 t by Colombia.

Small-scale precious-metal artisanal mining in Mexico was historically for silver, but is now mainly for gold, with some operations also producing silver (González Sanchez and Camprubí 2010, Veiga 2016). It is not part of the formal economy and its production value is not included in national statistics. The miners commonly work long days to acquire ore, grind it, and extract the gold through amalgamation (bonding gold to mercury). Gold is sold below the market value and the miners are vulnerable to exploitation, as well as to health and safety risks, in this unregulated industry (González Sanchez and Camprubí 2010).

Mercury is also mined "informally" in Mexico, and this practice has increased in recent years to supply ASGM operations in Latin America. Mercury, because it readily forms an amalgam with gold and silver, has been used for thousands of years to separate precious metals from ore. Recognition of the toxicity of mercury to human and environmental health led to a switch to other processing substances in large-scale gold mining—primarily cyanide. ASGM in Mexico and elsewhere, however, continues to rely on mercury amalgamation as it is easy and cheap (Sippl and Selin 2012). This practice is a health and safety risk to the miners, as heating the amalgam vaporizes about one-third of the mercury and the fumes are highly toxic (Pirrone and Mason 2009). The vaporized mercury also becomes a broader health and environmental risk because it disperses through the atmosphere. The remainder of the mercury used by ASGM operations is discharged to water where it may enter aquatic food webs or enter the atmosphere through volatilization (Pirrone and Mason 2009).

Mining for mercury as a primary commodity ceased in 1994 in Mexico, but production of mercury continued after that date through processing of tailings from old silver mines that had used mercury amalgamation (CEC 2013). Demand for mercury has increased recently due to the rise in ASGM in some Latin American and Caribbean countries, and Mexico has become the region's main supplier of mercury (Camacho et al. 2016, Santana et al. 2014). Increased demand has led to an estimated ten-fold increase in the informal production of mercury in the past two years (Camacho et al. 2016) and an increase in mercury export from 1 or 2 t annually in the early 2000s to over 300 t in each of 2014 and 2015 (Secretaría de Economía 2016). Mexico has become the world's leading exporter of mercury (UN 2016). Between 20 and 50 t of mercury are recovered annually from old silver mine tailings and there are an estimated 300 to 400 artisanal mercury mining operations, the largest being in the Sierra Gorda in Querétaro (Jiménez 2016 pers. comm.).

Concerns about health risks to miners and communities from informal mercury mining operations led to a recent study in a mercury mining region in the State of Querétaro (Camacho et al. 2016). The study found elevated mercury in soils and creek sediments. Miners and women and children in the nearby community (groups identified as being most vulnerable) have high levels of exposure to this toxic metal, based on results of urine sampling (Camacho et al. 2016).

ASGM and associated adverse effects of mercury use are addressed through the Minamata Convention on Mercury (2013), which commits signatories to ban new mercury mines, phase out existing mines, phase out or reduce mercury usage, restrict mercury export, control environmental releases, and take measures aimed at eliminating mercury use in ASGM (UNEP 2016). National and international initiatives are also underway to improve the economic opportunities and health of ASGM miners, their families and communities (Artisanal Gold Council 2016). An important focus of these initiatives is replacement of mercury amalgamation with safer, affordable gold processing technology (UNEP 2012, Veiga et al. 2014).

Table 9. **Examples of Pollutant Releases Typically Associated with Production of Some North American Mineral Commodities**

Commodity	Examples of Pollutant Releases	References
Copper, silver, zinc and lead	**Acid rock drainage (ARD)**. Ore bodies bearing these minerals are often rich in iron sulfide (pyrite) or other sulfide minerals. If the rock comes into contact with oxygen and water, sulfuric acid may be produced. The acidic (low pH) water drains through waste rock and tailings, dissolving metals. The metal-laden water flows into streams or seeps into surface and groundwater. The acidity may become neutralized when the water runs through rocks and soils, which causes some of the metals to precipitate out into sediments. Even at high pH levels, however, significant amounts of some metals may remain dissolved. Metals occur naturally in water, but at elevated levels are toxic to aquatic organisms and often render the water downstream of the mine unsuitable for other uses. If not properly managed, ARD can become a long-term pollution problem when mining any mineral deposit containing sulfide rock. This includes some coal deposits.	(Hudson et al. 1999) (USGS 2008b)
Gold	**Mercury** was often used in the past in gold recovery. This practice is now banned due to health and environmental concerns, although mercury is still used in artisanal gold mines in Mexico (box 4). Mercury is often a component of gold-bearing ore and can still be a significant pollutant in emissions from gold ore processing facilities. Mercury vapor is transported through air, deposited to water and builds up as methylmercury in fish. The consumption of fish is the main route of exposure of humans to this persistent, bioaccumulative and toxic pollutant. **Arsenic** is widely distributed in the natural environment and is commonly found in gold deposits. It occurs in various chemical forms, often associated with sulfide ores that are prone to ARD, which dissolves arsenic along with metals from rocks. Arsenic can also be elevated in high-pH water discharges from gold beneficiation processes that use cyanide. Arsenic at elevated concentrations is toxic to aquatic organisms and limits the use of downstream waters. **Cyanide,** a chemical compound of carbon and nitrogen, is used in gold and silver extraction, especially for gold leaching. It is most commonly a constituent of effluent (released to water) and its greatest threat is to aquatic life. Cyanide in water is converted naturally to non-toxic substances, first oxidizing into the less toxic cyanate, and then breaking down into ammonia and carbon dioxide.	(US EPA 2011, SME 2014, Straskraba and Moran 1990)
Iron ore	**Toxic air pollutants** are emitted mainly from the furnaces that harden and oxidize the iron ore, producing the pellets used to make steel. Toxic compounds in the emissions may contain manganese, chromium, cobalt, arsenic, mercury and lead. Because levels of particulate matter closely track the levels of these air toxics, mitigation and regulation efforts focus on minimizing particulate matter in furnace emissions. Pellets are produced at some iron ore mines only—some mines ship the ore following concentrate production. Air emissions for all iron ore mines typically include fine particulates released as dust from mining and related activities.	(US EPA 2003, Berndt 2003, Hanchar and Kerr 2012)
Potash	**Fine airborne particulates.** PM_{10} and $PM_{2.5}$ (particulate matter with a diameter less than 10 microns and 2.5 microns, respectively) present a health hazard, have adverse effects on vegetation and contribute to haze. Fine particulates are common pollutants from potash production. Drying and compacting activities are the source of 80 percent of sector particulate emissions. **Salts and fines**. Waste streams from potash mines include tailings laden with salt and smaller amounts of other minerals, slurry brines containing sodium chloride or magnesium chloride, and slimes consisting of fine clay and dolomite.	(ECCC 2016a, UNEP and IFIA 2001) (ECCC 2017)
Uranium	**Metals, arsenic and radionuclides.** Sediments in Canadian lakes located adjacent to conventional uranium mines have higher levels of uranium, arsenic, molybdenum and selenium compared with lakes further from the mines. Potential pathways for the spread of these pollutants from mine sites are through air (windblown tailings and mill dust), and through water (surface runoff or groundwater flow) if facilities are not properly managed. Most US uranium mines do not have mills and tailings, as they use groundwater and chemical additives to dissolve uranium from the ore body (in situ leaching). With this type of mining, the main risk is that groundwater in aquifers surrounding or down-gradient of the targeted ore body could become contaminated with leaching solutions, uranium and its decay products, metals, arsenic, or other ions such as sulfates. For this reason, uranium mining is not permitted in aquifers that are currently or could become sources of drinking water.	(Saunders et al. 2016, Laird et al. 2014)
Sand, gravel and rock	**Air contaminants**. The main pollutants associated with these operations are stack emissions of particulates and other air contaminants, fugitive dust and vehicle emissions. As with other types of mining, environmental issues associated with quarries are broader than just pollution. Issues include land-use conflicts—sand and gravel deposits, especially, often occur in areas that are favorable for other lands uses. Other impacts that are only partly pollutant-related include esthetic changes to landscape, loss of land and water habitat, erosion, sediment addition to streams, noise and dust.	(Kogel et al. 2006, Blodgett 2004)
Coal	**Ionic content of water**. In Appalachian coalfields in the United States, pyrite coal minerals dissolve and generate sulfuric acid, increasing sulfate concentrations and other ions such as bicarbonate, chloride, magnesium, sodium and calcium. This increase in dissolved solids is linked to impacts on stream life. The conductivity (a measure of the ionic content) of the effluent and the receiving waters is used to set targets and thresholds for pollution mitigation and regulation. Western Canadian Rocky Mountain coal mining areas have naturally hard water with higher background conductivity than in Appalachian coalfields, but conductivity and sulfate levels are also elevated through coal mining. Water chemistry conditions promote streambed calcite accumulation (calcium carbonate precipitation), which increases when water passes through waste rock areas and picks up more dissolved calcite. This can lead to concretion of stream channels, which degrades or destroys habitat. **Selenium**. Coal deposits in some regions have high levels of selenium. This metal, which is released in effluents and runoff from mine sites, has toxic effects on fish and aquatic invertebrates.	(Kuchapski and Rasmussen 2015, Clements and Kotalik 2016, Cormier et al. 2013)

2.3 Mining Laws and Regulations

North American regulatory systems for mining reflect each country's federal government structures, with mining being regulated at federal and state, provincial and territorial levels. Municipal regulations and regulations based on Indigenous land and governance regimes are also relevant in some areas and for some types of mining. The regulatory regimes are complex and this section provides only a broad overview. The focus is on regulation in relation to pollutants released and transferred from mining activity.

2.3.1 Canada

Mineral resources management in Canada is a shared responsibility between federal, provincial/territorial and Aboriginal governments. Most land in Canada is government-owned and rights to subsurface minerals, even on private land, are generally reserved by government (either federal or provincial/territorial). Allocation and management of mining claims and leases falls under provincial and territorial authority. The federal government has jurisdiction over some areas that can be affected by mining, such as fisheries, migratory birds and transboundary waters. The environment, however, is a shared jurisdiction without clear boundaries. The federal government's regulatory framework plays a strong role in mining. Main federal laws that are relevant to pollutant releases and transfers from mining activities are summarized in table 10.

Table 10. **Key Federal Laws Regulating Pollution from the Canadian Mining Sector**

Canadian Environmental Assessment Act (CEAA)	Provides for the assessment and mitigation of environmental effects of a project.
Canadian Environmental Protection Act (CEPA)	Addresses pollution prevention and the protection of the environment and human health. Also regulates the use and disposal of toxic substances.
Fisheries Act	Contains provisions to prevent deposit of deleterious substances in waters frequented by fish. The Metal Mining Effluent Regulations under this Act establish criteria for effluent discharges and standards for monitoring environmental effects.
Transportation of Dangerous Goods Act	Sets requirements for handling and transporting hazardous substances, including explosives, toxic substances and gases.
Nuclear Safety and Control Act	Governs all aspects of uranium mining, including environmental effects.

Sources: MAC (2016a); Baldwin and Fipke (2010); Canadian Nuclear Safety Commission (2014).

Permitting and oversight of mining is the responsibility of federal and provincial or territorial governments, as well as Aboriginal governments, where there are settled land claims and self-government agreements. Some examples of areas for which regulatory permits, licenses and authorities are required for mining are:

- water use and water discharge;
- land use;
- protection of aquatic and fisheries resources;
- protection of wildlife and terrestrial resources;
- protection of cultural and heritage resources;
- closure and reclamation planning (including security assessment);
- protection of species at risk;
- transport, handling and storage of dangerous goods and use of explosives; and
- storage and management of mine waste.

Provincial and territorial governments, and some Aboriginal governments, have their own regulatory processes for many of the above areas. In addition, provincial and territorial governments are largely responsible for the roads and other infrastructure associated with most mine development projects.

Uranium production is regulated by an independent nuclear regulator, the Canadian Nuclear Safety Commission, in accordance with the Nuclear Safety and Control Act. The Commission approves and regulates all stages and aspects of uranium production, including environmental assessment, pollution control and decommissioning (NRCan 2014, Canadian Nuclear Safety Commission 2014). Uranium mines are also subject to the Metal Mining Effluent Regulations under the Fisheries Act.

Environmental impact assessments, or EIAs (expanded to include socio-economic impact assessments in some jurisdictions), consider mining projects in terms of terrestrial, aquatic, socio-economic and cultural settings. Environmental effects, mitigation measures, cumulative and residual effects (potential effects remaining after mitigation) are assessed through a process that includes public consultation. Management, mitigation and monitoring plans, plans for preventing and responding to accidents and malfunctions, and closure and reclamation plans must be developed before the project is approved.

Each province and territory has its own approach to conducting environmental assessments. The federal act (CEAA) applies in partnership with provincial assessment processes. Depending on the jurisdiction and the scale of the project, proposed mines may be required to undergo an assessment through both provincial and federal systems. In northern Canada (Yukon, Northwest Territories and Nunavut) assessment processes have been established through land claims agreements and are overseen by appointed boards (see box 5). A completed EIA does not allow a mining project to proceed to construction, but provides a basis for regulatory approvals for both federal and provincial or territorial governments.

Box 5. Yukon Environmental and Socio-Economic Assessment: An example of an environmental assessment process established through a Canadian land claims agreement

Environmental and socio-economic assessment of mining projects proposed for the Yukon are governed by the federal Yukon Environmental and Socio-Economic Assessment Act (YESAA) of 2003, a requirement of the Yukon First Nations land claim settlement agreements. YESAA sets out the terms and processes for project assessment and provides for the establishment of an independent board (including board members nominated by First Nations) to conduct assessments and make decisions on project approvals. Assessments under YESAA must consider projects' potential effects on Yukon Aboriginal persons' rights under the land claim agreements, their special relationship with the wilderness environment, and their cultures, traditions, health and lifestyles.

Source: (YESAB 2016).

2.3.2 Mexico

Mexican government ownership of mineral commodities is enshrined in the country's constitution and the mining industry falls under federal jurisdiction. The Ministry of Economy (*Secretaría de Economía*) oversees Mexico's mining laws and regulations, and grants concessions and titles. The Mining Law (*Ley Minera*), which governs the exploration, production and processing of mineral resources through concessions, allows 100 percent private ownership of capital stock for mineral exploration and production of all minerals (excluding oil and radioactive materials). Exploration concessions are granted for 6 years and cannot be renewed, while production concessions are granted for 50 years, renewable for another 50 years. Foreign ownership of equity in mining companies is permitted. Changes were introduced to mineral sector taxation, fees and regulatory regimes in 2014 to streamline administration and as part of a comprehensive tax reform.

Mexican federal law provides the framework for regulation of mining-related pollution through laws, regulations and enforceable official standards (*Normas Oficiales Mexicanas*—NOMs). The main environmental legislation is the Law of Ecological Balance and Environmental Protection (LGEEPA), which comes under the authority of the Ministry of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*—Semarnat). Environmental authorizations issued by Semarnat include mine operating permits, permits for water discharge and permits related to disposal of waste rock and tailings. Mexico's main federal laws that are relevant to the control of pollution from mining are presented in table 11.

Table 11. **Key Federal Laws Regulating Pollution from the Mexican Mining Sector**

Mining Law (*Ley minera*)	This law authorizes mining concessions and activities (exploration, extraction and beneficiation). The regulation of this law requires that these activities comply with all federal and state environmental regulations, including requirements for environmental impact assessments.
General Law of Ecological Balance and Environmental Protection (*Ley General del Equilibrio Ecológico y la Protección al Ambiente* – LGEEPA)	The primary environmental law, LGEEPA, sets out policies and overall legislation for environmental regulation. The law also lays out the division of responsibilities among federal, state and municipal governments.
General Law on the Prevention and Comprehensive Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*)	Regulations under the law cover waste characterization and management, including hazardous waste and other wastes requiring special management. The law also covers remediation of contaminated sites and establishment of liabilities and responsibilities for remediation.
National Waters Law (*Ley de Aguas Nacionales*)	Regulates water use and preservation of water quantity and quality. Constitutional reform in 2012 mandated development of a new National Water Law and a new law, developed through citizen consultation, has been proposed.

Sources: (Mendoza and Jiménez 2016, *Secretaría de Economía* 2013).

In addition to the laws presented in the above table, specific activities undertaken by the mining sector in Mexico must comply with the standards (NOMs) listed in box 6.

Box 6. Official Mexican Standards (NOMs) related to the mining sector

NOM-120-Semarnat-2011. Establishes measures for environmental protection relative to mineral exploration activities in agricultural, livestock and uncultivated zones; dry and temperate climatic zones with xerophytic bush vegetation; tropical deciduous forests; and coniferous or oak forests.

NOM 141-Semarnat-2003. Establishes procedures for characterizing mine tailings, as well as specifications and criteria for site preparation, construction, operation and post-operation of mine tailings dams.

NOM 147-Semarnat/SSAI-2004. Establishes criteria for determining the concentrations for remediation of soils contaminated by arsenic, barium, berillium, cadmio, hexavalent chromium, mercury, nickel, silver, lead, selenium, thallium and vanadium.

NOM 155-Semarnat-2007. Establishes environmental protection requirements of mineral leaching systems for gold and silver mining.

NOM 157-Semarnat-2009. Establishes criteria and procedures for implementing management plans for mine waste.

NOM 159-Semarnat-2011. Establishes environmental protection requirements of mineral leaching systems for copper mining.

Source: (*Secretaría de Economía* 2013).

Water use allocation for most mining activity is also under national authority, as the federal government has jurisdiction over waters that cross state boundaries or international borders, as well as other water bodies that are considered national property. Water concessions are granted through the National Water Commission (*Comisión Nacional del Agua*—Conagua), which holds responsibility for management and safekeeping of national water bodies.

State governments are empowered to prepare and enforce policies to protect the environment from pollutant releases. States have authority over the fate of special management wastes, or wastes generated during production processes and not defined as hazardous (Basurto and Soza 2007).

A requirement for submission of Environmental Impact Statements (EIS) for mines and beneficiation plants was introduced in 1996. The statements must be approved by Semarnat before licenses and permits are issued. The EIS for a new mine requires the identification of potential hazards from mining wastes and plans for waste management and disposal sites. The proponent must demonstrate that mining facilities will be designed, constructed and operated in accordance with environmental standards and specifications to protect groundwater, surface water and other aspects of the environment.

2.3.3 United States

Mining in the United States is managed through a comprehensive regulatory system that is based on a framework of federal and state laws. The regulatory regime applicable to any one mine depends on whether the mine is on federal, state, tribal or private land (or a combination). Mineral rights in the United States are either associated with surface land ownership (mainly in the eastern states) or are retained by the federal government (mainly in the western states).

Hardrock mining operations must comply with federal environmental laws and they must obtain approvals from the appropriate federal and state agencies. The permitting process is intended to ensure that operations are fully protective of public health and safety, the environment, and wildlife. The applicant must demonstrate that it will comply with design and operational requirements that minimize the risk of significant spills or other releases that could adversely impact the environment, and that it will undertake post-mining reclamation activities.

Several laws authorize and govern mining on public lands, including the General Mining Act of 1872 and the Federal Coal Leasing Amendment Act of 1976 (U.S. Fish and Wildlife Service 2013). Federal land is managed by two agencies: 1) the Bureau of Land Management (BLM), which derives its authority from the Federal Land Policy and Management Act; and 2) the Forest Service, which derives its authority from the Organic Act and the National Forest Management Act. The National Environmental Policy Act (NEPA) defines processes for evaluating major federal actions that significantly affect the environment, including the permitting of new mine development on Federal lands by BLM and the Forest Service. Other U.S. federal government authorities that have responsibilities for the approval and permitting of mining projects include the Army Corps of Engineers, the Department of Interior's Office of Surface Mining, The Nuclear Regulatory Commission and the Environmental Protection Agency (EPA).

Examples of major laws that authorize environmental regulation of U.S. mining operations are summarized in table 12.

Regulations to protect against impacts from uranium processing are under the Atomic Energy Act and the Uranium Mill Tailings Radiation Control Act. The EPA, the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE) all have defined roles through these regulations. Conventional uranium extraction by underground and open pit mining is regulated by the BLM or Forest Service and/or the states, depending on land status. In situ mining, now the most common uranium recovery method in the United States (see table 9), is regulated by the NRC as it is considered to be primarily processing, rather than mining, because the ore is chemically altered during the extraction process (U.S. Nuclear Regulatory Commission 2016). However, BLM, the Forest Service and states consider in situ uranium recovery to be mining, so in situ uranium operations are also governed by those regulatory authorities, as well.

Table 12. **Key Federal Laws Regulating Pollution from the United States Mining Sector**

National Environmental Policy Act	Ensures that environmental considerations are brought into federal decisions, including federal approvals of mining operations.
Clean Air Act	Regulates specific types of air emissions from mining through air permits.
Clean Water Act	Regulates the discharge of pollutants, including mining discharges, pumping or draining of groundwater to the surface, and control of seepage and runoff through permitting.
Resource Conservation and Recovery Act	Regulates the release of hazardous wastes. However, most high volume, low toxicity mine wastes are exempt from regulation under the act. When regulations were first developed in 1978, all mining wastes were categorized as "special waste," subject to further study and not included as hazardous wastes. Regulation changes since then have replaced the overall exclusion with a list of specific mining waste types that are excluded from federal hazardous waste regulations.
Toxic Substances Control Act	Requires the EPA to prioritize existing chemicals for risk evaluation and conduct evaluations of high-priority chemicals. When unreasonable risks are identified, the act requires the EPA to take risk management action, which could include conditions on use, phase-outs, or bans of the toxic substances.
Comprehensive Environmental Response, Compensation, and Liability Act	Enables the government to clean up (and hold responsible parties liable for the costs of) unremediated sites, including closed mines, that release hazardous substances.
Surface Mining Control and Reclamation Act	Establishes a national program for permitting surface coal mining operations and regulating the surface impacts of surface and underground coal mining. The act establishes federal performance standards for permitting and reclamation, which are met or exceeded by approved state programs.

Source: American Geosciences Institute (2016) and US EPA (2016c).

Numerous state laws govern the permitting and regulation of mine projects in relation to reclamation requirements, water pollution, groundwater quality, water rights, wetland protection, and others. Mining regulatory regimes vary from state to state and by land type. Mining regulations in the state of Nevada, an important U.S. mining region, are summarized in box 7. Other jurisdictions across the United States have similar responsibilities for the approval and operation of mines. Federal and state agencies, for example, require that waste rock be placed in engineered structures that contain contaminants and control ARD. Agreements between federal and state agencies provide frameworks for coordinating regulatory and approval processes.

Box 7. Regulation of mining in Nevada

Mining in Nevada is primarily managed by the state Bureau of Mining Regulation and Reclamation (BMRR), which is part of the Nevada Division of Environmental Protection. The BMRR is responsible for state laws and permits related to water resources and the reclamation of mined land. For example, every mine in Nevada must obtain a Water Pollution Control Permit that is issued by BMRR prior to the construction of a mining project. Any mine that may discharge pollutants to surface water must also obtain a National Pollutant Discharge Elimination System (NPDES) permit from the Nevada Bureau of Water Pollution Control. Air quality permits are obtained from the Nevada Bureau of Air Pollution Control. This agency also manages the Nevada Mercury Control Program, which regulates mercury emissions from gold and silver mines. Approval through a federal process of environmental impact assessment is generally required, as 85 percent of land in Nevada is under federal jurisdiction. State and federal regulatory and review processes are coordinated.

Source: Butler (2013).

Proposed mining projects that are on (or may affect) federal land or require a federal permit, and that have the potential for significant effects on the environment, require Environmental Impact Statements (EIS) under the authority of NEPA. The EIS includes consideration of project alternatives, description of the environment, assessment of potential impacts and plans for mitigation. The scoping and review processes for the EIS include public consultation and provide a clear record of decisions for mine operations and for mitigation measures. For smaller mine proposals, a less comprehensive environmental assessment is often required to assist federal regulators in assessing the significance of the project's effects. If the determination is that the effects will be significant, the mine developer must prepare an EIS.

2.4 Reporting of Pollutant Releases and Transfers by Mining Facilities

While there are many sources and pathways for potential pollution from the mining industry, pollutant releases and transfers reported through the PRTRs are mainly limited to the production stage. Pollutant releases and transfers from other stages of the mining life cycle are not generally reported. PRTR reporting also takes into account only those disposals, or releases directly to air, to land, or to a stream or water body and does not include subsequent pollution that may result from wastes placed on land that interact with water and then pollute groundwater or surface water. The most common example of this delayed effect is acid rock drainage, which can be a source of pollution for many years after the initial disposal of acid-generating rock onto land.

The PRTR programs of Canada, Mexico and the United States all require operating mines to submit annual reports when specific conditions are met. Differences in the reporting requirements of the three systems, however, contribute to significant differences in the types of mines that report, and the types and quantities of pollutant releases and transfers they report. This section describes the three national PRTRs, the differences among the systems and the significance of these differences for interpreting data reported by North American mines and integrated and presented in the CEC's North American PRTR database, Taking Stock Online (see: www.cec.org/takingstock).

2.4.1 PRTR Reporting Requirements

The North American Industry Classification System (NAICS) provides a standardized way of classifying and describing industrial activities in North America. Canada, Mexico and the United States all use the NAICS as a basis for reporting through their PRTRs. The system uses activity codes that reflect its hierarchical structure. Codes range from two to six digits, with each added digit providing more specificity. The two- and three-digit codes related to the mining industry are:

- 21: Mining, quarrying, and oil and gas extraction, which is subdivided into
    - 211: Oil and gas extraction
    - 212: Mining and quarrying (except oil and gas)
    - 213: Support activities for mining, and oil and gas extraction
- 31-33: Manufacturing, which includes
    - 327: Non-metallic mineral product manufacturing (which includes cutting and grinding of stones and making bricks, cement and ceramic products)
    - 331: Primary metal manufacturing (which includes smelting and refining of metals and the production of alloys).

The focus of this chapter and chapter 3 is NAICS code 212, Mining and quarrying (except oil and gas). Although the three PRTR systems use somewhat different NAICS versions for classifying types of mining at the more detailed level, they all use the primary four-digit NAICS division into mining for coal, metals and non-metallic minerals. Box 8 describes what is included in each of these codes.

Box 8. North American Industry Classification System (NAICS) codes for mining

2121 Coal mining. Establishments primarily engaged in mining bituminous and lignite coal by underground mining, and auger mining, strip mining, culm bank mining and other surface mining. Mining operations and preparation plants (also known as cleaning plants and washeries), whether or not such plants are operated in conjunction with mine sites, are included.

2122 Metal ore mining. Establishments primarily engaged in mining metallic minerals (ores). Also included are establishments engaged in ore dressing and beneficiating operations, whether performed at mills operated in conjunction with the mines served or at other mills, such as custom mills, operated separately. These include mills that crush, grind, wash, dry, sinter, calcine or leach ore, or perform gravity separation or flotation operations. [Further subdivided into types of ores, including precious metals, iron, base metals and other metals such as uranium.]

2123 Non-metallic mineral mining and quarrying. Establishments primarily engaged in mining or quarrying non-metallic minerals, except coal. Primary preparation plants, such as those engaged in crushing, grinding and washing, are included. [Further subdivided into types of products mined.]

Notes: "Auger mining" involves boring horizontally into coal seams; "culm bank mining" recovers marketable coal from waste heaps from previous mining. "Ore dressing and beneficiating operations" (or beneficiation) refers to adding value to an ore through processing, making the ore more concentrated or enriched.

Characteristics of the national PRTR programs, particularly as they relate to mining (NAICS code 212), are summarized in table 13. The three North American PRTR programs, which are described more generally in "Using and Understanding *Taking Stock*" (see appendix 1) are:

- Canada: National Pollutant Release Inventory (NPRI)
- Mexico: *Registro de Emisiones y Transferencia de Contaminantes* (RETC)
- United States: Toxics Release Inventory (TRI).

Table 13. Selected Characteristics of the North American Pollutant Release and Transfer Registers

	Canada NPRI	Mexico RETC	United States TRI
Mining industry coverage	All mining facilities and activities, except operations at pits and quarries where production is less than 500,000 tonnes	Metal mines (beneficiation only); lime and cement facilities; all facilities releasing pollutants to federal waters; activities involving the handling of hazardous waste	Coal mines; metal mines (excluding iron ore and uranium mines); non-metallic mineral mines (beneficiation only)
Pollutants subject to reporting	346 pollutants or pollutant groups	104 pollutants[2]	675 pollutants and 30 pollutant categories
Facility employee threshold	10 full-time employee equivalents (or operations at pits and quarries where production is 500,000 tonnes or more)	No threshold	10 full-time employee equivalents
Pollutant threshold[1]	Activity (manufacture, process or other use) of 10,000 kg of core substances; lower thresholds apply for many substances; some substances, especially air pollutants, have release-based thresholds	Activity threshold (typically, 2,500 kg or 5,000 kg); or release threshold (from 1 kg to 1,000 kg); for heavy metals, the activity threshold is 5 kg and the release threshold is 1 kg.	Activity (manufacture or process) of 11,340 kg (25,000 lbs) of listed pollutants; Other use* threshold: 4,536 kg (10,000 lbs); lower thresholds apply for PBTs

1. Thresholds are the levels above which reporting is required. Lower pollutant thresholds apply to some listed pollutants in all three PRTR systems (see the List of Pollutants Reported to the North American PRTRs at : <**PRTR Reporting Requirements**>). *The US TRI "Otherwise use" applies to any other use (e.g., remediating waste or cleaning equipment) of a chemical such as a solvent, lubricant, refrigerant, etc.
2. The RETC list of pollutants was expanded from 104 to 200 substances, effective for the 2014 reporting year. The pollutants added to the list are not substances commonly released or transferred by the mining sector (Semarnat 2014).

2.4.2 Data Interpretation and Comparability Across PRTRs

Table 13 summarizes only the PRTR reporting requirements that apply to specific mining activities in each country. The three PRTR programs, however, do not cover every activity within this and other industrial sectors. Moreover, PRTRs do not cover some important non-industrial sources of pollutants, such as agricultural activities and transportation, which are known to contribute significantly to North American pollution.[28]

As can be seen in this table, the PRTR systems differ in the types of facilities or activities subject to reporting, in the pollutants required to be reported, and in the thresholds that trigger the requirement to report. Because of these differences, which are demonstrated in the data analyses in chapter 3, Mexico reports much lower quantities of mine-related pollutant releases and transfers than Canada and the United States, even when the relative sizes of the mining industries are considered. An additional reason may be a lower rate of facility compliance with reporting requirements.

Another consequence of the differences in reporting requirements is that relatively fewer mining facilities report in the United States than in Canada (when the sizes of the industries are taken into account). This is because the TRI has more exemptions for specific mining types and activities. Differences in pollutant thresholds also lead to significant differences in what is reported. For example, selenium has a much lower reporting threshold in Canada than in the United States, potentially yielding more reporting of selenium releases and transfers in Canada. The main features of the three national PRTRs in relation to mining are discussed below.

Canada's NPRI

Reporting is not restricted to specific sectors or industrial activities but instead is based on whether or not a facility releases or transfers pollutant types that must be reported (EC 2015). Reporting is required when thresholds for pollutants and the number of facility employees or production levels for certain activities are reached or exceeded. Mining extraction and crushing activities were exempt from the NPRI prior to 2006 and reporting of pollutants disposed of on-site in waste rock and tailings was not required until 2009 (retroactive to 2006) (ECCC 2015, Thorpe 2009).

Mexico's RETC

The RETC requires reporting by 11 industrial sectors under federal jurisdiction, along with facilities that handle hazardous waste and any facility that discharges listed pollutants to national water bodies (which includes most water bodies in Mexico). Only pollutant releases and transfers related to beneficiation activities are reported—the extraction and crushing of ore is not included (CEC 2014c). Reporting on-site disposal of pollutants in waste rock is not required and, in practice, disposal of pollutants in tailings is also not reported. The pollutant list excludes many metals that are commonly associated with mine pollution, such as copper and zinc. Mexico's system, however, may capture some smaller mining operations as compared with the U.S. and Canadian systems, as the pollutant thresholds are lower and there is no reporting threshold based on numbers of employees.

U.S. TRI

With the exception of federal facilities, reporting is required when a facility corresponds to a 6-digit NAICS code covered by the TRI and when the pollutant thresholds and the number of facility employees are reached or exceeded. All NAICS codes associated with coal mining and metal mining are covered by the TRI, with the notable exceptions of the mining of iron ore and uranium. Non-metallic mineral mining operations (codes under 2123) are only required to report if they are primarily engaged in beneficiation and do not have a mine or quarry on-site (U.S. EPA 2016d). Pollutants released or transferred during excavation and crushing in non-metallic mineral mining are not reported.

Differences in reporting requirements can complicate comparisons of pollutant releases and transfers among the three countries. General PRTR reporting differences related to facility coverage, pollutant coverage, pollutant threshold, and employee threshold were introduced in the previous section. This section focuses on comparability issues important

28. For more information, see appendix 1.

in the interpretation of the pollutant releases and transfers reported by North American mining facilities for the 2013 reporting year, and presented in chapter 3. A more comprehensive comparison of the three PRTR systems can be found in annex 1 of the CEC's *Action plan to Enhance the Comparability of Pollutant Release and Transfer Registers (PRTRs) in North America* (CEC 2014a). This section is based on the CEC's *Action Plan* and on government documentation for the three PRTR systems (U.S. EPA 2016d, U.S. EPA 1999, U.S. EPA 2014b, EC 2013, ECCC 2015, Semarnat 2016a).

Assignment of NAICS codes

Use of a single classification system makes data reported by the three systems comparable across North America, but there remain some areas of inconsistency in the application of NAICS codes from facility to facility, and from country to country. Potential sources of inconsistencies include:

- **Facility activities corresponding to more than one NAICS classification.** Under the TRI, establishments can report under as many as six NAICS codes if they have multiple distinct businesses that fit into different NAICS categories, with one of these codes identified as the primary business activity. For example, a multi-business establishment may report pollutant releases and transfers as a metal mine (2122) and also as a smelter (33141) (U.S. EPA 2014b). However, if both smelting and mining activities are carried out by one business, only one NAICS code is used for reporting. In the NPRI and RETC, facilities are identified by one NAICS code only. As a result, in the three countries, pollutant releases and transfers associated with other activities, such as smelting, may be reported under a NAICS code for mining.
- **Different versions of the NAICS codes**. NAICS code descriptions are updated every five years in a collaborative process involving agencies in Canada, Mexico, and the United States. However, the three PRTR systems are not synchronized in their use of the most recent version of the NAICS, which can result in inconsistencies among the systems in terms of which codes and descriptions are used in a given reporting year (CEC 2014c). The most recent update to the NAICS codes was in 2012. No changes were made to codes or descriptions in the mining sector (U.S. BLS 2012); therefore the 2012 update is not likely to have resulted in any inconsistencies for the 2013 reporting year.
- **Similar activities**. NAICS codes are self-reported by facilities and are sometimes reported incorrectly or inconsistently. This is particularly true at the five- and six-digit code level where facilities that undertake very similar activities sometimes report incorrect or invalid codes (CEC 2014a). Data analyses performed at the levels of "Mining, except oil and gas" (three-digit code) and industry group (four-digit codes) are less likely to be affected than analyses at the five-digit and six-digit levels.
- **Facility familiarity with NAICS codes**. In the United States, implementation of NAICS codes for TRI reporting began in 2006, bringing the TRI in line with Canada's NPRI. In Mexico, facilities have only been required to report using NAICS codes beginning in 2012. Prior to 2012, Mexican facilities reported according to the *Clasificación Mexicana de Activades y Productos* (CMAP) industrial classification codes, which were mapped to NAICS codes by the RETC staff. The short history of NAICS code use by Mexican facilities compared to its use in the United States and Canada is a potential source of inconsistency in code application.

Reportable pollutants

The number of reportable pollutants under each PRTR system differs (table 13), with the U.S. and Canadian systems covering far more pollutants than the Mexican system. Mining facilities reported releases or transfers of 79 substances for 2013 (chapter 3). Only 15 of these were common to all three PRTR systems. The expansion of the RETC pollutant list, effective for the 2014 reporting year (Semarnat 2014), does not alter this low degree of comparability, as none of the pollutants reported only by Canadian and U.S. mines were added to the list. Only seven of the top 25 mining sector pollutants (which make up greater than 99 percent of the sector's releases and transfers) were common to all three reporting systems: lead, arsenic, nickel, chromium, cadmium, cyanides and mercury (and their compounds). Zinc, manganese and copper (and their compounds), all commonly released or transferred by metal mines, are required to be reported in Canada and the United States, but not in Mexico. Total phosphorus is only reported in Canada, and barium is only reported in the United States.

An issue of PRTR comparability related to the reporting of metals is that in Canada, with a few exceptions, facilities must report releases or transfers of metals together with their compounds (e.g., cadmium and its compounds). The U.S. TRI and Mexican RETC generally require separate reporting of individual metals and their compounds—but as there is no way to know which substance or its compound(s) were released or transferred by Canadian facilities, the data are grouped in the CEC's North American PRTR database, Taking Stock Online.

The PRTR systems also differ in the pollutant thresholds that trigger reporting, with the RETC in general having lower thresholds. The differences are marked for several of the most common mining-related pollutants (table 14), and this needs to be taken into consideration when comparing reported releases and transfers of these substances.

Table 14. National PRTR Reporting Thresholds for Selected Mining Pollutants

Reporting Threshold (kg)

Substance	Canada NPRI	Mexico RETC		United States TRI	
	MPO (kg)	MPO (kg)	Release (kg)	MP (kg)	Other Use (kg)
Lead*	50	5	1	45	45
Arsenic*	50	5	1	11,340	4,536
Chromium*	10,000**	5	1	11,340	4,536
Cadmium*	5	5	1	11,340	4,536
Cyanides	10,000	5,000	100	11,340	4,536
Nickel*	10,000	5	1	11,340	4,536
Mercury*	5	5	1	4.5	4.5

Note: The threshold values shown apply to mass of a substance manufactured (M), processed (P), or otherwise used (O).
* and its compounds.
** There is a lower threshold in NPRI for Cr6 (hexavalent chromium), a highly toxic form of chromium.

Tailings and waste rock

Mine tailings are the result of beneficiation, and disposal of pollutants in tailings is subject to reporting under all three PRTR systems—but there are some notable differences. In the RETC disposal is defined as an off-site transfer and, therefore, there is no category for the reporting of pollutants disposed of on-site through tailings. As a result, they are not reported. In both the TRI and the NPRI, a pollutant in tailings, including a natural substance, must be reported if it exceeds a threshold quantity that is manufactured, processed or used at the mine. *De minimis* exemptions (concentration thresholds below which reporting is not required) are not applied.

Because waste rock is a byproduct of mine excavation and does not result from beneficiation, pollutants in waste rock are not required to be reported in cases where the PRTR only applies to beneficiation. Disposal of pollutants in waste rock is, therefore, not reported for any mine in Mexico and is not reported for non-metallic mineral mines in the United States (table 13). Thresholds are applied to waste rock differently from the way they are applied to tailings. Under the TRI, a pollutant in waste rock (at a metal mine or a coal mine) disposed of on-site is not reported unless it exceeds the pollutant mass threshold due to releases through other pathways—the amount in waste rock does not count towards this calculation. If the mass threshold is exceeded, disposal of the pollutant through waste rock must be reported and the *de minimis* concentration exemption does not apply. Under the NPRI, waste rock is included in a substance's mass threshold calculation—unless the rock is classified as inert. If a substance is to be reported in waste rock, a *de minimis* exemption may apply, depending on the classification of the substance.

Waste rock disposal at any mine can vary dramatically from year to year, principally due to variations in the concentration of the metals and volumes of waste rock mined. This often accounts for the relatively large changes in total releases and transfers that are sometimes reported by metal mines in consecutive years. These year-to-year fluctuations can also be exaggerated by a facility crossing a quantity threshold or qualifying for the *de minimis* exemption one year and not the next, or vice versa. Box 9 summarizes information about *de minimis* thresholds and their application in the NPRI and TRI.

Box 9. De minimis (threshold) exemptions and concentrations in the TRI and the NPRI

"De minimis" is the term used by the TRI and "concentration threshold" is the term used by the NPRI. They both refer to a specific concentration of a pollutant below which the quantity is not required to be included in the threshold calculation. When there is no *de minimis* exemption for a pollutant, all releases of the pollutant must be reported, regardless of its concentration. There is no equivalent in the Mexican PRTR.

U.S. TRI

De minimis levels are consistent with the Occupational Safety and Health Authority (OSHA) Hazard Communication Standard requirement for development of Material Safety Data Sheets (U.S. EPA 2015). The *de minimis* level is 1.0 percent unless the substance is an OSHA-defined carcinogen, in which case the de minimis is 0.1 percent. The OSHA carcinogens include many common mining-related pollutants, including arsenic, cadmium, and cobalt. There are no *de minimis* exemptions for persistent bioaccumulative and toxic (PBT) chemicals. PBT pollutants commonly associated with mining activities include mercury and lead. *De minimis* exemptions do not apply to tailings, but may apply to waste rock.

Canada's NPRI

Substances subject to reporting under the NPRI are grouped into six categories: Part 1A—core substances; Part 1B—alternate threshold substances; Part 2—polycyclic aromatic hydrocarbons; Part 3—dioxins, furans, and hexachlorobenzene; Part 4—Criteria Air Contaminants; and Part 5—speciated volatile organic compounds. The concentration threshold for Part 1A substances is 1.0 percent. A number of Part 1A substances have been listed through the NPRI since its earliest days, with many of them considered to be toxic under CEPA. Part 1B substances (mercury, cadmium, arsenic, hexavalent chromium, lead, tetraethyl lead and selenium) can have significant impacts on human health and the environment, even at low levels. The concentration thresholds for these substances range from no threshold to 0.1 percent. There is no concentration threshold for any type of pollutant release for substances in Parts 2, 3, 4 and 5. Concentration-based exemptions do not apply to disposal of pollutants in tailings. For pollutants in waste rock, only Part 1A *de* concentration threshold exemptions apply (not Part 1B exemptions).

Sources: U.S. Environmental Protection Agency (U.S. EPA 1999, U.S. EPA 2016d) and Environment and Climate Change Canada (EC 2013, ECCC 2015).

PRTR reporting categories

The national PRTR systems differ in the categories under which pollutant releases and transfers are reported. This variability limits the types of comparative data analyses that can be undertaken. Table 15 shows the on-site reporting categories for each national PRTR and the categories used by the CEC's Taking Stock Online (the searchable North American PRTR database) to combine and standardize the data from the three national systems. The table illustrates the variety of waste management categories that creates challenges for comparing data across North America. As mentioned above, a difference that has a major impact on our ability to understand data reported by the mining sector (especially relating to the management of tailings) is that unlike Canada's NPRI and the U.S. TRI, Mexico's RETC does not have a category for reporting of on-site disposal.

Table 15. **On-site Reporting Categories for each PRTR System** (2013)

PRTR System	Air	Water	Disposal, on Land, and Underground
Canada NPRI[1]	- Stack emissions - Storage/handling - Fugitive emissions - Spills - Other emissions - Road dust emissions	- Direct discharges - Spills - Leaks	- Releases: · Spills · Leaks · Other - Disposal: · Land fill · Land treatment · Underground injection · Tailings · Waste rock
Mexico RETC	- Facility emissions	- Direct discharges to water	- Releases to land (soil)—the sum of spills, underground injection, landfilling, land farming *(There is no RETC on-site disposal category)*
United States TRI	- Fugitive or non-point air emissions *(including emissions resulting from accidents and malfunctions)* - Stack or point air emissions	- Discharges to receiving streams or water bodies *(includes end-of-pipe discharges and stormwater runoff where it is monitored; percent from stormwater is recorded)*	- Underground injection - Disposal to land: · Land fills · Land treatment/Application farming · Surface impoundments *(tailings and settling ponds)* · Other disposal *(combines waste rock and other releases, including leaks and spills)*
Taking Stock Online (North American PRTR database)	- Air emissions	- Surface water discharges	- Underground injection - Disposal or land releases

1. When a facility in Canada releases less than 1 tonne of a Part 1A substance during the year, the release can be reported as a "total release" without specifying the medium (air, water or land).

Sources: Semarnat (2016b), ECCC (2016b), CEC (2014a) and US EPA (2014b)

The NPRI and TRI require reporting on non-point-source air emissions, while the RETC does not. Fugitive and other non-point air emissions can be significant for mining, though they are often of concern in relation to particulate matter, which is only reported in the NPRI. The NPRI is the only system with a specific requirement for reporting particulate matter from road dust. As described in chapter 1, the Canadian program also requires reporting of criteria air contaminants (CACs), while Mexico's RETC includes reporting of greenhouse gas emissions (GHGs). However, because emissions of CACs and GHGs are not reported consistently under all three PRTRs, they are not included in Taking Stock Online.

Water releases, like air emissions, can be point-source or can be in the form of diffuse drainage through the mine site to streams and water bodies. The TRI requires stormwater runoff to be estimated and reported if it is monitored. Canadian mines subject to the Metal Mining Effluent Regulations must collect and treat stormwater before releasing it as a point source discharge. Pollutants in this managed runoff are reported through the NPRI.

Releases to land are aggregated in the RETC and include spills, underground injection, land farming, and landfilling. As noted previously, pollutants in waste rock are not required to be reported and there is no category that covers tailings. There is, in addition to the categories shown, an off-site RETC reporting category called "final disposition." As a result, the on-site land disposals that would be reported in the United States and Canada, and that make up the bulk of pollutants reported by the North American mining sector, are not reported by mines in Mexico.

In Taking Stock Online, pollutant disposals or releases in tailings, waste rock and spills are not distinguishable because they are grouped into the "disposal or land releases" category or, in the case of spills to water, into "surface water discharges." While this is necessary to accommodate key differences among the three PRTRs, it can limit our understanding of the data reported by mining facilities across North America, as these three types of pollutant disposals or releases are the most significant for many mines. They are also very different from one another in their potential risk to environmental and human health, and they are different in terms of scale; therefore, they should be looked at separately. Additional points about these types of mine disposals and releases are:

- Disposal of pollutants to tailings areas is reported as a separate category in both the NPRI and the TRI and thus can be analyzed and compared by accessing data from the national systems.
- Disposal of pollutants to waste rock disposal areas is reported as a separate category in the NPRI, but grouped with several other types of land releases in the TRI.
- Spills can be distinguished from other types of releases only in the NPRI. In addition to the inconsistencies among the three PRTRs in the categorization of spills, the requirements for spill reporting differ in a way that is significant for the mining sector. Spills from accidents that release pollutants from one medium to another (such as from tailings to surface water) are required to be reported through the NPRI. In the TRI, however, the quantity of a substance that has been reported as released to one medium is not required to be reported again if the substance, or a portion of it, later migrates to a different medium (e.g., if a chemical that is liquid in its natural state is released on land, the quantity released is reported. If over a time a portion of the chemical evaporates, the quantity that evaporates is not reported as a release to air—i.e., a release is not to be reported twice). Thus, a release from a breached tailings dam (the source of most major mine spills) would be required to be reported under the NPRI, but it would not necessarily be reportable under the TRI. In Mexico, data for spills from accidents are reported through the *Cédula de Operación Annual* (COA), the overarching program that includes the RETC; but they are not accessible through the RETC.[29]

29. Spills are also registered with Profepa (*Procuraduría Federal de Protección al Ambiente*), the Mexican agency responsible for enforcement relating to environmental protection.

2.5 Sustainability of North American Mining

Increasing the sustainability of the North American mining sector involves efforts and partnerships across public and private sectors as well as changes in regulatory regimes and investment practices. It also involves working with stakeholders to ensure that social and environmental risks and negative impacts are minimized and that local communities benefit from mining. Tools to improve mining sustainability include advances in pollution control technology and better assessment and decision-making frameworks. In this section, we look at some of the challenges and solutions for sustainable mining in North America, with a focus on pollution prevention.

2.5.1 Sustainable Mining: Concept and Initiatives

Much of current North American mining-related pollution is related to past practices that have damaged lands and waterways, negatively affected communities, and created public-sector social and economic liabilities (Asif and Chen 2016, Dashwood 2014). Current responsible mining practices, mindful of this legacy, seek to address the economic, social and environmental challenges of mining by addressing such concerns, ensuring that benefits will flow to communities in the mining region, and minimizing long-term environmental damage. Some of the efforts to bring mining more in line with sustainable development principles are government-led and some are industry-led, both driven by recognition of the need for improvement (MacDonald 2002, Dashwood 2014, IIED 2002).

Sustainable development was defined by the Bruntland Commission report in 1987 as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (p. 41 United Nations General Assembly 1987). The overall goal is long-term stability of both environment and economy. A key principle of sustainable development is the integration of economic, environmental and social concerns in decision-making.

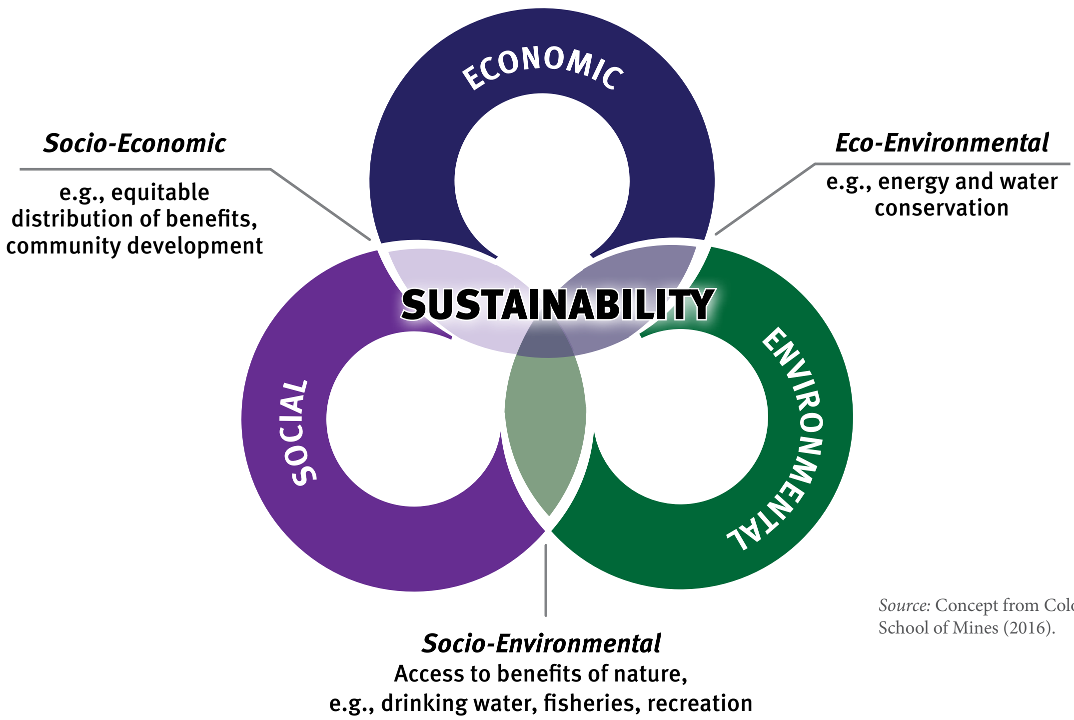
What is sustainable mining?

Mining operations have a defined lifespan, as they depend on non-renewable resources. Technology can extend a mine's lifespan through mineral processing techniques that economically mine lower-grade deposits that were at one time considered to be uneconomic. Many established mines have produced metals for over 100 years as mining methods and recovery methods have improved. Although individual mining projects cannot be sustained beyond a finite lifetime, the mining industry can apply a sustainable development paradigm (figure 25) by providing mining regions with lasting opportunities for economic and social development, while maintaining environmental integrity.

In the **economic sphere**, competitive global markets impose pressure to balance costs, productivity and value of mineral products. Greater knowledge and awareness of the **environmental sphere** has led to increasingly stringent requirements to reduce consumption of energy and water, reduce carbon emissions and wastes, avoid damage to aquatic and terrestrial biodiversity, and provide technical and financial assurance for the protection of ecosystems after mine closure. In the **social sphere**, mining ventures face a range of often contradictory expectations, including respecting and accommodating the rights, interests and heritage values of Indigenous Peoples, providing employment and socio-economic benefits to the region and the nation, and protecting pre-existing recreational and economic activities (Pimentel et al. 2016, ICMM 2012).

Sustainable development is the common framework underlying mining companies' policies on corporate social responsibility (Dashwood 2014). Given the international stature of a large number of mining companies, many sustainability initiatives are undertaken at the international level, particularly through the International Council on Mining and Metals and the Global Reporting Initiative (GRI 2016). National industry associations are also taking a lead in this field (MAC 2016b, PDAC 2016) (see box 10). Although these are voluntary programs, they are often a condition of membership in the associations and they incorporate formal commitments to principles and practices, external audits and public reporting.

Figure 25. Three Spheres of Sustainability



Source: Concept from Colorado School of Mines (2016).

Box 10. Industry initiative example: Towards Sustainable Mining

Towards Sustainable Mining, established by the Mining Association of Canada in 2004, is a "set of tools and indicators to drive performance and ensure that key mining risks are managed responsibly at our members' facilities" (MAC 2016b). When joining the initiative, a mining company commits to

- adherence to a set of commitments on responsible social, economic and environmental practices;
- integration of performance protocols and indicators into facility operation and management systems;
- annual self-assessment of performance (by assigning a letter grade to each indicator);
- external verification of the performance assessment every third year; and
- training on protocols and frameworks.

Protocols and technical guidance cover Indigenous Peoples and community outreach, energy and greenhouse gas emissions management, tailings management, biodiversity conservation management, safety and health, and crisis management planning.

Source: Mining Association of Canada (MAC 2016b).

Verification Program for Towards Sustainable Mining

Source: Adapted from MAC (2016b).

Another means of providing incentives for companies to adopt environmental sustainability practices is through the provisions in financing mechanisms for mining ventures and associated infrastructure. Investors are mindful of reducing their risks not only by evaluating the profitability of developing an ore body, but also by assessing the risks inherent in not addressing the social, economic and environmental dimensions of mine development. Requirements and standards for project assessment are increasingly being adopted by banks and other lending agencies. The International Finance Corporation standards and the Equator Principles (adopted by the World Bank and commercial banks) are examples of financial mechanisms that provide lenders with a measure of assurance that sustainability issues have been addressed (UN ECE 2014, Marshall 2015, Eamer et al. 2015).

Social License to Operate

Leaders of nine major world mining companies issued a statement in 1999 recognizing that the industry's "social license to operate" was in jeopardy due to the growing gap between industry practices and society's expectations (MacDonald 2002). They commissioned an independent study through the World Business Council on Sustainable Development to assess the mining and minerals sector in terms of transition to sustainable development (IIED 2002). The report stated that the mining industry is "*distrusted by many of the people it deals with day to day*" and highlighted the need to rebuild trust between the industry and stakeholders.

For the North American mining industry, efforts to build support for mining have coalesced under the concept of social license to operate (SLO) (Minería Sustentable 2016, ICMM 2015a, Rheaume and Caron-Vuotari 2013). SLO, a term that was first used by the Canadian mining industry in the late 1990s, is linked to the broader concept of corporate social responsibility, which includes ethical, legal and economic responsibilities of companies, including responsibilities linked to sustainable development (Fraser Institute 2012). SLO is an expression of the idea that mining companies need more than government approvals and operating permits—they also need social permission, or support, to open and run a mine. SLO is not in itself a legislated requirement, but it is increasingly seen as an essential part of obtaining approval for new mines. It overlaps with requirements in EIA processes for consultation and addressing public concerns.

There is no one definition of the term and how this "license" can be achieved. Use of the term can be controversial (Portales and Romero 2016, West Coast Environmental Law 2015, Owen and Kemp 2013). Acquiring a social license to operate can be interpreted by a mining proponent or others advocating for a mine to proceed as achieving a broad consensus of support for a project, even while failing to substantively address important and often conflicting rights and expectations of minority stakeholders. The promise of jobs in an area, for example, may provide this apparent critical mass of support and mask unresolved underlying social and environmental concerns. Taken more broadly, for a company to achieve and maintain an SLO requires a high standard of corporate social responsibility, transparency, and ongoing attention to sustainable mining practices.

Working towards acquiring a social license to operate can lead to substantive progress towards sustainable mining. Consultation with communities and groups representing social and economic interests that may be affected by the mine is crucial to obtaining project support. These consultations may lead to changes in project plans to accommodate concerns, and to formal agreements between mining companies and affected communities that lay out responsibilities and mechanisms for follow-up. Partnerships and joint ventures allow sharing of project decision making and benefits, and promote cooperation on mutually defined social, environmental and economic goals. These agreements can take the form of financial partnerships or formal agreements that spell out commitments by industry and communities (see box 11).

Box 11. Impact and Benefit Agreements (IBAs)

IBAs are legally binding agreements between industry and Indigenous organizations and communities in Canada. IBAs set out mutual commitments, typically covering impact mitigation, community participation in the mining project, and access to benefits. Agreements are based on contracts. An example is the Mary River Project Inuit IBA for a new iron ore mine in Nunavut, Canada. The IBA is a contract between the mining company (Baffinland) and the regional Inuit association for North Baffin, a region that includes five communities. The IBA includes provisions for mitigation and monitoring of impacts and for maximizing Inuit benefits arising from ownership of the land and from contracting, employment, education and training. The IBA is managed by a committee which includes members from the company and from the Inuit association (Baffinland Iron Ore Mines Corporation and the Qikiqtani Inuit Association 2013). There were 67 active IBAs in Canada in 2016, 41 of which were for producing mines. A further 317 active agreements of other types, such as Cooperation Agreements and Memorandums of Understanding, were in place between mining companies and Indigenous organizations (NRCan 2016e).

Despite progress in public engagement for mining ventures in many regions, local people are still often adversely affected by current and past mining operations due to pollution, environmental degradation and disruption of their communities and economies. Annual surveys of global public attitudes towards business in society show that public trust in the mining industry in North America and Europe remains low (GlobeScan 2014, GlobeScan 2017). Canada, Mexico and the United States were among the 6 countries with the lowest trust ratings of 24 countries surveyed in 2014. Respondents from North America had the highest frequency of identifying environmental issues as the most important issues for the mining industry to address (GlobeScan 2014).[30]

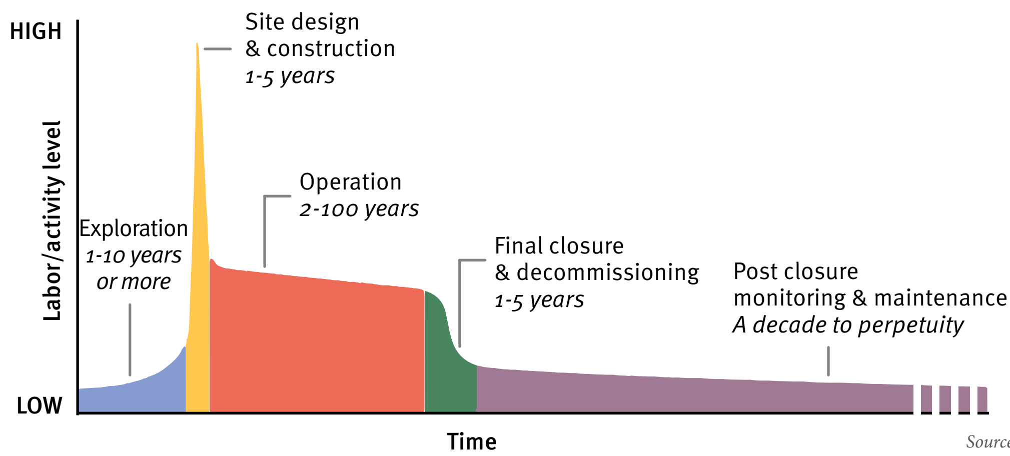
A mining industry stakeholder survey, commissioned by the International Council on Mining and Metals in 2014,[31] identified main concerns and issues facing the industry (ICMM and GlobeScan 2014). This survey also reflected the increasing emphasis on public engagement to address social and environmental issues. Environmental concerns, social license to operate and regulation topped the list of stakeholder concerns. Low commodity prices and associated pressures to reduce costs were identified as major challenges for the industry. Water usage and management and tailings management were set as high priorities by respondents.

2.5.2 Trends and Advances in Mine Planning, Permitting and Life-cycle Management

Sustainable mining requires planning for the life of the mine, from the exploration phase to post-closure (figure 26). Advances have focused on both ends of the cycle: upfront assessment and planning, and mine decommissioning/post-closure. Regulation of mining during construction and operation has become more stringent and often more complex (Marshall 2015), usually through amendments to regulations to adjust allowable levels of discharges or add specific requirements for pollutant control. For example, growing knowledge about increasing levels of selenium in water downstream of coal mines has led to improved regulation and more stringent reporting requirements for this pollutant (CEC 2014c, Hendry et al. 2015, EC 2012).

30. Based on interviews of representative samples of 1,000 adults per country in 24 countries; within-country sample error of +/- 2.8 to 4.9 percent, 19 times out of 20.
31. Responses were from 323 mining industry stakeholders in the United States and Canada and 200 in Latin America (including Mexico). Stakeholders were people familiar with the mining industry and associated with the private sector (over half of respondents), public sector, trade associations, non-government organizations or the media.

Figure 26. **Life Cycle of a Mine**



Source: Adapted from ICMM (2012).

Environmental Impact Assessment

Trends and advances in EIA include improved methodology for assessing risks to human health and the environment, and place-based (as opposed to project-based) assessment, such as for watersheds. Changes in policy, legislation and practices for EIA are grounded in expanded research in this field (for example, U.S. EPA 2016a, Olagunju and Gunn 2016).

Assessment of cumulative effects (the sum of effects from the proposed project, plus effects from other past, present and likely future human activities) is increasingly emphasized for mining project EIAs and through international agreements (for example, Columbia Center on Sustainable Investment et al. 2016a). While cumulative effects assessment is required by all North American jurisdictions, it has not always been effectively implemented, due to gaps in legal frameworks and practices and constraints in methodology (Mendoza Sammet 2008). New methods and tools for assessing risk from multiple sources of pollution advance the practice of cumulative assessment, though they are not widely applied (Solomon et al. 2016). EIAs have also broadened to incorporate emerging concerns or concerns that have become higher profile, such as species at risk, invasive species and climate change.

Compliance and enforcement

A crucial component of sustainable development is the protection by the public sector of common resources, foremost of which, in relation to mining and pollution, are clean water and clean air (Emas 2015). Protection of common resources requires more than laws and regulations—adequate monitoring of compliance and enforcement of the rules are also needed.

Lingering pollution from abandoned mines, public liability for reclamation, and several recent major mine spills contribute to public concern about mine pollution issues. Recent major spills at mines in North America include breaches of tailing facilities at the Mount Polley copper and gold mine in British Columbia, Canada; the Obed coal mine in Alberta, Canada; and the Bacis gold mine in Durango, Mexico; as well as a spill caused by a broken pipe at the Buenavista del Cobre mine in Sonora, Mexico. These spills are discussed further in relation to PRTR reporting in chapter 3.

Recent initiatives that aim to learn from accidents and pollution issues in order to improve enforcement and compliance include government follow-up to the Mount Polley tailings breach in British Columbia (see box 12) and the EPA's enforcement initiative to reduce pollution from active mineral processing operations in the United States (U.S. EPA 2016b). The EPA conducts enforcement initiatives to address national pollution challenges. These initiatives, which last for three years, address areas where there is significant non-compliance with laws. The mineral processing enforcement initiative ends in 2017, returning to baseline levels of enforcement. The initiative was undertaken with the recognition that the mining and mineral processing industry generates more toxic and hazardous waste than any other industrial sector. Enforcement actions taken during the initiative reduced the risk of mining waste contamination from operating facilities and led to cleanup at mining sites across the United States (U.S. EPA 2016b).

Box 12. Mount Polley tailings breach: Learning from a major mine facility failure

Concern about the Mount Polley tailings dam failure and its consequences prompted an independent engineering investigation of the causes of the failure and how it could have been prevented (Independent Expert Engineering Investigation and Review Panel 2015) and an audit of mining compliance and enforcement in British Columbia (Auditor General of British Columbia 2016). The audit concluded that the province's compliance and enforcement activities need improvement to protect the province from significant environmental risks. The audit pointed to gaps in resources, planning and tools for regulatory oversight. The audit also addressed the post-closure phase of mining, concluding that the current approach to mine permitting does not adequately reduce the risk to taxpayers to pay costs associated with long-term environmental impacts from mines. Ten percent of British Columbian mines have or will require long-term or perpetual water treatment due to ARD and leaching of metals and arsenic. The audit estimated the total cost of outstanding reclamation for British Columbia mines at $C2.1 billion, with less than half of this amount being secured by financial commitments. Over half of the unsecured liability is for mines that will require long-term water treatment, a liability that is difficult to cost.

Mine closure and abandoned mines

The potential for high costs and long post-closure timeframes (figure 26) makes mine closure a crucial and challenging component of sustainable mining (Dance 2015). All mining regions of North America can point to abandoned or "orphaned" mines that continue to be sources of pollution. Canadian and U.S. jurisdictions have varying mechanisms in place for requiring decommissioning and post-closure planning and financing. Mexico also has environmental regulations relating to the closure of mines, but does not have financial mechanisms comparable to those of the other two countries. Initiatives to ensure that plans are in place and mine operators do not walk away from responsibility for mine sites requiring reclamation, care and maintenance are clearly important for the sustainability of North American mining (NOAMI 2015).

Mines that have been abandoned without adequate decommissioning and reclamation may have ongoing environmental issues, including contaminated land, ongoing land instability and erosion, land subsidence, and pollution of surface and groundwater from runoff and water seepage through mine wastes and disturbed land (for example, Pokhrel and Dubey 2013, Jamieson 2014, Roberts 2016, Esteller et al. 2015). Both Canada and the United States have ongoing programs to coordinate work on abandoned mines (NOAMI 2015, BLM 2015). Both countries are undertaking inventories of such mines, which is a difficult task as there are few records for older operations.

Remediation of abandoned mines may range from monitoring and maintenance to solutions that can involve millions of dollars of work and require many years to stabilize impoundments and contain wastes (Cowan and Mackasey 2006, Vaughan et al. 2012, Horvath 2011).The U.S. Bureau of Land Management's program has successfully reclaimed many past mining areas on federal land and restored land and waterways, often through collaborative programs involving communities and volunteers (BLM and Forest Service 2007). The mining industry has also cleaned up remnants of long-abandoned mines and restored streams in some areas, both on their own lands and through initiatives to benefit people and the environment in regions in which mining companies are active. For example, the mining company, Freeport-McMoRan, in partnership with Trout Unlimited, a non-governmental organization that conserves and restores freshwater fisheries and watersheds, runs a program that addresses historical mining issues in Colorado (Freeport-McMoRan 2014).

2.5.3 Technological and Methodological Advances that Make Mining More Sustainable

Advances in technologies and practices that reduce environmental impacts from current and past mining operations contribute to the sector's sustainability toolkit. This includes advances in tailings and waste rock management, water monitoring and treatment, mine site reclamation, energy efficiency and greenhouse gas emissions reduction. Mineral processing technologies that make use of less toxic or persistent reagents, or that use reagents more efficiently, also advance the sustainability of mining. Research and development strategies that aim to reduce or eliminate mine waste tackle the issue on several fronts. The Canadian Mining Innovation Council's strategy, "Towards Zero Waste Mining," for example, is based on a combination of research and development goals including minimizing waste during ore extraction, reducing water and energy use through closed-system processing, and refining tailings into benign and marketable products (Kondos and Weatherell 2016, Kondos and Weatherell 2014). Some mines in Mexico use water from municipal sewage treatment facilities instead of depleting valuable clean water sources. The municipal wastewater is further treated at the mine facilities and used in mineral processing (Briseño 2017, pers. comm.).

Improved mining practices can reduce pollutant releases from modern operating mines. Water pollution from past mining activities and spills and malfunctions, however, presents an ongoing risk to aquatic ecosystems and to people's access to clean water in some areas. The possibility of long-term water pollution also remains an issue for the post-closure phase of mines with persistent wastes. Treatment of mining-influenced water is a priority for technological development and new and improved treatment methods are coming into use (box 13).

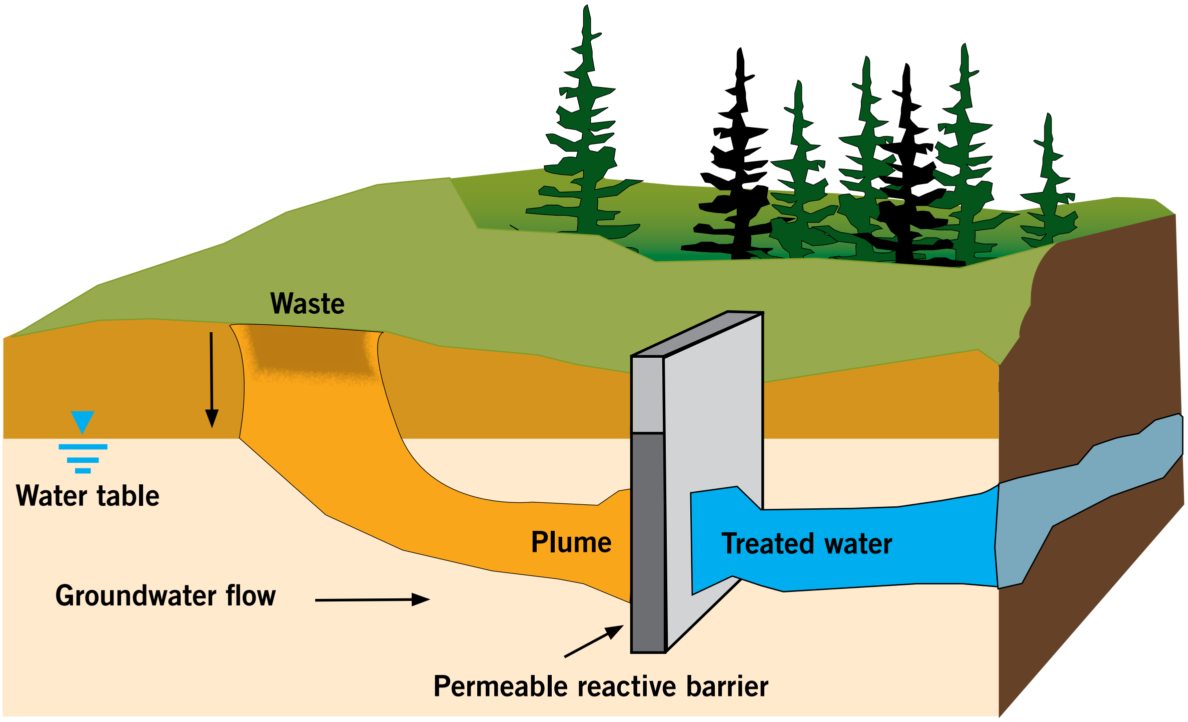
Box 13. Advances in treatment of mining-influenced waters

The United States has an estimated 16,000 km of mine-influenced waters (MIW)—streams and rivers that are degraded through ongoing mining-related pollution from past mining activities. The pollutant releases to these waters are mainly associated with acid rock drainage. The U.S. Environmental Protection Agency's guide to treatment technologies for MIW focuses mainly on passive treatments as they tend to be lower cost, lower energy use, and lower maintenance. Passive treatments typically use natural treatment materials and gravity flow. Maintenance is still needed, and usually more than one treatment method is required. Examples of passive MIW treatment technologies include:

- Anoxic limestone drains. Acidic water runs through a lined and covered trench containing limestone; this is followed by metals precipitation in settling ponds.
- Constructed wetlands. As water flows through the wetlands pollutants are taken up by plant roots or removed from the water through biochemical reactions involving bacteria. Sulfates, various metals and arsenic can be stripped from the water, eventually settling into the substrate of the wetland.
- Biochemical reactors. Water is directed through specially-designed tanks, trenches or ponds inoculated with sulfate-reducing bacteria. The bacterial action removes sulfates, metals and metalloids (including arsenic and selenium) from the water.
- Permeable reactive barriers (figure 27). Groundwater flows through a reactive barrier, which may be a form of granular iron, limestone, compost or another material. The technology can be used to remove radionuclides (from water contaminated by uranium tailings), metals, sulfate and other ions.

New and developing passive treatment technologies are in use or being tested by government for treatment of MIW from some abandoned mines, and by some mining companies, especially for decommissioning of mines.

Figure 27. **Permeable Reactive Barrier, an Example of Long-term Passive Treatment of Mining-influenced Water**



Source: Adapted from U.S. EPA (2014a).

Advancements in monitoring of pollutant releases and their environmental effects can also improve the sustainability of mining operations. More comprehensive and cost-effective monitoring technologies allow industry and government to track the effects of mining and re-evaluate and adjust mitigation measures (adaptive management)—particularly important in light of climate change. Advancements include remote, real-time sensors for surface and groundwater monitoring (CMIC 2014) and ecological monitoring protocols, for example, to detect effects on fish habitat (Ziglio et al. 2006) (EC 2012).

2.5.4 Climate Change: A Challenge to Sustainability Requiring Adaptation and Long-term Thinking

This emerging issue is being addressed through incorporating consideration of climate change into existing processes for mine assessment and planning (ICMM 2013, NRCan 2016a). As most established assessment processes and design standards are based on an assumption that the climate is static—using historical averages as the baseline to represent future conditions—major changes are needed. Government, industry and collaborative initiatives at international, national and regional scales are underway, driven by the growing awareness of climate change and its consequences for sustainable development in the mining sector (box 14) (Columbia Center on Sustainable Investment et al. 2016b).

The International Council on Mining and Metals' (ICMM) initiative on climate change aims to strengthen the industry's commitment to sustainable development, through reductions in greenhouse gas emissions and adaptation to climate change (ICMM 2015b, ICMM 2013). Adaptation actions can achieve complementary sustainable development goals related to, for example, community engagement and stewardship of natural resources.

Box 14. Climate change and mining: Examples of risks and consequences

- **Water** supply shortages and use conflicts; water quality changes affecting water supply and impacts of pollutants
- **Energy** supply changes from streamflow change and glacier melt affecting hydro power or cooling water availability for fossil-fuel-based power generation; severe storms damaging transmission infrastructure; changes in regional energy needs from hotter, drier summers
- **Severe storms and altered flow regimes** overloading or damaging mine infrastructure such as dams or pumping systems; increased risk of erosion
- **Increased complexity of environmental assessment and regulatory processes**—biophysical changes (such as degrading permafrost, changing vegetation communities, potential for new invasive species and altered water courses) which need to be incorporated into EIA predictions and regulatory processes
- **Consequences for supply chains and logistics**—risks to transport of mine supplies and shipment of products, such as disruption due to severe weather events and reduced ice-road seasons in the North, but also the potential advantage of longer open-water seasons for shipping; damage to ocean port facilities due to sea level rise and more severe storms
- **Market changes**—altered commodity values, such as from lowered demand for coal due to a switch to renewable energy, or increased demand for lithium for batteries to store solar power
- **Business implications**—potentially greater liability, higher insurance costs and overall less certainty, with consequences for project financing.

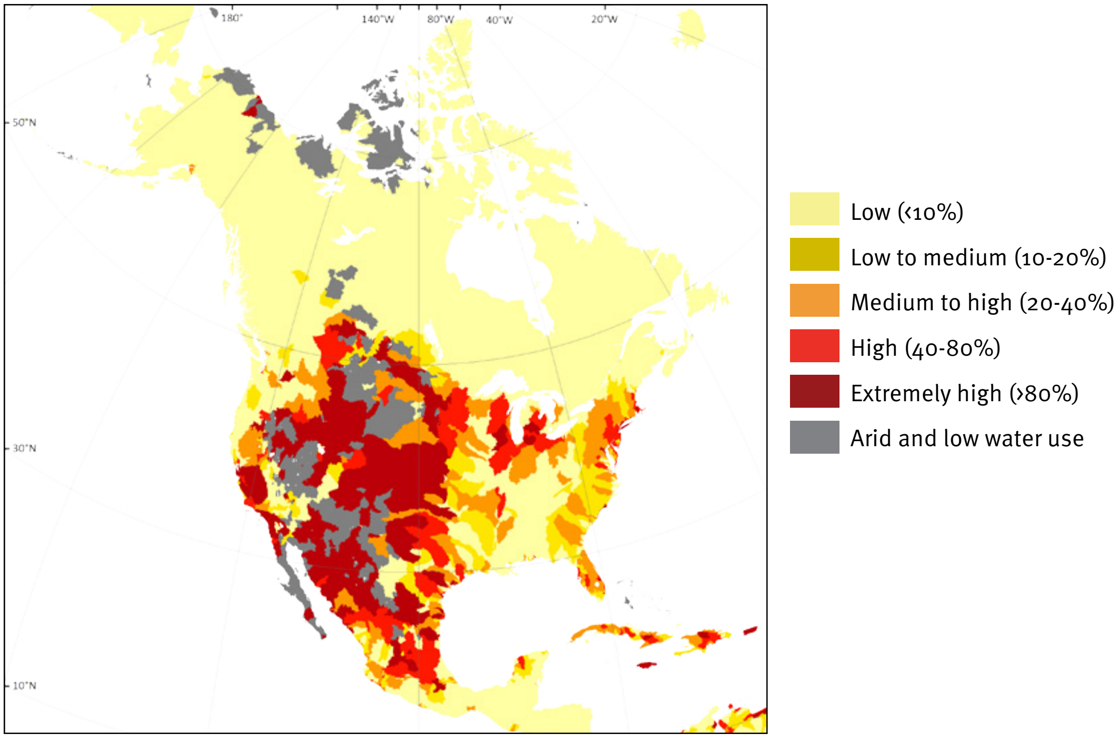
Sources: ICMM (2013), Hatch (2013).

Water is critical to mining. A clean, reliable water supply is needed for processing ore and water management, including control of pollutant releases, is central to mine operations and planning for mine decommissioning. Water is also essential for domestic use and for agriculture and other types of economic development. Modern mining methods emphasize the reuse of water by returning it from the waste stream to the beneficiation process (milling). This reduces the amount of fresh water required, reduces the volume of waste to be treated, and benefits the communities surrounding mining operations.

Climate change brings uncertainty and risks to water quantity, varying with the region and the season. Expected changes include both higher peak flows and increased drought. Figure 28 shows current levels of water stress across North America. Gold and copper mines in the southwestern United States (southern California, Nevada and Arizona) and northern Mexico (Sonora) operate in areas with extreme water stress and climate change models project that there will be further severe reductions in water availability in these areas by the end of the century (ICMM 2013). Mining companies are building projected increases in water shortages into their planning. Rio Tinto, for example, a global company with mines concentrated in Australia and North America, has developed a strategy to reduce water use in its operations and prepare for future shortages (Rio Tinto 2013).

Climate change can affect temperatures, rainfall, snowmelt, and evaporation rates and patterns, all of which combine and interact through the chemical, physical and biological processes that determine water quality (Anawar 2013). Pollutant releases and their impacts are affected by these conditions. Amounts of toxic pollutants in the water may increase, for example, if changing conditions lead to greater release of some metals from organic matter. The impact of the pollutants can also change. Increased water temperature, for example, can lead to an increase in toxicity of metals, including copper and cadmium, to aquatic life, though the effects of temperature vary with species and environmental conditions (Holmstrup et al. 2010).

Figure 28. **Baseline Water Stress in North America**



Note: Levels of water stress are water withdrawals as a percentage of total water flows.
Source: World Resources Institute (Gassert et al. 2015).

Building climate change into planning for mine decommissioning is of particular importance, given the need for long-term stability of structures and long-term effectiveness of reclamation measures. In northern Canada, changing permafrost conditions and projected higher peak flow conditions are taken into account in mine decommissioning. One of the first mine reclamation plans to incorporate these considerations was for the Polaris mine, a lead-zinc mine in the high Arctic that ceased operations in 2002 (Cowan et al. 2013). In northern Yukon, where warming has been marked over the past 50 years (Bush et al. 2014), an asbestos mine ceased operations in 1978, leaving tailings that eroded into streams, damaging and destroying fish habitat. The erosion resulted from permafrost degradation that had not been anticipated in site remediation plans (Pearce et al. 2011, Duerden et al. 2014).

Uncertainty about future climate conditions and how these will influence environments adds a level of complexity to mining assessment and planning. Tools like vulnerability assessment and development of scenarios with climate change projections can help to plan, operate and decommission mines that are resilient to climate change (CEC 2014b).

References

American Geosciences Institute. 2016. What are environmental regulations on mining activities? http://www.americangeosciences.org/critical-issues/faq/what-are-regulations-mining-activities. Consulted on 15 July 2016

Anawar, H.M. 2013. Impact of climate change on acid mine drainage generation and contaminant transport in water ecosystems of semi-arid and arid mining areas. *Physics and Chemistry of the Earth, Parts A/B/C* 58–60: 13–21

Arezki, R., and A. Matsumoto. 2015. *Metals and oil: A tale of two commodities*. International Monetary Fund. Available at: https://blog-imfdirect.imf.org/2015/09/14/metals-and-oil-a-tale-of-two-commodities/

Artisanal Gold Council. 2016. Projects. http://www.artisanalgold.org/our-projects. Consulted on 30 October 2016

Asif, Z., and Z. Chen. 2016. Environmental management in North American mining sector. *Environ Sci Pollut Res Int* 23 (1): 167–79

Auditor General of British Columbia. 2016. *An Audit of Compliance and Enforcement of the Mining Sector*. Office of the Auditor General of British Columbia. Available at: http://www.bcauditor.com/pubs/2016/audit-compliance-and-enforcement-mining-sector

Baffinland Iron Ore Mines Corporation and the Qikiqtani Inuit Association. 2013. *The Mary River Project Inuit Impact and Benefit Agreement*

Baldé, C.P., F. Wang, R. Kuehr, and J. Huisman. 2015. *The global e-waste monitor 2014. United Nations University, IAS – SCYCLE, Bonn, Germany*. United Nations University Institute for Advanced Study of Sustainability

Baldwin, C., and J. Fipke. 2010. *Canadian mining law*. Paper presented at a Rocky Mountain Mineral Law Foundation Mining Law Short course, Boulder CO (May 11-15, 2009). Lawson Lundell LLP. Available at: http://www.lawsonlundell.com/media/news/135_CanadianMiningLaw.pdf

Basurto, D., and R. Soza. 2007. *Mexico's federal waste regulations: An overview*. Air and Waste Management Association

Bauer, A. 2007. Image:heapLeaching.png. BioMineWiki. Illustration by Anna Bauer. http://wiki.biomine.skelleftea.se/wiki/index.php/Image:HeapLeaching.png

Berndt, M.E. 2003. *Mercury and Mining in Minnesota*. St. Paul: Minnesota Department of Natural Resources, Division of Lands and Minerals, Minerals Coordinating Committee

BLM. 2015. Abandoned mine lands portal. Bureau of Land Management. http://www.abandonedmines.gov/index-2.html. Consulted on 11 July 2016

BLM, and Forest Service. 2007. *Abandoned mine lands: A decade of progress reclaiming hardrock mines*. BLM Publication Number BLM-WO-GI-07-013-3720. US Department of the Interior, Bureau of Land Management and US Department of Agriculture, US Forest Service. Available at: http://www.dtsc.ca.gov/SiteCleanup/upload/AML_Ten-Year_Rpt.pdf

Blodgett, S. 2004. *Environmental Impacts of Aggregate and Stone Mining*. Center for Science in Public Participation. Available at: http://www.csp2.org/files/reports/Environmental Impacts of Sand and Gravel Operations in New Mexico.doc.pdf

BLS. 2016. Bureau of Labor Statistics. US Department of Labor. http://www.bls.gov/home.htm. Consulted on 15 July 2016

Brasdefer, L., R. Contreras, and J. Enriquez. 2016. Mining in Mexico: A destination for Canadian investments. *Negocios ProMéxico* February: 30–31

Briseño, O. 2017. Personal communication, March 2017. Grupo México

Bush, E.J., J.W. Loder, T.S. James, L.D. Mortsch, and S.J. Cohen. 2014. An overview of Canada's changing climate. In *Canada in a changing climate: Sector perspectives on impacts and adaptation*, 23–64. Ottawa, ON: Government of Canada

Butler, J. 2013. Environmental regulation of Nevada's mining industry. *Nevada Lawyer* April: 8–11

Camacho, A., E. Van Brussel, L. Carrizales, R. Flores-ramírez, B. Verduzco, S.R. Huerta, M. Leon, and F. Díaz-barriga. 2016. Mercury mining in Mexico: I . Community engagement to improve health outcomes from artisanal mining. *Annals of Global Health* 82 (1): 149–55

Campa, M.F., and P.J. Coney. 1983. Tectono-stratigraphic terranes and mineral resource distributions in México. *Canadian Journal of Earth Sciences* 20 (6): 1040–51

Camprubí, A. 2009. Major metallogenic provinces and epochs of Mexico. *SGA News* 25 (June): 1, 7–20

Canadian Nuclear Safety Commission. 2014. "Regulatory oversight report for uranium and nuclear substance processing facilities in Canada: 2014". http://www.nuclearsafety.gc.ca/eng/resources/publications/reports/2014-CNSC-staff-report-performance-of-uranium-and-nuclear-substance-processing-facilities/index.cfm. Consulted on 20 October 2016

CEC. 2013. *An assessment of primary and secondary mercury supplies in Mexico*. Montreal, QC: Commission for Environmental Cooperation

CEC. 2014a. *Action plan to enhance the comparability of Pollutant Release and Transfer Registers (PRTRs) in North America*. Montreal, QC: Commission for Environmental Cooperation. Available at: http://www3.cec.org/islandora/en/item/11583-action-plan-enhance-comparability-pollutant-release-and-transfer-registers-prtrs-en.pdf

CEC. 2014b. *Conservation assessment for the Big Bend-Rio Bravo Regio: A binational conservation approach to conservation*. Montreal, QC: Commission for Environmental Cooperation

CEC. 2014c. *Taking stock vol. 14: Exploring changes in PRTR reporting, 2005-2010, with a focus on releases to air and water from pulp, paper and paperboard mills*. Montreal, QC: Commission for Environmental Cooperation

CEC. 2016. "PRTR reporting requirements". http://www.cec.org/tools-and-resources/taking-stock/prtr-reporting-requirements. Consulted on 7 July 2016

Ciacci, L., E.M. Harper, N.T. Nassar, B.K. Reck, and T.E. Graedel. 2016. Metal dissipation and inefficient recycling intensify climate forcing. *Environmental Science & Technology (in review)*

CIM Council. 2014. *CIM definition standards - For mineral resources and mineral reserves. Adopted by CIM Council on May 10, 2014*. Canadian Institute of Mining, Metallurgy and Petroleum. Available at: http://web.cim.org/standards/menupage.cfm?sections=177&menu=178

Clark, K.F., and D.C. Fitch. 2009. *Evolution of metallic deposits in time and space in Mexico*. University of Texas at El Paso. Available at: http://www.geo.utep.edu/pub/Clark-Fitch/ClarkandFitchJan2013.pdf

Clements, W.H., and C. Kotalik. 2016. Effects of major ions on natural benthic communities: an experimental assessment of the US Environmental Protection Agency aquatic life benchmark for conductivity. *Freshwater Science* 35 (1): 126–38

CMIC. 2014. *Pre-feasibility report of the ESI Water Working Group*. Canada Mining Innovation Council. Available at: http://www.cmic-ccim.org/wp-content/uploads/2014/06/20140612__ESI-Water-Working-Group-Pre-Feasibility-Study-Report.pdf

Colorado School of Mines. 2016. "Inside.Mines: Sustainability". https://inside.mines.edu/SUS-Sustainability. Consulted on 8 August 2016

Columbia Center on Sustainable Investment, UNDP, UN Sustainable Development Solutions Network, and World Economic Forum. 2016a. *Mapping mining to the sustainable development goals: A preliminary atlas (executive summary)*. Geneva: World Economic Forum

Columbia Center on Sustainable Investment, UNDP, UN Sustainable Development Solutions Network, and World Economic Forum. 2016b. *Mapping mining to the sustainable development goals: A preliminary atlas (white paper)*. Geneva: World Econommic Forum

Compound Interest. 2014. "The chemical elements of a smartphone". www.compoundchem.com/2014/02/19/the-chemical-elements-of-a-smartphone/

Cormier, S.M., S.P. Wilkes, and L. Zheng. 2013. Relationship of land use and elevated ionic strength in Appalachian watersheds. *Environmental Toxicology and Chemistry* 32 (2): 296–303

Cowan, W.R., and W.O. Mackasey. 2006. *Rehabilitating abandoned mines in Canada: A toolkit of funding options*. Sudbury, ON: Cowan Minerals Ltd. (prepared for National Orphaned/Abandoned Mines Initiative)

Cowan, W.R., W.O. Mackasey, and J.G.A. Robertson. 2013. *Case studies and decision making process for the relinquishment of closed mine sites*. Cowan Minerals Ltd. (prepared for National Orphaned/Abandoned Mines Initiative)

Damigos, D. 2006. An overview of environmental valuation methods for the mining industry. *Journal of Cleaner Production* 14 (3): 234–47

Dance, A. 2015. Northern reclamation in Canada: Contemporary policy and practice for new and legacy mines. *41 The Northern Review* 41 (2015): 41–80

Dashwood, H.S. 2014. Sustainable development and industry self-regulation developments in the global mining sector. *Business & Society* 53 (4): 551–82

Duerden, F., T. Pearce, J. Ford, and J. Pittman. 2014. *Case studies of adaptation to climate change in the Yukon mining sector: From planning and operation to remediation and restoration*. Ottawa, ON: Report submitted to Climate Change Impacts and Adaptation Division, Natural Resources Canada

Eagles-Smith, C.A., J.G. Wiener, C. Eckley, J.J. Willacker, D.C. Evers, M. Marvin-DiPasquale, D. Obrist, et al. 2016. Mercury in western North America: An overview of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife. *Science of the Total Environment* 568 (January): 1213–26

Eamer, J., L. Wakelyn, and S. King. 2015. Industrial development activity in terrestrial ecosystems, with a focus on cumulative effects (North American Arctic). In *The Economics of Ecosystems and Biodiversity (TEEB) scoping study for the Arctic*, edited by Conservation of Arctic Flora and Fauna (CAFF) working group of Arctic Council. Akureyri, Iceland

EC. 2012. *Metal mining technical guidance for environmental effects monitoring*. Gatineau, QC: Environment Canada. Available at: https://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=AEC7C481-1&offset=3&toc=hide

EC. 2013. *Guide for reporting to the National Pollutant Release Inventory (NPRI) 2012 and 2013. Canadian Environmental Protection Act, 1999 (CEPA 1999)*. Gatineau, QC: Environment Canada, National Pollutant Release Inventory

EC. 2015. *Overview of reviewed facility-reported data. National Pollutant Release Inventory (NPRI), 2014*. Environment Canada. Available at: https://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=386BAB5A-1&printfullpage=true

ECCC. 2015. Guidance for the reporting of tailings and waste rock to the National Pollutant Release Inventory (NPRI). Environment and Climate Change Canada. http://ec.gc.ca/inrp-npri/default.asp?lang=En&n=FEC85072-1. Consulted on 17 August 2016

ECCC. 2016a. *Code of practice for the management of PM 2.5 emissions in the potash sector in Canada*. Environment and Climate Change Canada, Mining and Processing Division

ECCC. 2016b. National Pollutant Release Inventory (NPRI) - 2013 Pollutant release and transfer data reported by facilities, single year tabular format. Updated September 29 2016

ECCC. 2017. Criteria air contaminants and related pollutants. Environment and Climate Change Canada. https://www.ec.gc.ca/air/default.asp?lang=En&n=7C43740B-1. Consulted on 2 March 2017

Eckstrand, O.R., W.D. Sinclair, and R.I. Thorpe, ed. 1996. *Geology of Canadian mineral deposit types*. Natural Resources Canada

Emas, R. 2015. *The concept of sustainable development : Definition and defining principles (brief for GSDR)*

Esteller, M.V., E. Domínguez-Mariani, S.E. Garrido, and M. Avilés. 2015. Groundwater pollution by arsenic and other toxic elements in an abandoned silver mine, Mexico. *Environmental Earth Sciences* 74 (4): 2893–2906

Fraser Institute. 2012. What is the Social Licence to Operate (SLO)?. http://www.miningfacts.org/Communities/What-is-the-social-licence-to-operate/

Freeport-McMoRan. 2014. *Mining reclamation in North America: Supporting a sustainable future*. Available at: http://www.fcx.com/sd/pdf/mining_red_na_2014.pdf?t=257

Gassert, F., M. Landis, M. Luck, P. Reig, and T. Shiao. 2015. *Aqueduct Global Maps 2.1. Indicators*. Washington, DC: World Resources Institute. Available at: http://www.wri.org/publication/aqueduct-global-maps-21-indicators

GlobeScan. 2014. *Mining industry report/2014*. Globescan and International Council on Mining and Metals

GlobeScan. 2017. GlobeScan Radar. http://www.globescan.com/news-and-analysis/globescan-radar.html. Consulted on 19 April 2017

González Sanchez, F., and A. Camprubí. 2010. La pequeña minería en México. *Boletín de la Sociedad Geológica Mexicana* 62 (1): 101–8

Graedel, T.E., E.M. Harper, N.T. Nassar, and B.K. Reck. 2015. On the materials basis of modern society. *Proceedings of the National Academy of Sciences of the United States of America* 112 (20): 6295–6300

Grewal, I. 2016. Mineral processing introduction. Met-Solve Laboratories Inc. http://met-solvelabs.com/library/articles/mineral-processing-introduction. Consulted on 20 July 2016

GRI. 2016. Empowering sustainable decisions. Global Reporting Initiatives. https://www.globalreporting.org/Pages/default.aspx. Consulted on 8 August 2016

Hanchar, J.C., and A.D. Kerr. 2012. *Mineral commodities of Newfoundland and Labrador: Iron ore*. St John's, NL: Geological Survey Mineral Commodities Series Number 7. Newfoundland Labrador Natural Resources

Hatch. 2013. *Environmental analysis of the mining industry in Canada*. Prepared for the Canadian Mining Innovation Council (CMIC)

Hendry, M.J., A. Biswas, J. Essilfie-Dughan, N. Chen, S.J. Day, and S.L. Barbour. 2015. Reservoirs of selenium in coal waste rock: Elk Valley, British Columbia, Canada. *Environmental Science & Technology* 49 (13): 8228–36

Holmstrup, M., A.M. Bindesbøl, G.J. Oostingh, A. Duschl, V. Scheil, H.R. Köhler, S. Loureiro, et al. 2010. Interactions between effects of environmental chemicals and natural stressors: A review. *Science of the Total Environment* 408 (18): 3746–62

Horvath, J. 2011. *Development and implementation of a closure and remediation plan : A case study of the Faro Mine closure project, YT*. Kingston Ontario: Queen's University

Hudson, T.L., F.D. Fox, and G.S. Plumlee. 1999. *Metal mining and the environment*. Alexandria, VA: AGI Environmental Awareness Series. American Geological Institute

ICMM. 2012. *Mining's contribution to sustainable development – An overview*. International Council on Mining and Metals

ICMM. 2013. *Adapting to a changing climate: Implications for the mining and metals industry*. London: International Council on Mining and Metals

ICMM. 2015a. *Indigenous Peoples and mining. Good practice guide*. International Council on Mining and Metals

ICMM. 2015b. "International Council on Mining and Metals (ICMM) statement on climate change". http://www.icmm.com/. Consulted on 23 May 2016

ICMM and GlobeScan. 2014. *2014 ICMM stakeholder perception study: Tracking progress*. International Council on Mining and Metals and GlobeScan. Available at: http://www.icmm.com/document/8615

IIED. 2002. *Breaking new ground: The report of the Mining, Minerals and Sustainable Development Project*. London: Earthscan Publications Ltd. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25129583

IMF. 2015. *World Economic Outlook: Adjusting to lower commodity prices*. Washington: International Monetary Fund. Available at: https://www.imf.org/external/pubs/ft/weo/2015/02/pdf/text.pdf

IMF. 2016a. International Monetary Fund primary commodity prices. http://www.imf.org/external/np/res/commod/index.aspx. Consulted on 30 June 2016

IMF. 2016b. *World economic outlook: Too slow for too long*. World Economic and Financial Surveys. Washington: International Monetary Fund

Independent Expert Engineering Investigation and Review Panel. 2015. *Report on Mount Polley tailings storage facility breach*. Province of British Columbia. Available at: https://www.mountpolleyreviewpanel.ca/final-report

ISRI. 2015. Recycling. Institute of Scrap Recycling Industries, Inc. http://www.isri.org/docs/default-source/recycling-industry/facts-and-figures-fact-sheet---recycling.pdf?sfvrsn=16

ISRI. 2016. *The ISRI scrap yearbook 2016*. Institute of Scrap Recycling Industries, Inc. Available at: https://cld.bz/Sk9SJhe#

Izatt, R.M., S.R. Izatt, R.L. Bruening, N.E. Izatt, and B.A. Moyer. 2014. Challenges to achievement of metal sustainability in our high-tech society. *Chemical Society reviews* 43 (8): 2451–75

Jamieson, H.E. 2014. The legacy of arsenic contamination from mining and processing refractory gold ore at Giant Mine, Yellowknife, Northwest Territories, Canada. *Reviews in Mineralogy and Geochemistry* 79 (1): 533–51

Jiménez, G. 2016. Personal communication, November 2016. University of British Columbia, Norman B. Keevil Institute of Mining Engineering

Kelly, T.D., and G.R. Matos. 2016. Historical statistics for mineral and material commodities in the United States. (US Geological Survey Data Series 140; 2014 version). http://minerals.usgs.gov/minerals/pubs/historical-statistics/. Consulted on 4 July 2016

Kogel, J.E., N.C. Trivedi, J.M. Barker, and S.T. Krukowski, ed. 2006. *Industrial minerals and rocks: Commodities, markets, and uses*. 7th ed. Littleton, CO: Society for Mining Metallurgy, and Exploration

Kondos, P., and C. Weatherell. 2014. *Towards Zero Waste Mining: The evolution of Canada's mineral sector*. Factsheet. Canada Mining innovation Council. Available at: http://www.parl.gc.ca/Content/HOC/Committee/412/FINA/WebDoc/WD6615327/412_FINA_PBC2014_Briefs%5CCanadaMiningInnovationCouncil-e.pdf

Kondos, P., and C. Weatherell. 2016. *Towards zero waste mining: Fundamentally transforming Canada's mineral sector*. A submission to Finance Canada for Budget 2016. Canada Mining Innovation Council

Kuchapski, K.A., and J.B. Rasmussen. 2015. Surface coal mining influences on macroinvertebrate assemblages in streams of the Canadian Rocky Mountains. *Environmental Toxicology and Chemistry* 34 (9): 2138–48

Laird, K.R., B. Das, and B.F. Cumming. 2014. Enrichment of uranium, arsenic, molybdenum, and selenium in sediment cores from boreal lakes adjacent to northern Saskatchewan uranium mines. *Lake and Reservoir Management* 30 (4): 344–57

Long, K.R., J.H. DeYoung Jr., and S. Ludington. 1998. *Database of significant deposits of gold, silver, copper, lead, and zinc in the United States*. Open File Report 98-206-A,B. US Geological Survey. Available at: https://pubs.er.usgs.gov/publication/ofr98206AB

MAC. 2016a. The Mining Association of Canada. http://mining.ca/. Consulted on 23 May 2016

MAC. 2016b. Towards Sustainable Mining. Mining Association of Canada. http://mining.ca/towards-sustainable-mining. Consulted on 25 May 2016

MacDonald, A. 2002. *Industry in transition: A profile of the North American mining sector*. Winnipeg: International Institute for Sustainable Development

Marshall, B. 2015. *Facts and figures of the Canadian mining industry: F&F 2015*. The Mining Association of Canada

McLeod, C.R., and S.R. Morison. 1995. Placer gold, platinum. In *Geology of Canadian mineral deposit types*, edited by O.R Eckstrand, W.D. Sinclair, and R.I. Thorpe. Geological Survey of Canada, Geology of Canada Series No. 8

Mendoza, R.C., and A. Jiménez. 2016. Mining 2015: Mexico. Latin Lawyer, the business law resource for Latin America. http://latinlawyer.com/reference/topics/46/mining/. Consulted on 31 May 2016

Mendoza Sammet, A. 2008. *Cumulative effects in Mexico: Legislation and practice*. Conference paper presented at "Assessing and managing cumulative environmental effects", 6-9 November 2008, Calgary, AB. International Association for Impact Assessment

Mine-Engineer.com. 2016. "Why do we mine? Why mining is necessary". http://mine-engineer.com/mining/mine2.htm. Consulted on 6 November 2016

Minerals UK. 2016. World mineral statistics data. Minerals UK Centre for Sustainable Mineral Development. https://www.bgs.ac.uk/mineralsuk/statistics/wms.cfc?method=searchWMS. Consulted on 2 November 2016

Minería Sustentable. 2016. 15 grandes proyectos que cuentan con licencia social. http://mineriasustentable.com.mx/15-grandes-proyectos-que-cuentan-con-licencia-social/. Consulted on 3 August 2016

MMR. 2016. Mexico mining review 2015. Online version. http://www.mexicominingreview.com/mmronline2015/index.html. Consulted on 31 May 2016

Morton-Bermea, O., R.G. Jiménez-Galicia, J. Castro-Larragoitia, E. Hernández-Álvarez, R. Pérez-Rodríguez, M.E. García-Arreola, I. Gavilán-García, and N. Segovia. 2015. Anthropogenic impact of the use of Hg in mining activities in Cedral S.L.P. Mexico. *Environmental Earth Sciences* 74 (2): 1161–68

NAS. 2007. *Coal: Research and development to support national energy policy*. National Research Council of the National Academies; Committee on Coal Research Technology and Resource Assessments to Inform Energy Policy. National Academies Press

NMA. 2014. *The economic contributions of U.S. mining (2012)*. National Mining Association

NOAMI. 2015. *National Orphaned/Abandoned Mines Initiative NOAMI performance update 2009-2015*. Ottawa: Natural Resources Canada, NOAMI Secretariat

NRCan. 2014. About uranium. Natural Resources Canada. http://www.nrcan.gc.ca/energy/uranium-nuclear/7695. Consulted on 10 October 2016

NRCan. 2016a. Adaptation Platform. Natural Resources Canada. http://www.nrcan.gc.ca/environment/impacts-adaptation/adaptation-platform/10027. Consulted on 1 August 2016

NRCan. 2016b. Annual statistics of mineral production. Natural Resources Canada. http://sead.nrcan.gc.ca/prod-prod/ann-ann-eng.aspx. Consulted on 1 July 2016

NRCan. 2016c. *Canadian mineral production in 2015*. Information Bulletin, March 2016. Available at: http://www.nrcan.gc.ca/mining-materials/resources

NRCan. 2016d. Mineral trade - annual statistics. Natural Resources Canada. http://sead.nrcan.gc.ca/trad-comm/TradeTable.aspx?FileT=1&Lang=en. Consulted on 5 July 2016

NRCan. 2016e. The Atlas of Canada - Indigenous mining agreements. http://atlas.gc.ca/imaema/en/

Olagunju, A., and J.A.E. Gunn. 2016. Integration of environmental assessment with planning and policy-making on a regional scale: a literature review. *Environmental Impact Assessment Review* 61: 68–77

Organization for International Investment. 2016. *Foreign direct investment in the United States: September 2016 report*. Washington, DC. Available at: http://ofii.org/sites/default/files/Foreign Direct Investment in the United States 2016 Report.pdf

Owen, J.R., and D. Kemp. 2013. Social licence and mining: A critical perspective. *Resources Policy* 38 (1). Elsevier: 29–35

Papp, J.F. 2016. *2014 Minerals Yearbook: Recycling-Metals [Advance Release]*. US Geological Survey. Available at: https://minerals.usgs.gov/minerals/pubs/commodity/recycle/myb1-2014-recyc.pdf

PDAC. 2016. e3 Plus. Prospectors and Developers Association of Canada. http://www.pdac.ca/programs/e3-plus. Consulted on 8 August 2016

Pearce, T.D., J.D. Ford, J. Prno, F. Duerden, J. Pittman, M. Beaumier, L. Berrang-Ford, and B. Smit. 2011. Climate change and mining in Canada. *Mitigation and Adaptation Strategies for Global Change* 16 (3): 347–68

Perez, A.A. 2016. The mineral industry of Mexico. In *2013 Minerals Yearbook Mexico [Advance Release]*, edited by USGS. US Geological Survey

Perucca, C.F. 2003. Potash processing in Saskatchewan - A review of process technologies. *CIM Special Volume 53: Industrial Minerals in Canada* 53: 1–5

Pimentel, B.S., E.S. Gonzalez, and G.N.O. Barbosa. 2016. Decision-support models for sustainable mining networks: fundamentals and challenges. *Journal of Cleaner Production* 112: 2145–57

Pirrone, N., and R. Mason, ed. 2009. World emissions of mercury from artisanal and small scale gold mining. In *Mercury Fate and Transport in the Global Atmosphere: Emissions, Measurements and Models*, 131–72. Springer US

Pokhrel, L. r., and B. Dubey. 2013. Global scenarios of metal mining, environmental repercussions, public policies, and sustainability: A review. *Critical Reviews in Environmental Science and Technology* 43 (21): 2352–88

Portales, L., and S. Romero. 2016. *Inconsistencies and limitations of the Social License to Operate: the case of Mexican mining*. Humanistic Management Network Research Paper Series No. 01/16. Universidad de Monterrey

ProMéxico. 2015. *México: Mining*. Government of México. Available at: http://www.promexico.gob.mx/documentos/folletos-sectoriales/mining.pdf

ProMéxico. 2016. Mexican mining: A competitive industry. *Negocios ProMéxico* February: 10–19

Reichl, C., M. Schatz, and G. Zsak. 2016. *World mining data: Volume 31, minerals production*. Vienna: International Organizing Committee for the World Mining Congresses

Rheaume, G., and M. Caron-Vuotari. 2013. *The future of mining in Canada's North: Economic performance and trends*. Conference Board of Canada. Available at: https://www.canada2030.ca/wp-content/uploads/2013/08/Future-of-mining-in-Canadas-north_cfn.pdf

Rio Tinto. 2013. *Rio Tinto and water*. Available at: http://www.export.gov.il/uploadfiles/04_2013/riotinto_and_water.pdf

Roberts, K. 2016. A legacy that no one can afford to inherit: The Gold King disaster and the threat of abandoned hardrock legacy mines. *Journal of the National Association of Administrative Law Judiciary* 36 (1)

Rohrig, B. 2015. Smartphones. Smart chemistry. *ChemMatters*, 10–12.

Santana, V., G. Medina, and A. Torre. 2014. *The Minamata Convention on Mercury and its implementation in the Latin America and Caribbean region*. Montevideo, Uruguay: United Nations Environment Programme

Saunders, J.A., B.E. Pivetz, N. Voorhies, and R.T. Wilkin. 2016. Potential aquifer vulnerability in regions down-gradient from uranium in situ recovery (ISR) sites. *Journal of Environmental Management* 183: 67–83

Seccatore, J., M. Veiga, C. Origliasso, T. Marin, and G. De Tomi. 2014. An estimation of the artisanal small-scale production of gold in the world. *Science of the Total Environment* 496. Elsevier B.V.: 662–67

Secretaría de Economía, ed. 2010. *Statistical yearbook of the Mexican Mining: Extended, 2009 (2010 version)*

Secretaría de Economía. 2013. Medio ambiente y mineria. http://www.siam.economia.gob.mx/work/models/siam/Resource/Avisos/pag_prin.pdf

Secretaría de Economía. 2016. SIAVI: Sistema de Información Arancelaria Vía Internet (tariff number 28054001, mercury). http://www.economia-snci.gob.mx/siavi4/fraccion.php

Semarnat. 2014. *NORMA Oficial Mexicana NOM-165-SEMARNAT-2013, Que establece la lista de sustancias sujetas a reporte para el Registro de Emisiones y Transferencia de Contaminantes.* Diario Oficial Viernes 24 de Enero de 2014. Secretaría de Medio Ambiente y Recursos Naturales. Available at: http://www.profepa.gob.mx/innovaportal/file/6640/1/nom-165-semarnat-2013.pdf

Semarnat. 2016a. Registro de Emisiones y Transferencia de Contaminantes (RETC). http://apps1.semarnat.gob.mx/retc/index.html. Consulted on 24 January 2017

Semarnat. 2016b. RETC data for 2013. Secretaría de Medio Ambiente y Recursos Naturales

SGM, ed. 2014. *Statistical yearbook of the Mexican mining, 2013 (Edition 2014)*. Servicio Geológico Mexicano

Sippl, K., and H. Selin. 2012. Global Policy for Local Livelihoods: Phasing Out Mercury in Artisanal and Small-Scale Gold Mining. *Environment: Science and Policy for Sustainable Development* 54 (April): 18–29

SME. 2014. *The safe and effective use of cyanide in the mining industry*. Society for Mining Metallurgy, and Exploration. Available at: http://www.smenet.org/gpac/

Solomon, G.M., R. Morello-Frosch, L. Zeise, and J.B. Faust. 2016. Cumulative environmental impacts: Science and policy to protect communities. *Annual Review of Public Health* 37 (1). Annual Reviews: 83–96

SSHRC. n.d. "Canadian environmental health atlas: Asbestos production in Canada. (Social Sciences and Humanities Research Council of Canada)." http://www.ehatlas.ca/asbestos/trends/asbestos-production-canada-0#footnote5_er7xspc

Statistics Canada. 2012. *North American Industry Classification System (NAICS) Canada*

Statistics Canada. 2016a. Imports, exports and trade balance of good on a balance-of-payments basis, by country or country grouping. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/gblec02a-eng.htm

Statistics Canada. 2016b. International investment position, Canadian direct investment abroad and foreign direct investment in Canada, by North American Industry Classification System (NAICS) and region. http://www5.statcan.gc.ca/cansim/a26. Consulted on 15 July 2016

Story, R., and T. Yalkin. 2014. *Federal contaminated sites cost*. Office of the Parliamentary Budget Officer of Canada. Available at: http://www.tbs-sct.gc.ca/fcsi-rscf/home-accueil-eng.aspx

Straskraba, V., and R.E. Moran. 1990. Environmental occurrence and impacts of arsenic at gold mining sites in the western United States. *International Journal of Mine Water* 9 (1–4). Springer-Verlag: 181–91

Tetreault, D. 2015. Social environmental mining conflicts in Mexico. *Latin American Perspectives* 42 (5): 48–66

The World Bank. 2013. Artisanal and small-scale mining. http://www.worldbank.org/en/topic/extractiveindustries/brief/artisanal-and-small-scale-mining

Thorpe, M. 2009. The decision in Great Lakes United v. Canada (Minister of Environment): The federal government's responsibility to report on pollution from the mining sector, and beyond? *News Brief: Environmental Law Centre* 24 (2): 8–11

UN. 2016. UN Comtrade Database. 280540 Mercury; 2015 data. United Nations Department of Economic and Social Affairs, Statistics Division. https://comtrade.un.org/. Consulted on 6 November 2016

UN ECE. 2014. *Safety guidelines and good practices for tailings management facilities*. New York and Geneva: United Nations. Available at: https://www.unece.org/fileadmin/DAM/env/documents/2014/TEIA/Publications/1326665_ECE_TMF_Publication.pdf

UNEP. 2012. *Reducing mercury use in artisanal and small-scale gold mining*. United Nations Environment Programme. Available at: http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/ASGM/Techdoc/UNEP Tech Doc APRIL 2012_120608b_web.pdf

UNEP. 2016. Minamata Convention on Mercury. http://www.mercuryconvention.org/Convention/tabid/3426/Default.aspx. Consulted on 1 November 2016

UNEP and IFIA. 2001. *Environmental Aspects of Phosphate and Potash Mining*. United Nations Environment Programme and International Fertilizer Industry Association

United Nations General Assembly. 1987. *Report of the world commission on environment and development: Our common future*. Oslo: United Nations General Assembly, Development and International Co-operation: Environment. Available at: www.un-documents.net/our-common-future.pdf

US BLS. 2012. NAICS 2012 changes since 2007. (US Bureau of Labor Statistics). www.bls.gov/cew/naics2012.xls. Consulted on 1 October 2016

US EIA. 2016a. Data: Coal. US Energy Information Administration. http://www.eia.gov/coal/data.cfm. Consulted on 4 July 2016

US EIA. 2016b. Today in energy: US mining and exploration investment declined 35% in 2015. US Energy Information Administration. http://www.eia.gov/todayinenergy/detail.php?id=24912. Consulted on 1 November 2016

US EPA. 1999. *EPCRA Section 313 industry guidance: Metal mining facilities*. Available at: https://nepis.epa.gov/Exe/ZyNET.exe/20001DOH.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1995+Thru+1999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=

US EPA. 2003. *Final rule to reduce toxic air emissions from taconite iron ore processing facilities (fact sheet)*. Environmental Protection Agency, Office of Air Quality Planning and Standards. Available at: https://www.epa.gov/sites/production/files/2016-04/documents/tiop_fs2.pdf

US EPA. 2011. *Final rule to reduce mercury emissions from gold mine ore processing and production sources (fact sheet)*. Environmental Protection Agency, Office of Air Quality Planning and Standards. Available at: https://www.epa.gov/sites/production/files/2016-01/documents/gold_mines_fs_121610.pdf

US EPA. 2014a. *Reference guide to treatment technologies for mining-influenced water*. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. Available at: https://clu-in.org/download/issues/mining/reference_guide_to_treatment_technologies_for_miw.pdf

US EPA. 2014b. *Toxic Chemical Release Inventory reporting forms and instructions - revised 2013 version*. Environmental Protection Agency. Available at: https://www.epa.gov/sites/production/files/2014-02/documents/rfi_ry2013_120413.pdf

US EPA. 2015. *Toxic Release Inventory (TRI): Basis of OSHA carcinogens*. US Environmental Protection Agency. Available at: https://www.epa.gov/sites/production/files/2015-03/documents/osha_carcinogen_basis_march_2015_0.pdf

US EPA. 2016a. About the National Center for Environmental Assessment. (US Environmental Protection Agency). https://www.epa.gov/aboutepa/about-national-center-environmental-assessment-ncea

US EPA. 2016b. National Enforcement Initiative: Reducing Pollution from Mineral Processing Operations. US Environmental Protection Agency. https://www.epa.gov/enforcement/national-enforcement-initiative-reducing-pollution-mineral-processing-operations. Consulted on 20 December 2016

US EPA. 2016c. Special wastes. US Environmental Protection Agency. https://www.epa.gov/hw/special-wastes. Consulted on 4 December 2016

US EPA. 2016d. Toxics Release Inventory. https://www.epa.gov/toxics-release-inventory-tri-program. Consulted on 8 July 2016

US Fish and Wildlife Service. 2013. Digest of federal resource laws. https://www.fws.gov/laws/lawsdigest/Resourcelaws.html. Consulted on 4 December 2016

US Nuclear Regulatory Commission. 2016. Uranium recovery. http://www.nrc.gov/materials/uranium-recovery.html. Consulted on 4 December 2016

USGS. 1997. *Geologic province map*. US Geological Survey. Available at: http://earthquake.usgs.gov/data/crust/maps.php

USGS. 2005. *Mineral commodity summaries 2005*. US Geologial Survey. Available at: http://minerals.usgs.gov/minerals/pubs/mcs/2005/mcs2005.pdf

USGS. 2008a. *Mineral commodity summaries 2008*. US Geological Survey

USGS. 2008b. *Understanding contaminants associated with mineral deposits*. US Geological Survey Circular 1328. Available at: http://pubs.usgs.gov/circ/1328/

USGS. 2014. *Mineral commodity summaries 2014*. US Geological Survey

USGS. 2016. *Mineral commodity summaries 2016*. US Geologial Survey

Vaughan, S., B.C. Sloan, T.R. Shaw, and R. Hilier. 2012. Federal contaminated sites and their impacts, Chapter 3. In *2012 Spring report of the commissioner of the Environment and Sustainable Development*, 40. Ottawa: Office of the Auditor General of Canada

Veiga, M. 2016. Personal communication, November 2016. University of British Columbia, Norman B. Keevil Institute of Mining Engineering

Veiga, M., G. Angeloci-Santos, and J.A. Meech. 2014. Review of barriers to reduce mercury use in artisanal gold mining. *Extractive Industries and Society* 1 (2). Elsevier Ltd: 351–61

Wellington, T.A.A., and T.E. Mason. 2014. The effects of population growth and advancements in technology on global mineral supply. *Resources Policy* 42. Elsevier: 73–82

West Coast Environmental Law. 2015. Social licence: mob rule or democracy in action?. http://wcel.org/resources/environmental-law-alert/social-licence-mob-rule-or-democracy-action. Consulted on 8 August 2016

Williams, I.D. 2016. Global metal reuse, and formal and informal recycling from electronic and other hig-tech wastes. In *Metal sustainability: Global challenges, consequences, and prospects*, edited by R.M. Izatt. Wiley

YESAB. 2016. How Yukon's assessment process works. Yukon Environmental and Socio-economic Assessment Board. http://www.yesab.ca/the-assessment-process/how-does-yukons-assessment-process-work/. Consulted on 1 December 2016

Zientek, M.L., and G.J. Orris. 2005. *Geology and nonfuel mineral deposits of the United States*. Open-File Report 2005-1294A. US Geologial Survey. Available at: https://pubs.usgs.gov/of/2005/1294/a/of2005-1294a.pdf

Ziglio, G., M. Siligardi, and G. Flaim, ed. 2006. *Biological monitoring of rivers: Applications and perspectives*. Chichester: John Wiley and Sons, Ltd.

3

Releases and Transfers from the North American Mining Sector, 2013

Introduction

The objective of this chapter is to provide additional information about the North American mining industry to help readers interpret the data on the sector's pollutant releases and transfers. As shown in chapter 1, approximately one-third of the approximately 5.23 billion kilograms reported for 2013 by all industry sectors covered by the North American PRTRs was from the mining sector.[32] Much of this amount consisted of pollutants disposed of in tailings and waste rock. A better understanding of the nature of these disposals, as well as the other releases and transfers reported by mining facilities, can provide a starting point to evaluate if and how they pose a risk to human and environmental health.

The analyses in the following sections reveal that releases and transfers are often dominated by one or a few facilities, and that looking at totals, averages, and changes over time may thus be misleading. Much more can be learned by examining PRTR data in greater detail, by specific pollutants, mining types, regions and facilities. Therefore, the data are also disaggregated by reported North American Industry Classification System (NAICS) codes to provide clearer profiles of the eight mining types covered under the three PRTR programs.

These analyses also illustrate that differences among national PRTR reporting requirements strongly affect the data reported by mining facilities. An assessment of these gaps yields additional insights into some of the differences that are particularly important in the context of this extractive sector, which generates very large quantities of waste containing pollutants that, depending on how they are managed, may or may not be of concern. They point to ways in which the three North American PRTRs can be improved to more accurately reflect the activities of this important industry.

3.1 Scope and Methodology

3.1.1 Sources of Data

This analysis examines the data on pollutant releases and transfers, as reported for 2013 by North American mining sector facilities to their respective PRTR program. The data presented are the most recent available for all three countries at the time of writing. They have been compiled into the CEC's integrated North American PRTR database, Taking Stock Online (see chapter 1). The present chapter provides additional analyses of the amounts, types, sources, and management of the pollutants reported by North American mining facilities.

As noted in chapter 1, annual PRTR data are often published with updates one or more times by the national programs after quality assurance/quality control checks and industry revisions, and the data are also periodically refreshed in Taking Stock Online to capture these revisions. It is also important to remember that releases and transfers are reported annually by industrial facilities to meet national requirements and do not necessarily provide a comprehensive listing of all pollutant releases and transfers from each facility. To explore the data reported by the North American mining sector, see Taking Stock Online, at: **www.cec.org/takingstock**.

The data used for the analyses in this chapter are from the NPRI, TRI and RETC datasets from September 2016, November 2016, and August 2014, respectively. The NPRI program made some additional, mainly minor, changes to the 2013 data after September 2016. They are noted in the chapter where they are relevant to data interpretation.[33] The most significant NPRI change was a revision of the Obed coal mine spill report, submitted by the mine owners. Because

32. Readers are reminded that differences among the three PRTRs in industry and pollutant coverage affect the resulting picture of industrial pollution for North America. For more information, see appendix 1.
33. A note about data for Total Reduced Sulfur (TRS): In order to avoid double counting and provide the most accurate view of releases and transfers from this sector, reported amounts of TRS (which is subject only to NPRI reporting) have been removed from all analyses in this chapter. The only reduced sulfur compound emitted by mines in 2013 was carbon disulfide (a constituent of TRS), which is also reported separately under the Canadian PRTR. NPRI reporting requirements changed as of the 2014 reporting year for reporting of TRS and its components, whereby only releases to air of TRS are required to be reported. Because the 2013 data still contain some records with duplicate amounts for TRS and carbon disulfide, these duplicate records have been removed for the purposes of the analyses in this chapter.

the revision corrected several major errors in the facility's original report, all data analyses in this chapter have been adjusted to conform to the revised Obed mine report.

In addition to PRTR data, information from other sources (e.g., industry and media reports for certain mines) has also been included, where it can provide additional context.

3.1.2 Industry Coverage

The facilities included in the analyses and discussion in this chapter are those involved in mining activities, as indicated by their North American Industrial Classification (NAICS) codes.[34] Specifically, this chapter pertains to facilities classified as "mining (except oil and gas)" (NAICS 212), including the following major mining industry groups (at the 4-digit NAICS industry level):

- coal mining (NAICS 2121),
- metal ore mining (NAICS 2122), and
- non-metallic mineral mining and quarrying (NAICS 2123).

The analyses by mining type in section 3.4 are based on reporting aggregated at the 5-digit NAICS industry level (for example, gold and silver ore mining, NAICS 21222). Some facilities that report under NAICS mining codes, however, also operate smelters (NAICS code 33141). In the United States, combined mining and smelting operations may split their chemical reporting to align with the appropriate NAICS codes. In Canada and Mexico one code only is used for reporting for each facility.

3.2 Overview of PRTR Reporting by the North American Mining Sector, 2013

3.2.1 North American and National Profiles

Across North America, 373 mining facilities reported more than 1.67 billion kilograms in releases and transfers for the 2013 reporting year (table 16). This amount represents an increase of approximately 286 million kilograms (or 20 percent) from 2010, the last year for which data were analyzed (see *Taking Stock*, volume 14). Facilities reported a total of 79 pollutants released or transferred in 2013, with 14 pollutants making up 99 percent of the total.

Table 16. **Profiles of PRTR Reporting by the Mining Sector, 2013**

PRTR program	Number of facilities reporting*	Number of Substances*	Total releases and transfers (kg)
Canada NPRI	117	63	770,697,863
United States TRI	182	59	901,359,624
Mexico RETC	74	8	1,244,628
North American mining total	**373**	**79**	**1,673,302,115**

* Reporting values of at least 0.0001 kg.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

34. NAICS code 212, "mining (except oil and gas)" is a subsector in the NAICS classification. "Mining including oil and gas" (NAICS code 21) is the sector. For simplicity, and to conform to common terminology, NAICS code 212 is referred to as the mining sector throughout this report. See chapter 2 for more information.

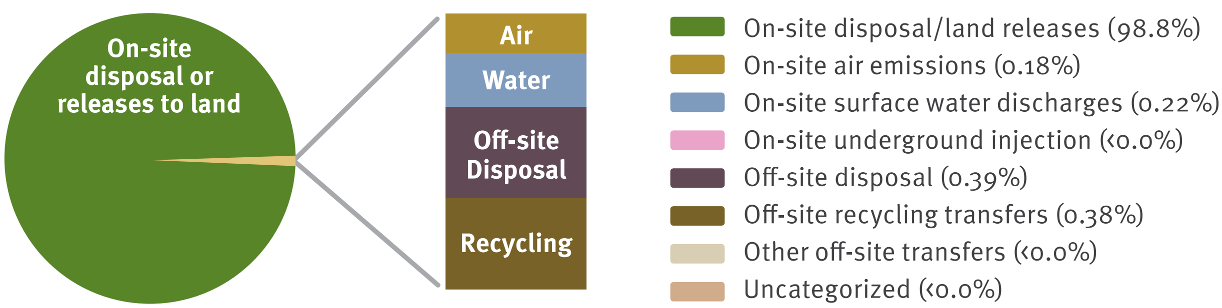
Table 16 provides a breakdown of the North American PRTR data by country. It reveals similarities in the total amounts reported by the Canadian and U.S. mining sectors for 2013. The production value of mining in the United States that year, however, was almost three times that of Canada (chapter 2, section 2.1.3), indicating that, overall, a greater proportion of mining-related releases and transfers is reported through the NPRI than through the TRI. By comparison, Mexico's mining industry is smaller, with half the production value of Canada's mining industry in 2013. Nevertheless, with 74 mining facilities in Mexico that reported, the total mass of pollutant releases and transfers was still far below that of the other two countries—less than 0.1 percent of the North American total.

These national reporting profiles reflect variations in the size and composition of the domestic mining industries, as well as differences in national PRTR reporting requirements for industrial activities and pollutants. Chapter 2 and "Using and Understanding *Taking Stock*" (appendix 1) describe the main features of the three PRTR programs and show how they are similar, as well as how they are unique. The differences among the three systems create gaps in reporting that have important impacts on the North American picture of releases and transfers from the mining sector. These differences are discussed in greater detail in the following sections.

3.2.2 Types of Releases and Transfers Reported

In terms of the total reported for North America for 2013, on-site disposal and land releases made up the vast majority (99 percent) of releases and transfers, followed distantly by off-site disposal (0.4 percent), off-site recycling transfers (0.4 percent), on-site air emissions (0.2 percent) and on-site surface water discharges (0.2 percent) (figure 29).

Figure 29. **North American Mining Releases and Transfers, by Category** (2013)



Total releases and transfers: 1,673,302,115 kg

Note: "Uncategorized" includes data from Canada's NPRI. With the exception of specific pollutants, facilities can report amounts of <1 tonne (1,000 kg) in the "Total releases" category, rather than identify the specific media to which the release occurred.

Metals account for almost all reporting in the off-site transfers to recycling category. As mentioned in chapter 2, there are strong linkages between the prices of metals and minerals and production, and mining companies can benefit from recycling some of the waste generated at their facilities. It can also be profitable for them to transfer mining waste containing valuable raw materials to a processing facility in a neighboring country. North American mining facilities did not report any cross-border transfers of pollutants in 2013, but have done so in previous years (see the Cross-border Transfers tool in Taking Stock Online, at: **www.cec.org/takingstock**).

The national profiles of reported releases and transfers, shown in table 17, reveal significant differences among the countries. This table shows that almost the entire amount of on-site disposal or releases to land in 2013 was reported by Canadian and U.S. facilities. In terms of the mining sector, the category "on-site disposal and land releases"[35] refers mainly to disposal in the form of waste rock and tailings in the United States and Canada. In both the NPRI and the TRI programs, pollutants in waste rock and tailings are required to be reported under specific circumstances that differ between the two countries[36] (chapter 2, section 2.4.2). While tailings and waste rock generally make up the bulk of on-site disposal, some facilities with integrated mineral processing operations also dispose of metals contained in slag from smelters.

The NPRI is the only PRTR system to distinguish between disposals of pollutants to tailings areas and waste rock areas as separate categories, with the data indicating that 83.4 percent of the total mass of on-site disposal and land releases reported by Canadian mining facilities for 2013 was disposal of pollutants to tailings areas, 16.5 percent was pollutants disposed of to waste rock areas, and only 0.15 percent was disposal through on-site landfill and releases to land (calculated from NPRI data (ECCC 2016a).

Table 17. **Mining Sector Reported Releases and Transfers, by Country** (2013)

Release or Transfer Type	Canada NPRI		Mexico RETC		United States TRI	
	Amount (kg)	% of national total	Amount (kg)	% of national total	Amount (kg)	% of national total
ON-SITE						
Releases to Air	1,251,367	0.2%	2,075	0.2%	1,783,926	0.2%
Releases to Water	3,069,265	0.4%	11,206	0.9%	677,022	0.1%
Releases to Underground Injection	--	--	N/A	N/A	50,462	<0.1%
Disposal or Land Releases	760,787,885	98.7%	1,457	0.1%	892,756,664	99.0%
Uncategorized	4,203	<0.1%	N/A	N/A	N/A	N/A
OFF-SITE						
Disposal	3,904,882	0.5%	1,101,851	88.5%	1,478,489	0.2%
Transfers to Recycling	1,634,199	0.2%	128,039	10.3%	4,607,822	0.5%
Other Transfers	46,062	<0.1%	0	0%	5,238	<0.1%
TOTAL	**770,697,863**		**1,244,628**		**901,359,624**	

Notes: "Other transfers" refer to pollutants sent off-site for treatment, energy recovery, or to sewage treatment at publicly-owned treatment works (POTWs). Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. "--" means not reported.

Under Mexico's RETC program, disposal is defined as an off-site transfer and is not included among the on-site reporting categories—with facilities required to report only on-site releases to air, water, or land (see chapter 2, table 13). Additionally, because only beneficiation (or processing) activities must be reported in Mexico, facilities are not required to report the quantities of reportable chemicals disposed of in the form of waste rock. These features of the Mexican PRTR

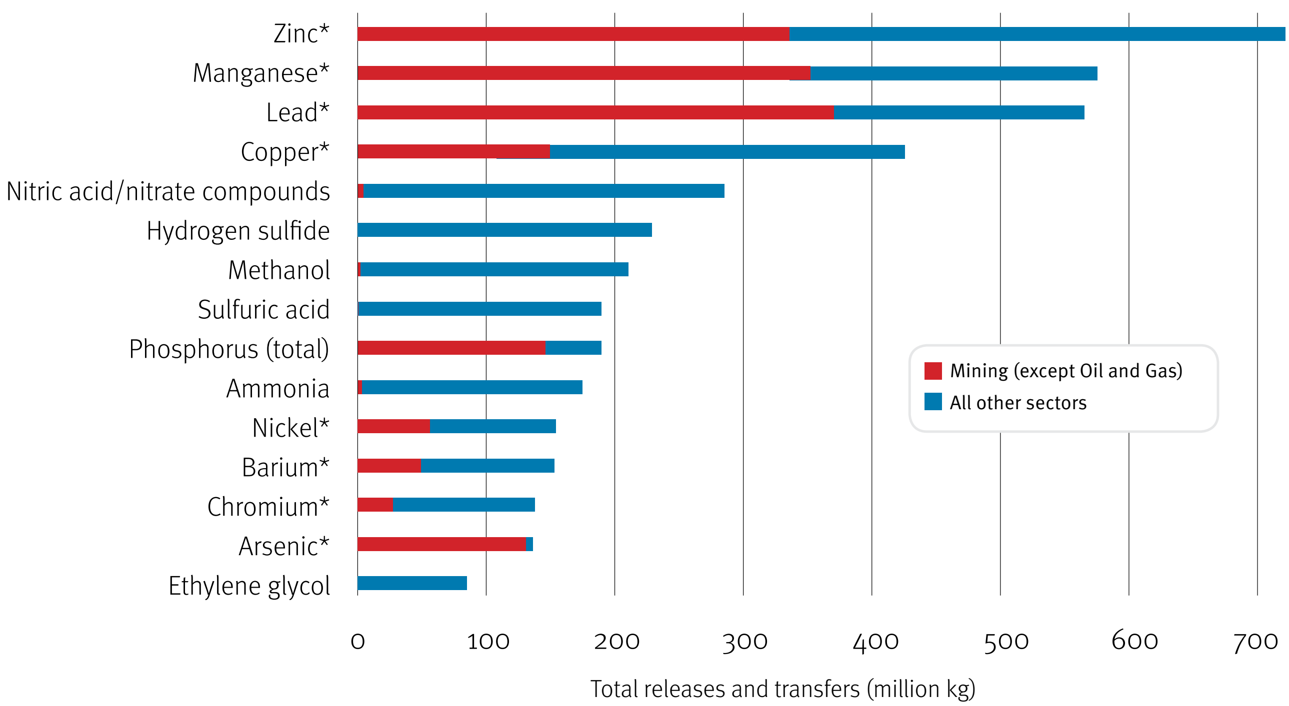
35. This category brings together data for on-site releases to land and disposal that are characterized differently under each of the three PRTR programs, which means the data cannot be completely harmonized at the North American level. See 'Using and Understanding *Taking Stock*" for more details.
36. Tailings are ground rock and effluents produced by a mine processing plant, and disposed of in a tailings pond on the facility site. Waste rock is low-grade ore and other rock that has been excavated, but not processed (see chapter 2, section 2.2.1).

result in the dramatic contrasts in reporting between that country's mining sector and those in the other two countries, because unlike their U.S. and Canadian counterparts Mexican mining facilities did not report any on-site disposal of tailings and waste rock. They reported relatively minor quantities of pollutants released on-site to land, along with some off-site disposal—almost exclusively of cyanides (which accounted for almost 90 percent of all releases and transfers reported for 2013 by that sector in Mexico).

3.2.3 Releases and Transfers by the Mining Sector, in the Context of All Industry Reporting in North America

Mining facilities in North America are a major source of many of the top reported pollutants, especially metals (and their compounds). Of the 5,227,020,104 kilograms of pollutants reported released or transferred in 2013 by all North American industry sectors, more than 1.67 billion kilograms (or 32 percent) were reported by mining facilities (table 16), with metal ore mining accounting for almost all of the total mass of mining pollutants reported.

Figure 30. **Top 15 Pollutants** (by Total Releases and Transfers)**, 2013: Mining vs All Sectors**



Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.
* and its compounds.

Figure 30 presents the contribution of the mining sector to total releases and transfers of the pollutants reported in the largest quantities by all North American industry sectors for 2013. Mining facilities accounted for 95 percent of all arsenic reported, 78 percent of total phosphorus, 66 percent of lead, 61 percent of manganese, 47 percent of zinc, 35 percent of nickel, 35 percent of copper, and 32 percent of barium. The total reported amounts of barium from mining in 2013 were higher than normal (see box 16 in section 3.5.2).

The contribution of the mining sector to releases and transfers of total phosphorus, shown in this graphic, is arguably a gross underestimate, given that this pollutant is only reported in Canada.[37] Similarly, the mining sector's contributions to North American amounts of metals commonly released and deposited during mining operations—notably zinc, manganese and copper (and their compounds)—are likely underrepresented due to lack of reporting by Mexican facilities, since those metals are not subject to RETC reporting.

The issue of gaps created by differences among the national PRTR systems is not specific to the mining sector, but the absence of reporting by metal mines in Mexico of many substances that are typical of the industry draws particular attention to this point, especially in light of the large quantities of waste reported in Canada and the United States. As mentioned above, much of this reported waste consists of substances in tailings and waste rock disposed of on the facility site. In Mexico, on-site disposal is not a RETC reporting category, a factor which amplifies the gaps in reporting across the region.

Chapter 2 (figure 24 and table 9) discussed the main pollutants associated with mining activities and provided an explanation of the typical pathways by which these pollutants, if not properly managed, can enter the environment and have negative impacts. The following sections provide additional information about the releases and transfers and the types of pollutants reported that can help readers interpret the data from the mining sector.

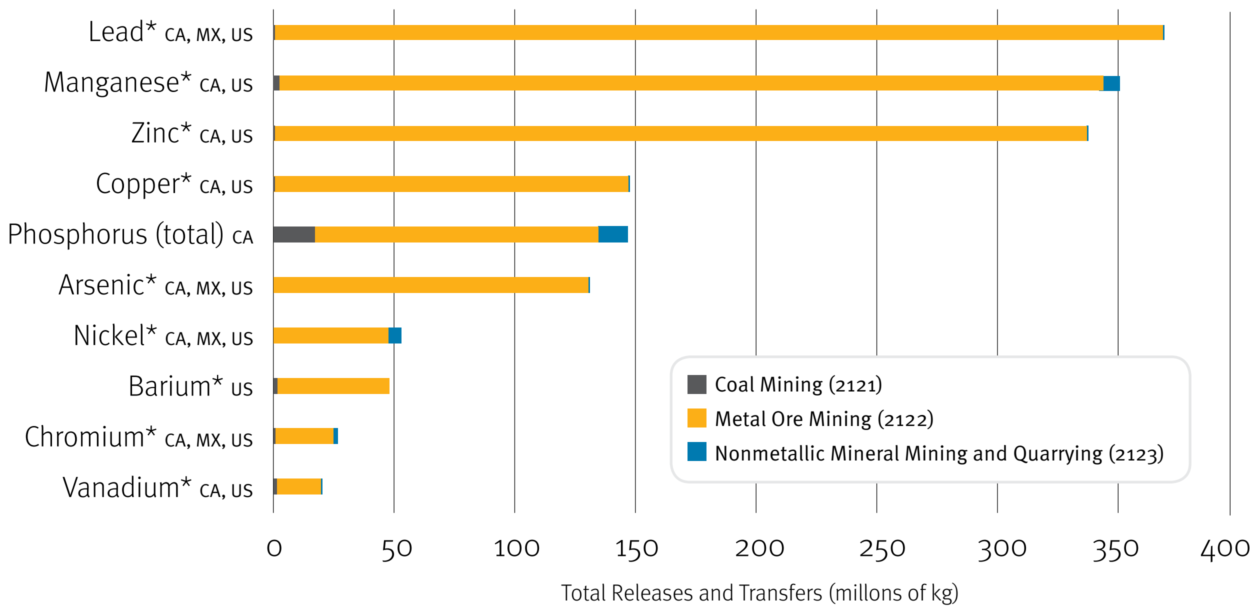
3.3 Understanding Pollutant Releases and Transfers from the Mining Industry

3.3.1 Pollutants Reported in Largest Proportions by the Mining Sector, 2013

Figure 31 presents the top ten pollutants, by total release and transfer quantities, reported by North American mining facilities for 2013. It also indicates the proportion of the total contributed by each of the three main mining industry groups (coal mining, metal ore mining, and non-metallic mineral mining and quarrying). Most of these pollutants are common to the three mining groups and differed only by relative significance (or rank). Exceptions are aluminum, which only appeared among the top ten for coal mining (and was only reported by one coal mining facility in Alberta); lead and barium, which were only released or transferred in substantial quantities from coal and metal ore mining facilities; and ammonia, which was a significant pollutant for coal and non-metallic mineral mining, but not for metal ore mining. Phosphorus (total) was by far the pollutant reported in highest quantities from both coal mining and non-metallic mineral mining and quarrying facilities, even though it is only reported in Canada.

37. The yellow or white physical forms (allotropes) of phosphorus are reported through the TRI, but these forms of phosphorus are not released through mining.

Figure 31. **Top 10 Mining Sector Pollutants, by Total Releases and Transfers,** 2013



Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.
* and its compounds. "CA" = Canada; "MX" = Mexico; "US" = United States.

The top eight substances shown in this figure made up 95 percent of total releases and transfers reported by mining facilities for 2013: lead and its compounds (22 percent), manganese and its compounds (21 percent), zinc and its compounds (20 percent), copper and its compounds (9 percent), total phosphorus (9 percent), arsenic and its compounds (8 percent), nickel and its compounds (3 percent) and barium and its compounds (3 percent). However, only four pollutants of the top ten featured—lead, arsenic, nickel and chromium—are required to be reported under all three PRTR systems.

Along with the variation among the North American PRTRs in the substances subject to reporting, the thresholds triggering pollutant reporting in each country can differ greatly (table 18). For example, the thresholds for arsenic are much higher under the U.S. TRI than under the RETC and the NPRI. Each program sets thresholds for reporting of pollutants that are intended to capture releases and transfers that reflect national industrial activity levels and use of pollutants (specifically, "manufacture, process or otherwise use," or MPO). In addition, Mexico's RETC program also sets pollutant "release" thresholds, which are lower than the MPO thresholds. Each of the three programs has also established lower reporting thresholds for certain substances, in order to capture information about much smaller releases to the environment.[38]

The differences among the PRTRs in pollutant reporting requirements create significant data gaps in the North American picture of pollutant releases and transfers from the mining sector. As a result, the relative importance of each of these substances as mining-related pollutants is somewhat unclear. However, in the same way that gaps among the PRTR programs relative to certain pollutants affect the resulting pollution profiles of other industries, the gaps in reporting of these substances, which are typically associated with mining activities (particularly metal ore mining) are likely to result in a significant underestimation of the sector's overall contribution to pollutant releases and transfers in North America.

38. See List of Pollutants Reported to the North American PRTRs at <**PRTR Reporting Requirements**>.

Table 18. **National Reporting Thresholds for the Top 10 Mining Sector Pollutants**

Pollutant	Canada NPRI	Mexico RETC		United States TRI	
	(MPO) (kg)	(MPO) (kg)	(Release) (kg)	(M,P) (kg)	(Other Use) (kg)
Lead*	50	5	1	45	45
Manganese*	10,000	N/A	N/A	11,340	4,536
Zinc*	10,000	N/A	N/A	11,340	4,536
Copper*	10,000	N/A	N/A	11,340	4,536
Phosphorous (total)	10,000	N/A	N/A	N/A	N/A
Arsenic*	50	5	5	11,340	4,536
Nickel*	10,000	5	1	11,340	4,536
Barium*	N/A	N/A	N/A	11,340	4,536
Chromium*	10,000†	5	1	11,340	4,536
Vanadium*	10,000	N/A	N/A	11,340	4,536

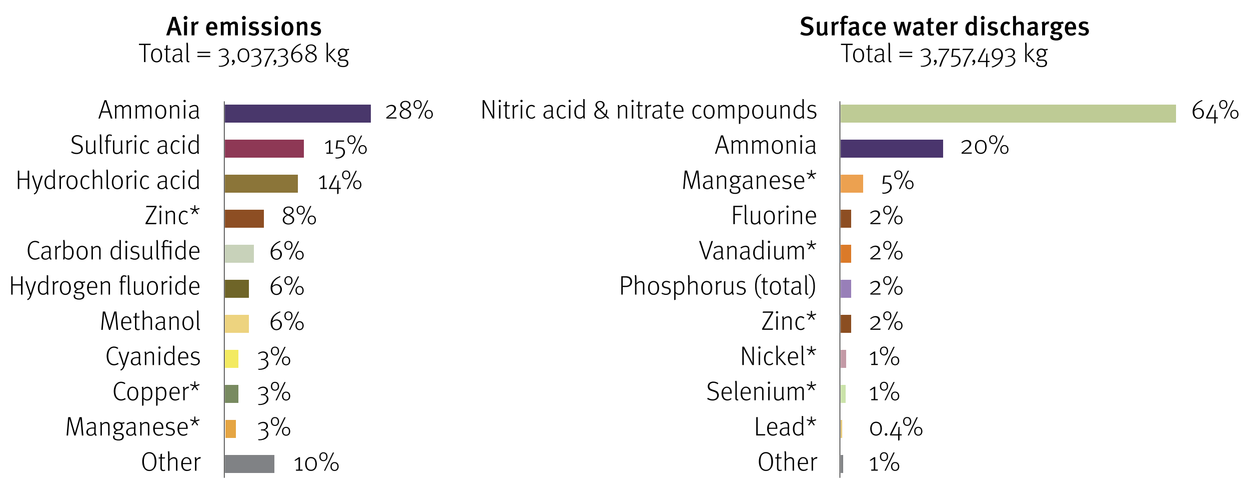
Notes: * and its compounds. "MPO": manufacture, process, or otherwise use. † There is a lower threshold in NPRI for Cr(VI) (hexavalent chromium), a highly toxic form of chromium.

3.3.2 Evaluating Potential Risk from Mining Pollutants

The graphics in the preceding section provide a good snapshot of the pollutants that accounted for a majority of the release and transfer quantities reported by the mining sector for 2013. However, as explained at the beginning of this report, assessing the potential impact of pollutant releases on human or environmental health is a complex task and therefore, factors other than total amounts must be taken into account to understand whether there is potential risk. For example, asbestos disposed of in a secure landfill poses a much different risk than asbestos released to air. The pathways followed by pollutants and the effects of these substances on the environment depend on local climate, topography, and rock, soil and water characteristics; the amount and form of the pollutant released, and its inherent toxicity; exposure or residence time; and so on.

Figure 32 presents the top ten pollutants reported by North American mining facilities for 2013, ranked by amount released to air and water. It shows that non-metals, including ammonia, sulfuric acid and hydrochloric acid, comprised the majority (57 percent) of pollutants reported as air emissions; and that nitric acid and nitrate compounds and ammonia accounted for 84 percent of surface water discharges. Facilities also reported releases, to one or both of these media, of smaller proportions of metals (and their compounds) such as zinc, manganese, vanadium, and copper.

Figure 32. **Ten Pollutants Released to Air and Water in Largest Proportions by the North American Mining Sector** (2013)



Notes: "Other" represents the sum of all other pollutants with reported releases for that medium. As explained in the methodology section, TRS has been removed from all analyses in this chapter to avoid double-counting. Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. * and its compounds.

3.3.3 Toxicity Risk Scores for Air and Water Releases

In addition to assessing total amounts reported, pollutant releases to air and to water can also be evaluated in terms of risk to human health. Section 1.3.2 in chapter 1 presented an explanation of the Toxicity Equivalency Potentials (TEPs) that are used in Taking Stock to indicate risk scores for certain pollutants released to air and water, based on the quantities and toxicity of pollutants. While a TEP score does not constitute a risk assessment, it indicates the potential for risk based on the amount released and the inherent toxicity of a substance, without taking other risk factors into consideration. TEPs are useful because they draw attention to highly toxic substances that are often released in relatively small quantities and may not otherwise be recognized as pollutants of significance.

The mining sector accounted for only 0.7 percent of the total mass of air emissions from all industrial sectors in 2013, and 1.7 percent of the total mass of discharges to water. However, the TEP scores for some of the pollutants released to air and water (table 19) indicate that they have a high potential to negatively impact human health, even in very small amounts. Striking examples include the contrast between the low reported release quantities and high associated cancer and non-cancer risk scores for dioxins and furans, thallium and mercury.

Table 19. **Toxicity Equivalency Potential (TEP) Scores for Selected Pollutants Released to Air and Water by the Mining Sector, 2013**

	On-site Releases to Air			On-site Releases to Water		
Pollutant	kg	Cancer risk score (TEP)	Non-cancer risk score (TEP)	kg	Cancer risk score (TEP)	Non-cancer risk score (TEP)
Arsenic*	6,939	111,016,494	582,836,593	4,332	17,326,044	86,630,221
Cadmium*	2,387	62,061,812	4,535,286,238	1,471	2,794,560	205,914,937
Chromium*	4,797	623,620	14,870,938	4,484	0	1,973,135
Copper*	89,816	0	1,167,611,804	13,381	0	160,574,486
Dioxins and furans	0.0037	4,453,284	3,265,741,336	0.005	3,464,490	2,460,290,000
Lead*	27,072	758,009	15,701,619,981	14,271	28,542	599,387,079
Mercury*	1,421	0	19,887,271,783	60	0	775,970,759
Thallium*	1.81	0	21,772,434	227	0	612,349,700

Note: The TEP score is calculated by multiplying a pollutant's assigned toxicity equivalency potential (TEP) by the pollutant's release amount.
* and its compounds.

When examining the specific pollutant releases that contribute to toxicity risk scores, one or just a few facilities can contribute the bulk of the releases that translate into risk. For example, the arsenic accounting for 60 percent of the calculated risk score for air emissions in 2013 was reported by only three facilities (a Canadian nickel mine; a U.S. copper mine; and a Canadian iron ore mine). Therefore, it is useful to look at pollutant releases at the facility scale, even for those pollutants with small total releases.

As has been mentioned, the majority of pollutant reporting from the mining sector for 2013 was for disposal in waste rock and tailings. In Canada and the United States (where these large disposals were reported), federal and state, provincial or territorial agencies require that waste rock be placed in engineered structures designed to contain contaminants. The main human health and environmental risks from most toxic substances disposed of on land are through the potential for the pollutants to enter surface or groundwater and spread off-site. This can result from a malfunction of the pollutant storage operation on land, such as the breach of a tailings dam; or through runoff and seepage, especially where waste rock or tailings are acid generating. Pollutants disposed of on land may also become airborne through dust. Although risk scores cannot be calculated directly for land storage of toxic substances, the risk that toxics pose can be assessed based on the amounts and forms of the pollutants present at the facility, how they are disposed of and maintained, and other factors influencing the potential for exposure of humans to the pollutants.

3.4 A Closer Look at Pollutant Reporting by Mining Type and Facility

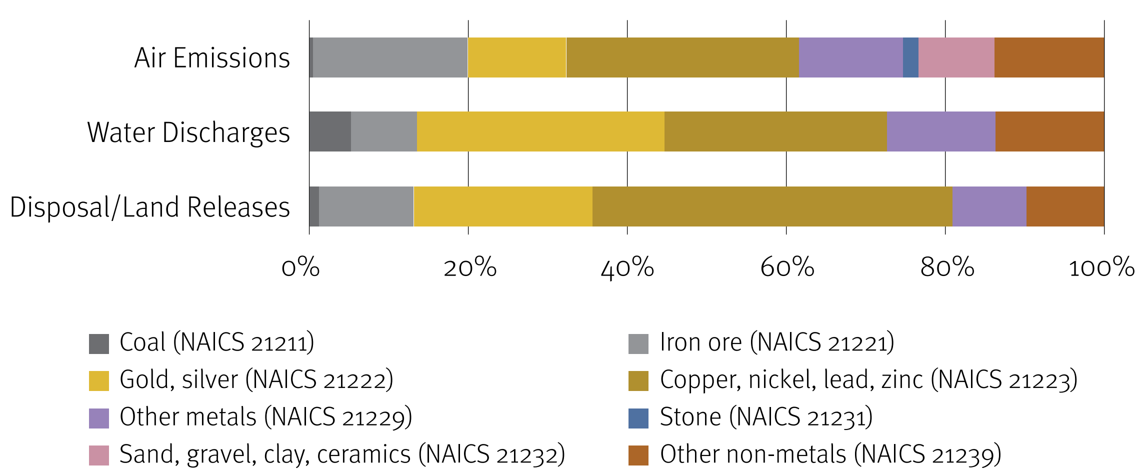
The analyses in the previous sections examined releases and transfers for the mining sector as a whole, and for the three broad mining industry groups: coal mining, metal ore mining, and non-metallic mineral mining and quarrying. While the mix of pollutants used and released or transferred from mines is site-specific, due to the properties of the ore body and the mining and beneficiation processes used to concentrate the minerals, certain pollutants or groups of pollutants tend to be associated with, or are typical of, specific types of mining. Therefore, it is important to examine the data reported by NAICS level 5 codes, as this allows a more nuanced interpretation of the data for the eight mining types included in this report.

These mining types are shown in the two figures below. The quantities and forms of pollutant releases and transfers can vary greatly among the facilities that are grouped together by mining type. This is partly because the NAICS level 5 codes combine mines of quite different types (especially in the two "other" categories: "Other metals" and "Other non-metals"), and partly due to differences in scale, location and nature of the mining operations (figure 33).

Figure 34 presents the top pollutants released or disposed of on site by the North American mining sector in 2013, and indicates the relative proportions contributed by each mining type included in this report. Two mining types: sand, gravel, clay and ceramics; and stone, are excluded from this figure because they contributed less than 0.01 percent of the total of each pollutant.

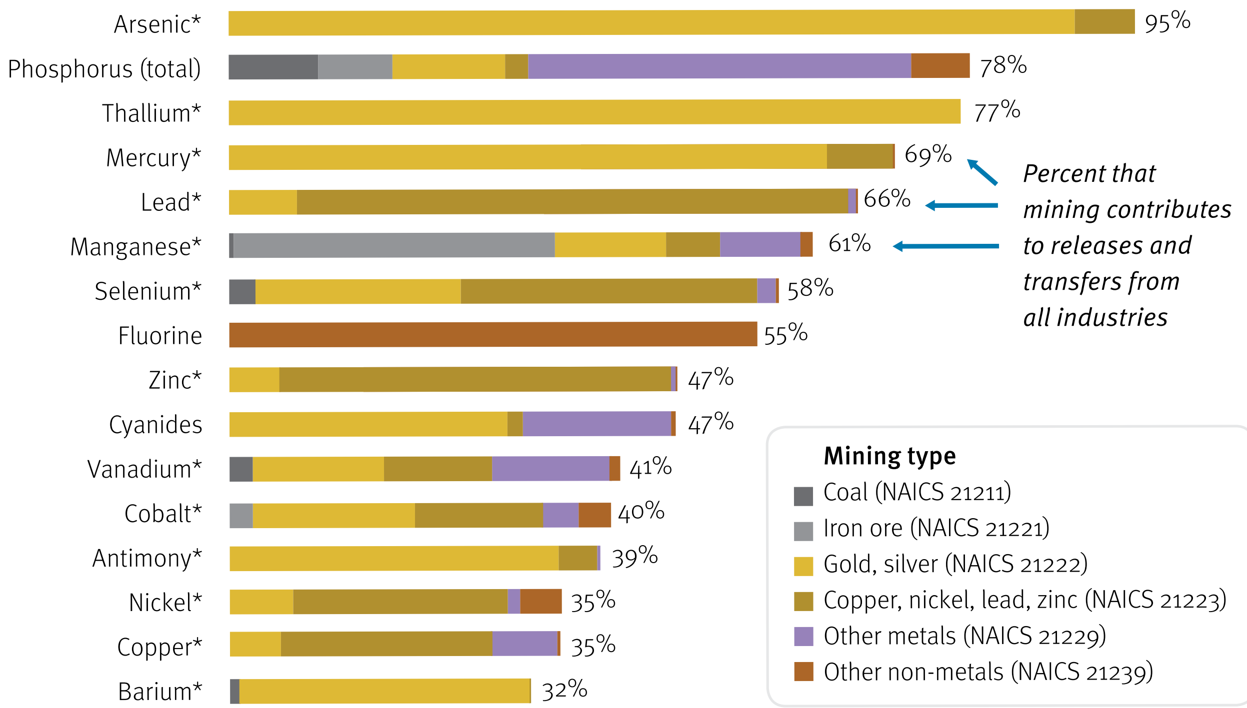
Total amounts of pollutants released and transferred are not very useful for determining the potential pollution and risk to human or environmental health from mining activities, since (as mentioned earlier) a number of other factors need to be considered in order to properly assess potential risk. However, summaries such as those presented in figure 34, provide information on the main pollutants associated with specific mining types and, especially, differences in the types and proportions of pollutants generated during the mining of metal ores, coal and non-metallic minerals.

Figure 33. **Reported On-site Releases to Air and Water, and On-site Disposal or Land Releases, by NAICS-level 5 Mining Type, 2013**



Note: Percentages represent the total for each mining type, for each medium.

Figure 34. **Contribution to Total Mining Sector Releases and Transfers by Selected Pollutants, by Mining Type** (NAICS-level 5), **2013**



Notes: * and its compounds. All pollutants with a contribution of mining to total releases and transfers of over 30 percent are shown. Stone, sand, gravel, clay and ceramics and refractory materials mines and quarries (NAICS codes 21231 and 21232) are omitted, as they represent less than 0.01 percent of the releases of each pollutant.

The next section presents brief summaries, in tabular format, for each NAICS level 5 mining type, including information on the size of the mining sector (from chapter 2); the number of facilities reporting for 2013; and a discussion of the sources and context of the reported pollutant releases to air, water and on-site disposal or land releases that are important because of their quantity and/or their potential impacts for human health or the environment.

Readers should keep in mind that some mines that produce a range of mineral products report through the "other" mining NAICS level 5 mining categories (e.g., "other metal ore mining," NAICS 21229; "other non-metallic mineral mining and quarrying," NAICS 21239). Thus, for example, mines that produce copper and gold, or lead and zinc, may be classified as "other metal ore mining."

3.4.1 Coal Mining

Coal mines reported relatively small amounts of pollutants in on-site disposals or releases. The data in *Taking Stock* do not include criteria air contaminants (CACs), a class of pollutants associated with smog, regional haze, acid rain and respiratory illnesses. CACs such as particulate matter and carbon monoxide are released through combustion and other activities and are common pollution concerns for coal mining facilities. CACs are reported through the Canadian NPRI,

Figure 35. **Coal Mining** (NAICS Code 21211)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$4.7	11
Mexico	$0.4	0
United States	$39.8	52

Coal mining facilities reporting for 2013

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	12,408	237,289	26,315,242
Percent of mining sector total	0.4%	6.3%	1.6%
Top 5 substances[2]	Hydrochloric acid Ammonia Propylene Lead* Benzo(b)fluoranthene	Ammonia Phosphorus (total) Manganese* Selenium* Zinc*	Phosphorus (total) Manganese* Barium* Vanadium* Zinc*

1. From Chapter 2, section 2.1.2
2. Most to least, by mass.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. * and its compounds.

but are not subject to reporting under the other two PRTRs.[39] However, air pollutant data from the NPRI for Canadian coal mines show that coal mining releases large quantities of CACs (especially particulate matter, along with carbon monoxide, nitrogen oxides, volatile organic compounds and sulfur dioxide) compared to air releases of all other substances (ECCC 2016a). Air pollution studies at coal mines in the United States and other locations indicate that high levels of fine particulate matter are often released through surface coal mining (Jaramillo and Muller 2016, Aneja et al. 2012).

Reporting through PRTRs also does not capture the addition of ions to receiving waters. Increases in ions, including sulfate (SO_4^{-2}), chloride (Cl^-), bicarbonate (HCO_3^-), calcium (Ca^{+2}) and magnesium (Mg^{+2}), have been linked to impairment of stream invertebrate communities downstream of U.S. coal mines (chapter 2, table 9).

Phosphorus (total), which is only subject to reporting in Canada, dominated reporting from coal mines. Almost all phosphorus reported (99.8 percent) was as on-site land disposal from the nine coal mines in western Canada. Although minor in quantity in comparison to land disposal, 93 percent of all mining sector discharges of phosphorus to water were from coal mining. Most of the phosphorus released and disposed of was from five coal mines in one region—the Elk River valley in British Columbia— reflecting the importance of regional geology in the make-up of mining wastes. Phosphorus is a nutrient that has the potential to change aquatic ecosystems. However, studies indicates that coal mines have not led to significant changes in available phosphorus or algal growth in the Elk River (Kuchapski and Rasmussen 2015, Hauer and Sexton 2013).

Barium, the third-most abundant substance in deposits to land at coal mines, is only subject to reporting in the United States, where it was reported by ten coal mines.

Selenium is of increasing concern as a pollutant associated with coal mining (chapter 2, table 9). It was reported by nine coal mines in Canada and two in the United States. Water discharges of selenium were reported only for the Canadian mines, with the two U.S. mines reporting disposal to land. The PRTR data likely underestimate releases of selenium. The reporting requirements vary greatly, with over 100 times lower reporting thresholds for the NPRI (100 kg) than for the TRI (11,340 kg) (see the List of Pollutants Reported to the North American PRTRs at <**PRTR Reporting Requirements**>). Selenium is not subject to reporting under Mexico's RETC.

Even if the pollutant threshold is met, all disposals and releases are not necessarily subject to reporting. For example, selenium deposited to land in the form of waste rock was not reported by coal mines in the Elk Valley for 2013 because the waste rock was classified as inert (NPRI comments, ECCC 2016d). All reported disposal to land for these mines was as tailings. Selenium is present in Elk Valley mine waste rock in various chemical forms at an average concentration of 3.12 mg/kg (Hendry et al. 2015). Measurements of selenium in water draining through waste dumps suggest that selenium is released into water through oxidation of selenium-bearing sulfides, which form about 20 percent of the selenium reservoirs in the waste rock (Hendry et al. 2015). Reporting of runoff and seepage water through waste rock, however, is very inconsistent among the three PRTRs.

Releases to water from coal mining for 2013 include data for a spill, caused by a breach in a settling pond wall, at the Obed Mine operated by Coal Valley Resources Inc., Alberta (Cooke et al. 2016). The spill accounted for significant proportions of the total releases to water from coal mining for three of the top water pollutants—phosphorus (total), manganese and zinc—but was not a significant source of ammonia and selenium (table 20). The spill was the only reported coal mining discharge of antimony and cobalt and also accounted for most of the arsenic, chromium, copper and lead reported discharged by coal mines that year. See section 3.5.3 and table 22 for further discussion on this spill.

The immediate effect was scouring and smothering of aquatic habitat and a turbidity plume that spread 1,100 km downstream to the river's delta. Toxicity tests using the released water and sediment indicated a relatively low order of acute toxicity; the spill's potential long-term impacts on downstream aquatic ecosystems continue to be monitored (Cooke et al. 2016).

39. Because CACs are not reported under all three PRTR programs, they are not included in Taking Stock. For an explanation, see chapter 1, and "Using and Understanding *Taking Stock*."

Table 20. **Pollutants spilled at the Obed Coal Mine, Alberta, Canada, compared with other coal mines** (2013)

Pollutant	Spilled at Obed mine (kg)[1]	Released to water from all coal mining (kg)	Percent of all coal mining releases that were from Obed spill
Ammonia	1,762	81,061	2%
Antimony*	29	29	100%
Arsenic*	567	641	88%
Cadmium*	23	114	20%
Chromium*	1,095	1,197	92%
Cobalt*	552	552	100%
Copper*	994	1,223	81%
Lead*	771	816	94%
Manganese*	36,800	39,504	93%
Mercury*	4	10	41%
Nickel*	1,463	4,588	32%
Phosphorus (total)	42,688	80,354	53%
Selenium*	27	16,681	Less than 1%
Vanadium*	1,762	2,015	87%
Zinc *	4,057	8,362	49%
Total	**92,594**	**237,147**	**39%**

1. Revised spill data provided by Environment and Climate Change Canada, December 2016.
* and its compounds.

3.4.2 Iron Ore Mining

Figure 36. **Iron Ore Mining** (NAICS Code 21221)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$5.2	8
Mexico	$0.7	10
United States	$5.4	exempt

Iron ore mining facilities reporting for 2013 →

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	675,704	345,045	212,084,903
Percent of mining sector total	22%	9%	13%
Top 5 substances[2]	Hydrochloric acid Sulfuric acid Hydrogen fluoride Manganese* Aluminum (fume/dust)	Nitric acid/nitrates Manganese* Ammonia Zinc* Nickel*	Manganese* Phosphorus (total) Chromium* Zinc* Cobalt*

1. From Chapter 2, section 2.1.2 2. Most to least, by mass. * and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

While the Canadian and U.S. iron ore mining industries were of a similar size in 2013, U.S. iron ore mining facilities are exempt from PRTR reporting. In Mexico the industry is relatively small, with a 2013 output about ten times lower than in the other two countries. Although ten Mexican iron ore mines filed reports, most of the top substances reported from Canadian and U.S. iron ore beneficiation are not required to be reported in Mexico. The data presented, therefore, mainly reflect the disposals and releases from the eight iron ore mining facilities active in Canada in 2013.

The Iron Ore Company's Carol Project in Labrador accounted for 37 percent of air emissions and 90 percent of disposal and releases to land, but only 15 percent of water discharges. The Carol Project produced about half of Canada's iron ore output in 2013 (Canadian Mining Journal 2013).

Pollutants to Air. Many iron ore facilities include processing furnaces that heat the ore to harden it and form pellets (chapter 2, table 9). Thermal processing produces air pollutants, especially sulfur dioxide, fine particulates and nitrous oxides. These pollutants, which are classified as criteria air contaminants (CACs) and reported only through the Canadian PRTR, are the focus of ongoing source-reduction initiatives at two Canadian iron ore facilities, the Carol Project in Labrador; and ArcelorMittal Exploitation Minière Canada's *Usine de Bouletage de Port-Cartier*, in Quebec (ECCC 2016e). These two facilities accounted for 82 percent of air emissions, excluding CACs, reported by iron ore facilities in 2013. Two pollutants, hydrochloric acid and sulfuric acid, together accounted for 76 percent of total air emissions reported by iron ore mines. Mexican iron ore mines reported only trace amounts of emissions (less than a kilogram in total) of arsenic, cadmium, chromium and lead. The top pollutants emitted to air through iron ore beneficiation (figure 36) are not on the RETC list of pollutants.

Pollutants to Water. Major water discharges were specific to a few facilities. For example, two facilities, ArcelorMittal's *Mine de Mont-Wright* in Quebec and the Mines Wabush Scully facility in Labrador, accounted for 92 percent of releases of nitric acid and nitrate compounds (the pollutant released in largest proportions to water). Nickel, the most toxic of the pollutants reported released to water, was mainly (89 percent) from the Carol Project, with much smaller amounts released from one Mexican and two additional Canadian mines.

Pollutants to Disposal or Land. As on-site disposal is not reported through the RETC, the land releases and disposal category showed low quantities for Mexico. For example, chromium, the third-most abundant substance, was reported as released or disposed of on land in quantities ranging from less than 0.01 kilograms to 4 kilograms, while chromium released or disposed of on land at Canadian mines ranged from about 20,000 to 280,000 kilograms for each mine. Manganese, the top pollutant disposed of on land, is not reported in Mexico. Manganese is associated with some of the iron ore deposits mined in Canada and selective mining and processing are sometimes needed to reduce the manganese content in the product, with manganese being disposed of on-site (Hanchar and Kerr 2012). Iron ore mining accounted for 34 percent of total releases and transfers of manganese from all North American industries, with the Carol Project making up 94 percent of this amount in 2013.

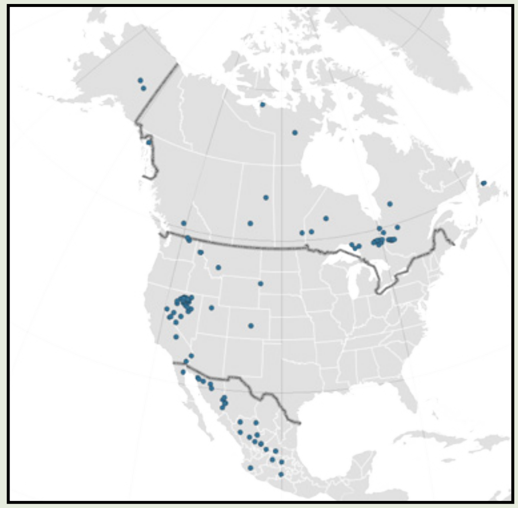
3.4.3 Gold Ore and Silver Ore Mining

Figure 37. **Gold Ore and Silver Ore Mining** (NAICS Code 21222)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$6.4	36
Mexico	$9.8	25
United States	$11.0	39

Gold ore and silver ore mining facilities reporting for 2013



B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	427,315	1,337,661	397,277,553
Percent of mining sector total	14%	36%	24%
Top 5 substances[2]	Zinc* Ammonia Cyanides Hydrogen cyanide Carbon disulfide	Nitric acid/nitrates Ammonia Manganese* Cyanides Arsenic*	Arsenic* Manganese* Barium* Lead* Zinc*

1. From Chapter 2, section 2.1.2 2. Most to least, by mass. * and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

As described in the previous sections, gold and silver mining accounted for significant proportions of total North American industry disposals or releases of several pollutants in 2013: arsenic, thallium, mercury, cyanide, antimony and barium. All except cyanide are constituents of some ore bodies mined for gold and silver, while cyanide is commonly used in processing at gold and silver mines. Of these pollutants, thallium and barium were primarily released through one incidence of land disposal (section 3.5.3).

Arsenic is the most clearly associated pollutant with this mining type, as 89 percent of all North American industry reporting of this mineral in 2013 was associated with gold and silver mines. Arsenic, a common constituent of many ore deposits, especially those mined for gold, was mainly reported as disposals in waste rock, tailings and ore heaps (in leaching operations). On-site disposal is not a RETC reporting category and in Mexico, gold and silver mines reported only very small amounts (typically less than 1 kilogram) of arsenic, mostly as water discharges. Arsenic is readily dissolved in water under both acidic and basic conditions, and is a common pollution issue for operating, decommissioned and abandoned gold and silver mines in all three countries (for example, Straskraba and Moran 1990, Jamieson 2014, Esteller et al. 2015, Razo et al. 2004). Arsenic in water is associated with both cancer and non-cancer toxicity risks (section 3.3.3).

Cyanide, commonly used to dissolve and separate gold and silver through extraction or leaching, is reported under all three national PRTRs. Twenty-nine gold or silver mines reported air emissions of cyanides and 22 mines reported cyanides in water discharges. Reports from a few mines dominated the air emissions of cyanide, notably St. Andrew Goldfields Ltd.'s Holloway mine in Ontario, and the Florida Canyon and Standard Mines facility in Nevada. Water discharges of cyanides for 2013 were mainly (75 percent) from four Canadian gold mines. The bulk of total cyanide comprised on-site disposal, with 60 percent reported by two mines (Barrick Goldstrike Mines Inc. in Nevada and Detour Gold Corporation's Detour Lake Project in Ontario). Despite having a lower reporting threshold for cyanide, Mexican gold and silver mines reported no releases of cyanides to air and only two percent of the total water discharges for this mining type. One Mexican mine, *Minera Real de Ángeles, S.A. de C.V.,* reported substantive off-site disposals of cyanide.

Mercury was used in the past in some silver and gold mines for the same purpose that cyanide is used today. Although this method is generally no longer practiced due to the high toxicity of mercury and its tendency to accumulate in fish and pose a human health risk, mercury is in use in artisanal and small-scale gold mining operations in Mexico (see chapter 2, box 4). Mercury, like arsenic, is often found in ore deposits mined for gold and silver, and thus is present in waste rock and tailings at many sites, and also in air emissions from processing facilities (Eagles-Smith et al. 2016, U.S. EPA 2011). Over 99.9 percent of mercury reported by gold and silver mines in 2013 was as on-site disposals, while the rest was almost all as air emissions. Although the quantities of mercury released rarely bring it into the top lists of pollutants, it ranks second for non-cancer toxicity risk for both air and water releases from all North American industries. The mercury in waste rock and tailings may become dissolved through ARD or moved into stream sediments through erosion or spills. Mercury was disposed of on-site or released to land at 53 mines, but 64 percent of the total was at three Nevada gold mines.

Pollutants to Water. Pollutant releases to water are relatively high for gold and silver mining, making up 36 percent of the total water releases from North American mines. The types of pollutants depend on the processing method used as well as the composition of the ore. Nitric acid and nitrate compounds, which are not subject to reporting in Mexico, were reported released at about one-third of the facilities in the other two countries—with 64 percent coming from three facilities: the Williams Mine in Ontario; Mines Agnico Eagle Ltée.'s *Division Laronde* in Quebec; and the Pogo Mine in Alaska. Ammonia, also not reported in Mexico, was mainly reported by Canadian mines, but not by U.S. mines, although the reporting thresholds are similar. Nickel was reported in water discharges from 19 facilities, with 50 percent being from two mines, Mines Agnico Eagle Ltée.'s *Division Laronde* (Quebec), and Silvermex Resources Inc.'s *La Guitarra Compañía Minera S.A. de C.V.* in Mexico.

3.4.4 Copper, Nickel, Lead and Zinc Mining

The mining of copper, nickel, lead and zinc accounts for the highest proportion of air emissions and disposal or releases to land of any type of mining, and is second only to gold and silver mining in the amount of pollutants discharged to water. This is partly a function of the large volume of material processed during base metal mining. The pollutants that make up significant proportions of total North American industrial releases and transfers for 2013 are all metals (and their compounds): zinc, cobalt, nickel, copper and lead, which were disposed of on-site through tailings and waste rock. These metals are also among the top pollutants reported by the mining industry, overall.

Figure 38. **Copper, Nickel, Lead and Zinc Mining** (NAICS Code 21223)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$8.6	37
Mexico	$4.9	20
United States	$10.8	32

Copper, nickel, lead and zinc mining facilities reporting for 2013

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	1,002,520	1,192,828	815,804,407
Percent of mining sector total	33%	32%	49%
Top 5 substances[2]	Sulfuric acid Methanol Carbon disulfide Zinc* Copper*	Nitric acid/nitrates Ammonia Zinc* Manganese* Nickel*	Lead* Zinc* Copper* Nickel* Manganese*

1. From Chapter 2, section 2.1.2 2. Most to least, by mass. * and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

Pollutants to Air. Most reported air emissions are stack emissions from processing. Sulfuric acid, zinc and copper were reported at many facilities. Carbon disulfide, which is only reported in Canada, was from two Ontario mine/mill complexes. All methanol emissions, however, were fugitive emissions from one facility, Teck America Inc.'s Red Dog Operations in Alaska. Methanol is used in the winter as antifreeze in dust control water (Northwest Arctic Borough 2009).

Pollutants to Water. Nitric acid/nitrate compounds and ammonia were reported in water releases at a relatively small number of facilities, mainly copper mines (12 mines for nitric acid/nitrate compounds, and 9 for ammonia). Zinc was reported in water discharges at many Canadian and U.S. mines, while manganese and nickel were each reported at fewer than 20 mines, with a few mines reporting the bulk of the total amounts discharged.

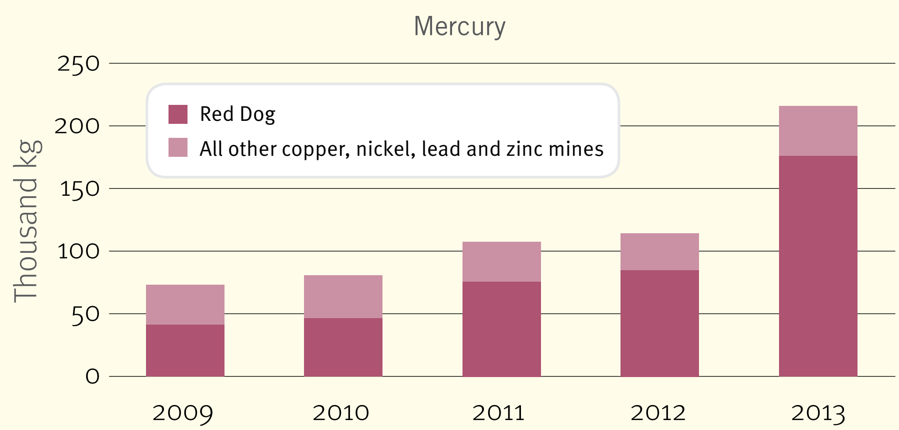
Pollutants to Disposal or Land. The five top substances disposed of or released to land from these mining facilities, combined, accounted for 62 percent of all releases and transfers from the mining sector and 32 percent of releases and transfers from all North American industries in 2013. Almost all of this is through disposal in waste rock and tailings in the United States and Canada. Reporting thresholds (for both quantities and concentrations of pollutants in waste rock and tailings), discussed in chapter 2, influence both the differences between the two countries and year-to-year changes at facilities. Of the top five metals, nickel and lead (and their compounds) are reported through the RETC, but only in very low amounts, as tailings and waste rock disposal are not subject to reporting.

The risk to environmental and human health from metals in tailings and waste rock is primarily related to their potential to enter surface water and groundwater through ARD, leaching, erosions or spills or, to a lesser extent, their potential to become airborne as dust (section 3.5.1). A high proportion of the total disposal through waste rock and tailings is from one mine, Teck American Inc.'s Red Dog lead-zinc mine in Alaska (box 15).

Box 15. Waste rock and tailings disposal of metals by the Red Dog mine (2009 to 2013)

The proportion of total disposals to land from base metal mining that is from the Red Dog mine varies with pollutant and year, from 1 to 2 percent for copper to 80 to 90 percent for zinc (and compounds). Zinc made up 79 percent of the mine's reported releases to land for 2013. Disposal as tailings, which is reported in a separate category in the TRI, accounts for 32 percent of the zinc (U.S. EPA 2015a). The remaining 68 percent reported in the "other disposal" category can be assumed to be mainly in waste rock. The Red Dog mine is also significant for several other metals (and their compounds) that are not disposed of in such high volume, including arsenic and mercury. A four-fold increase in mercury land disposal for all base metal mines in 2013, compared with the 4 previous years, reflects changes in mercury in waste rock and tailings at the Red Dog mine (see figure below).

Mercury (and compounds) Released to Land by All Copper, Lead, Nickel and Zinc Mines, Showing the Proportion from the Red Dog Mine in Alaska (2009–2013)



3.4.5 Other Metal Ore Mining

Figure 39. **Other Metal Ore Mining** (NAICS Code 21229)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$1.9	12
Mexico	$0.4	9
United States	$0.6	18

Other metal ore mining facilities reporting for 2013

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	466,783	587,653	172,857,890
Percent of mining sector total	15%	16%	10%
Top 5 substances[2]	Ammonia Manganese* Sulfuric acid Hydrochloric acid Vanadium*	Nitric acid/nitrates Fluorine Vanadium* Ammonia Manganese*	Phosphorus (total) Manganese* Copper* Vanadium* Lead*

1. From Chapter 2, section 2.1.2 2. Most to least, by mass. * and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

This NAICS mining code covers a mix of mine types producing different products:

- In Canada: five uranium mines and facilities mining niobium, cesium and tantalum, platinum group metals, tungsten, and combinations of metals that cross categories (copper-gold, and copper-gold-molybdenum)
- In the United States: molybdenum mines and other facilities producing metals including vanadium, beryllium and titanium
- In Mexico: molybdenum mines and a silver mine.

This "other metal ore" category accounted for significant proportions of total North American industry releases and transfers in 2013 of phosphorus (total), cyanide and vanadium. Phosphorus was almost all (over 99 percent) as on-site disposal by Imperial Metals Corporation's Mount Polley copper and gold mine in British Columbia, and Magris Ressources *La Mine Niobec*, Quebec (a niobium mine). The dominance of cyanide in this mining type is solely related to off-site disposal of over 1 million kilograms of cyanide in 2013 by a Mexican silver mine, *Minera La Encantada, S.A. de C.V.* in Coahuila (which likely reported under the wrong NAICS code). Vanadium was mainly (82 percent) from the Mount Polley mine, and represented an anomalously large on-site disposal that year.

The range of mining types is reflected in the lists of top pollutants (e.g., figure 30), which are, in some cases, related mainly or fully to one facility. For example:

- The ammonia was mainly from two facilities, mostly as land disposal at a beryllium mine in Utah (Materion Natural Resources Inc. Mill); and as air emissions at a vanadium mine in Arkansas (Evraz Stratcor Inc.). This NAICS code accounted for 50 percent of all mining sector ammonia air emissions.
- All fluorine released to water by mining or any other industry sector in Canada in 2013 was from Magris Ressources' *La Mine Niobec* in Quebec. Fluorine is enriched in the mine's ore deposit (Clow et al. 2011). Fluorine is only reported through the Canadian NPRI.
- Although the release is too small to show up in the top five pollutants for this mining category, the mining sector's total release to water of dioxins and furans — pollutants recognized for their high potential toxicity — was from one U.S. facility producing titanium and other minerals, the Chemours Starke Facility in Florida.

Uranium mining

Five Canadian uranium mining and milling facilities, all in northern Saskatchewan, reported for 2013. Main substances reported through the NPRI were as disposals of metals in tailings and waste rock. Lead (and compounds) comprised 62 percent of total disposals or land releases for the five mines. Tailings and waste rock also contain significant concentrations of radioactive elements that are not subject to reporting under the NPRI. These are, mainly, two decay products of uranium: thorium-230 and radium-226 (Canadian Nuclear Safety Commission 2015). Data on disposals or releases of these radioactive substances by facilities are not all accessible. Discharges of radium-226 to water are reported annually as part of compliance with the Metal Mining Effluent Regulations (EC 2015b).

3.4.6 Stone Mining and Quarrying

Figure 40. **Stone Mining and Quarrying** (NAICS Code 21231)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$1.5	1
Mexico	$1.1	5
United States	$11.8	26

Stone mining and quarrying facilities reporting for 2013 →

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	62,641	0.41	50,160
Percent of mining sector total	2.1%	<0.01%	<0.01%
Top 5 substances[2]	Ammonia Copper* Manganese* Mercury* Lead*	Copper*	Lead* Manganese* Chromium* Nickel* Zinc*

1. From Chapter 2, section 2.1.2 2. Most to least, by mass. * and its compounds.
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

Many stone quarrying operations do not meet the standard PRTR employee or production volume thresholds.[40] The relatively few facilities that report are mainly in the United States, reflecting the much larger size of the industry in that country. Reporting to the TRI for this mining type is only required for beneficiation, and only required for facilities that do not include a quarry (U.S. EPA 2016).

Amounts of reported pollutants are low for this mining type, with air pollutants being the most significant. The only reported water discharge was of less than one kilogram of copper at one facility.

For 2013, two facilities accounted for 80 percent of total releases and transfers for this mining type: Lhoist NA of Alabama LLC-O'Neal Plant, which produces limestone products; and 3M Co. Wausau Greystone in Wisconsin, which produces roofing granules for the asphalt shingle industry. The two had very different reporting profiles, with the Lhoist Alabama plant reporting close to 100 percent of all air emissions for this mining type, and the 3M Wausau facility data being approximately equally split between on-site disposals and transfers to recycling of metals.

40. For NPRI and TRI, the employee threshold is 10 full-time employees, or the equivalent person-hours. Mexico's RETC does not have an employee threshold. For the NPRI, pits and quarries are only required to report if annual production is 500,000 tonnes or more, regardless of the number of employees.

3.4.7 Sand, Gravel, Clay, and Ceramic and Refractory Minerals Mining and Quarrying

Figure 41. **Sand, Gravel, Clay, and Ceramic and Refractory Minerals Mining and Quarrying** (NAICS Code 21232)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$2.1	1
Mexico	$1.7	0
United States	$10.9	14

Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying facilities reporting for 2013

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	328,475	6	108,781
Percent of mining sector total	11%	<0.01%	<0.01%
Top 5 substances[2]	Ammonia Hydrogen fluoride Methanol Sulfuric acid Hydrochloric acid	Lead* Mercury*	Manganese* Zinc* Lead* Nitric acid/nitrates Cadmium*

1. From Chapter 2, section 2.1.2
2. Most to least, by mass.

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. * and its compounds.

This mining NAICS code includes several diverse types of mining and processing. As with stone mining and quarrying, most facilities reporting are in the United States due to that country's higher production of the mineral products covered by this code. Only beneficiation facilities that do not include quarries must report to the TRI. This category includes facilities producing a range of industrial minerals. Most releases and transfers (97 percent) were from facilities producing minerals used in the manufacture of ceramics (Imerys Pyramax Ceramics in Georgia; three Carbo Ceramics Inc. facilities in Georgia and Alabama; and Unimin Canada Ltd.'s nepheline syenite operations in Ontario).

Air emissions were relatively significant for this mining type. While the largest proportions of air emissions were the top five pollutants reported mainly from the U.S. ceramics facilities mentioned above, a range of pollutants were reported by other facilities. These include substances with high potential toxicity: polycyclic aromatic compounds (reported at five facilities), lead and its compounds (reported at seven facilities), and mercury and its compounds (reported at one clay mining facility). Almost all reported disposals or releases to land of metals were from the Canadian facility.

3.4.8 Other Non-metallic Mineral Mining and Quarrying

Figure 42. Other Non-metallic Mineral Mining and Quarrying (NAICS Code 21239)

A. Production and facilities, by country, 2013

	Value of production ($US billion)[1]	Number of facilities reporting
Canada	$11.3	15
Mexico	$2.1	6
United States	$10.8	9

Other non-metallic mineral mining and quarrying facilities reporting for 2013

B. On-site disposals or releases from all facilities, 2013

	Air	Water	Disposal/Land
Total (kg)	61,521	57,010	29,047,070
Percent of mining sector total	2.0%	1.5%	1.8%
Top 5 substances[2]	Hydrochloric acid Phosphorus (total) Ethylene Propylene Toluene	Nitric acid/nitrates Ammonia Nickel* Chromium* Lead*	Phosphorus (total) Manganese* Nickel* Chromium* Zinc*

1. From Chapter 2, section 2.1.2
2. Most to least, by mass.

Notes: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data. One Mexican mine, *Minera Roble S.A. de C.V.*, a copper mine in Durango, is included in this category. As the only report from this mine was for transfers off-site to recycling, this misclassification does not affect the data presented. * and its compounds.

This NAICS category represents a diverse range of mineral extraction and beneficiation facilities and the data must be looked at by type of facility to understand the pattern of releases and disposal. In addition to the most common mine types covered below, facilities in this category produced gypsum, diatomite (diatomaceous earth), vermiculite, fluorspar, wollastonite and roofing materials. Most of the 2013 reporting in this category came from Canadian mines, which reported a total of 29,046,765 kilograms of on-site disposal or land releases. The total reported by U.S. facilities was much lower, at 49,625 kilograms, with 84 percent of that from one facility, the Cargill Inc. salt mine. Mexican facilities in this category reported 9,042 kilograms of releases, most (91 percent) from *Roca Fosfórica Mexicana II S.A. de C.V.*, in Baja California Sur.

Potash mines

Ten facilities were active in Canada in 2013, nine of which are in Saskatchewan. Potash production in 2013 had a value of US$5.5 billion, almost half the value of mineral production from this mining type for Canada (chapter 2, section 2.1.3). No potash was produced in the United States or Mexico.

Potash mines reported no pollutants released through water discharges or air emissions. The main substances disposed or released to land, in order of decreasing total mass, were manganese (and compounds) from six mines, phosphorus (total) from one mine, vanadium (and compounds) from two mines, chromium (and compounds) from two mines, and smaller amounts of zinc, lead, arsenic, selenium and mercury (and their compounds).

The main pollution issues generally associated with potash mining, the release of fine particulate matter to air and release of salts and clays and other fine sediment to water (chapter 2, table 9), are not reflected in these data. Salts and fine sediment released to water are not required to be reported under the NPRI. The Canadian PRTR does require reporting of fine particulates released to air, which can be harmful to human health; however, for reasons explained earlier in this chapter, the data are not included in the Taking Stock Online database. Readers can consult the NPRI database for data on particulate emissions from potash mines in Canada.

Diamond mines

In 2013, four diamond mines were operating in Canada, three in the Northwest Territories and one in northern Ontario. No diamond mining took place in the United States or Mexico. The top substances disposed of on-site as waste rock were phosphorus (total), nickel, manganese and chromium (and their compounds).

The only air emissions of any significant quantities were 1,600 kilograms of propylene from the De Beers Canada Inc. Snap Lake mine, and 1,800 kilograms from the Dominion Diamond Ekati Corp. Ekati mine. Propylene is one component of emissions from diesel power generation. Other substances (CACs) in the emissions from diesel power generation at these sites are reported to the NPRI, but are not included in *Taking Stock*.

All four diamond mines reported emissions of dioxins and furans. Although the quantities were small, these emissions may be significant from a risk perspective, as these chemicals are highly toxic, bioaccumulate throughout the food web, and persist in the environment (section 3.3.3). Dioxin and furan emissions from waste incineration accumulated in sediments in a lake downstream of the Ekati mine, and were detected through sampling in 2008 (Wilson et al. 2011). This discovery led to the company taking measures to improve incineration practices to reduce emissions of dioxins and furans.

Only two diamond mines reported water discharges. The main releases from the Snap Lake mine were nitric acid and nitrate compounds, ammonia, and manganese compounds, while the Ekati mine reported a release of mercury compounds to water.

Salt and brine mines

One facility in Mexico and two in the United States reported releases and transfers of pollutants in 2013. Canada's salt production made up almost 1.5 percent of the value of mining for the country that year (chapter 2, section 2.1.3), but no salt facilities reported through the NPRI. Few on-site releases to air and water were reported for this mining type, but those reported were substantive. The Cargill Inc. Salt Division in New York reported a release to air of hydrochloric acid that accounted for 68 percent of all air emissions from this "other" mining category. The *Sales del Istmo S.A de C.V*. salt mine in Veracruz reported releases of nickel, chromium and cadmium (and their compounds) to water, ranking third among all Mexican mines for water discharges in 2013.

Phosphate rock mines

Only one Canadian and one Mexican phosphate rock mine reported amounts for 2013, but these were relatively substantial. Reporting from Agrium Inc.'s Kapuskasing operations in Canada was of phosphorus (total) and manganese compounds, with the largest quantities being through disposal to land. Phosphorus air emissions from this one facility accounted for 82 percent of total mining sector phosphorus emissions in 2013. *Roca Fosfórica Mexicana* in Baja California Sur reported releases to water of chromium, lead, nickel, cyanides, cadmium, arsenic and mercury (and their compounds) that, combined, made up 73 percent of all pollutants reported as water discharges for all Mexican mines that year.

3.5 Discussion: Completeness and Comparability of North American PRTR Data in the Context of the Mining Sector

The closer examination of releases and transfers by mining type in the previous section reveals a high degree of variability in pollutants and quantities from facility to facility. Some of this variability is related to mining type, some to regional geology, and much to the nature and scale of each individual mine, including the associated processing and support operations. Differences in PRTR reporting requirements among the three countries (presented in chapter 2, section 2.4) must always be taken into account when looking at data at the continental scale. Compliance with reporting requirements and consistency in reporting practices among facilities likely also play a role.

As stated earlier, total amounts of pollutants released and transferred by the mining sector do not provide a very useful measure of the pollution impacts associated with mining activities in North America. However, summaries such as those presented in section 3.2 provide information on the main pollutants to focus on for the industry and the main types of releases and transfers. Minerals that occur naturally in ore deposits and surrounding rock and that are disposed of on-site, primarily as tailings and waste rock, dominate total releases and transfers for the United States and Canada. This on-site disposal category is not included in Mexico's RETC. A quantity of a metal in waste rock or tailings managed on-site is very different, in terms of potential for exposure and risk to human and environmental health, from the same quantity of that metal emitted to air or discharged to water, where it can rapidly spread to the surrounding environment. This does not mean that quantities of pollutants disposed of on-site should be discounted, but just that the information needs to be interpreted from a different perspective. Most spills and long-term, difficult-to-mitigate environmental impacts from mining are related to years of cumulative disposal of mine waste on site. Annual reporting of the types and quantities of substances disposed of provides a record of the accumulation of stored pollutants at each facility—important information in the case of accidents. The risk posed by these stored pollutants is dependent upon the manner in which they are managed during and in the years following mine operation.

The hazards associated with pollutants also vary greatly. For example, some common mining-associated pollutants, such as mercury, arsenic and cyanide, are known to have acute and chronic toxic effects, while total phosphorus, an abundant mineral that is present in waste rock and tailings, is largely of concern because of its potential to alter aquatic ecosystems through nutrient addition. Appendix 2 summarizes information on potential effects of the main pollutants associated with mining.

The sections below provide further examination of some of the aspects of mining-related activities and pollutants that have been discussed throughout this chapter to evaluate if and how these are adequately reflected in the data reported to the North American PRTRs. Additional details are provided about mining waste management practices, the pollutants typically associated with certain types of mining, and the potential issues that can arise when these pollutants enter the environment. This information provides a basis for identifying how the national PRTR reporting requirements could be enhanced to provide a greater level of detail and thus serve as a starting point for understanding the nature and potential impacts of mining-related releases and transfers.

3.5.1 On-Site Disposal of Mining Waste

Mining dominates North American industry totals for on-site disposal or releases to land of pollutants, with the bulk of this being disposal of minerals that are common in ore and surrounding rock. These substances are deposited in large quantities as tailings, waste rock, and spent ore from heap leaching, as a part of the mining process. The effectiveness of pollution control measures for many industries can be measured by tracking the pollutants released as stack emissions or water discharge streams—but this is not true for the mining industry and on-site disposal. The amount of a pollutant disposed of annually on site is related to production trends and the characteristics of the ore body being mined. Pollution control is through containment and maintenance of this waste material, in order to prevent potentially deleterious substances from becoming mobilized through water or air during the life of the mine and beyond. The risks posed to environmental and human health from stored mining waste are influenced by many factors specific to the local situation and the pollutants of concern—for example, potential for generating acid rock drainage (ARD), climate and water regimes, terrain, and the nature and sensitivity of downstream aquatic ecosystems.

The risks posed by tailings and waste rock, and the mitigation and decommissioning measures for these two main categories of on-site disposal, are quite different. While both may need measures to control ARD or other leaching, waste rock is normally coarse material in piles on land, while tailings are finely ground particles, sometimes also containing process chemicals (such as cyanide), and are usually disposed of in ponds contained by dams. Distinguishing tailings from other forms of on-site disposal in the three PRTRs would provide better information for an evaluation of potential cumulative risk from pollutants on site. Tailings are reported in separate categories, and differently, under the NPRI and the TRI. In Mexico, disposal of pollutants in waste rock and tailings is regulated by other environmental authorities and reporting is not required through the RETC.

Other, key information that would be very useful in relation to the disposal of mining waste would be the consistent reporting of the concentrations of pollutants in waste rock and tailings. This information would contribute significantly to our ability to evaluate risk to downstream waterways if waste material enters or is at risk of entering the aquatic environment through spills or other unplanned releases. Canada's NPRI requires the reporting of the concentrations of pollutants contained in tailings and waste rock, and concentrations are provided by facilities to demonstrate how they have calculated amounts. However, this information is not consistently reported to and presented through all three PRTRs.

3.5.2 Main Pollutants Associated with Mining, and Year-to-Year Variations

As discussed in the previous analysis of pollutants by mining type, pollutant releases and transfers can be dominated by one or a few mine facilities and can be expected to vary from year to year with changes in production and mining life cycle events. For most pollutants, there is a high degree of variance in reporting from one facility to the next, and from year to year for individual facilities. For this reason, inclusion of facility comments on the PRTR reporting form can provide important context about the reported data. Canadian and U.S. facilities can provide comments regarding significant year-to-year changes in their data, but doing so is not mandatory; as a result, only a small percentage of facilities provided such information for 2013.

Many pollutant releases and transfers are highly correlated with production characteristics—both the amount of ore mined and the composition of the mineral deposit. As large quantities of tailings and waste rock are produced by most mines during the course of their operations, small changes in the concentration of the metals from year to year greatly affect the absolute amounts of metals that are reported annually through PRTRs.

Events in the life of a mine may lead to anomalies that are not representative of a pollution incident, but instead are a byproduct of mine development or decommissioning. These mine events might include, for example, preparation for opening a new pit that incurs a greater-than-normal excavation of waste rock. Examination of trends over the past few

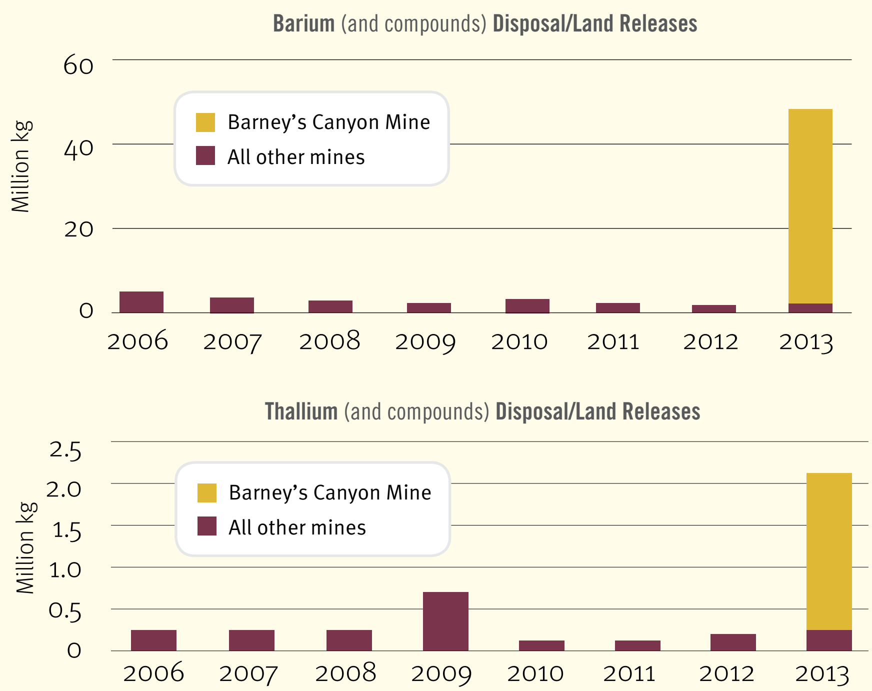
Box 16. Why was so much barium and thallium reported for 2013?

Examination of pollutant trends shows that releases to land of barium and thallium (and their compounds) from mining were much higher in 2013 than in previous years (see figure below). Closer examination shows that Rio Tinto America Inc.'s Kennecott Barney's Canyon Mining Co. gold mine in Utah accounted for 95 percent of barium and 88 percent of thallium releases and transfers for the mining sector in 2013. The explanation can be found in the mine's TRI form general comments section:

> "The majority of the quantity of release reported in section 5.5.4 (Other On-Site Land Disposal) is due to the one-time release from the closure of the heap leach pad. This was a one-time event that was not associated with the normal or routine production process…"

The closure of a heap leach pad is equivalent to disposing of tailings—but the pad, which had been used for processing gold for many years, was reported as on-site disposal in one year. While the material was being leached, it was ore undergoing mineral processing, not waste. When the mine closed, the material became a mine waste, which triggered a requirement to report the pollutants in the entire heap leach pad in one year. Aside from this heap leach pad decommissioning, the largest sources of reported barium from mining were coal mines, while gold and silver mines were the main sources for thallium.

Total Disposals/Land Releases of Barium and Thallium (and their compounds), Barney's Canyon Mine, vs All Other U.S. Mines (2006–2013)



Note: Barium and thallium (and their compounds) were only subject to reporting under the U.S. TRI during this period.

years show anomalously high levels of three pollutants in on-site disposal or land releases in 2013. Looking at the data at the facility level provides an explanation for this apparent trend (box 16).

Averages for pollutants reported from 2009 to 2013 were examined in order to develop a list of the main pollutants associated with the mining sector that excludes anomalous releases and does not overemphasize releases or transfers from one or a small number of facilities.

The top 25 pollutants reported over this 5-year period are listed in table 21, along with their means, a measure of variability of the means, and the number of facilities reporting each pollutant in 2013. Inspecting the data at the facility level when there is high variability from year to year (see the “Notes” column in the table) reveals patterns that are much more meaningful than simple time trends of the means. For example, data for one year may represent anomalously high releases from one or a few facilities, or a change in reporting practices may be the cause. Only the most recent 5-year period is included in the table, as changes in reporting requirements affect the data increasingly before 2009.

The pollutants highlighted in the table are included in appendix 2: Main Pollutants Reported to the PRTRs by the North American Mining Sector (2013): Summary of On-site Release and Disposal Information, Sources and Potential Effects. Excluded pollutants (not highlighted) were reported at fewer than ten facilities and typically had very high year-to-year variability, indicating that the releases or transfers are specific to beneficiation processes at only a few mines, associated with rare mine events, or perhaps are reported inconsistently or in error. Thallium, although it fits these criteria for exclusion, is included in appendix 2 as a main mining pollutant because it is likely under-represented in the PRTR data (as it is not reported in Canada and Mexico). Overall, the list derived from the 5-year average matches well with the list of main pollutants for 2013.

Table 21. **Main Mining Pollutants, Means and Variability (2009–2013)**

Pollutant	Mean annual total releases and transfers (kg)	Coefficient of variation of the mean[1]	Facilities reporting in 2013	Notes
Top 25 by 2009-2013 mean				
Zinc*	333,958,255	8%	133	
Lead*	286,453,597	25%	317	
Manganese*	259,589,893	20%	130	
Copper*	126,040,692	14%	153	
Arsenic*	108,210,844	41%	155	
Phosphorus (total)	104,473,764	27%	33	Reported only through the NPRI.
Nickel*	43,481,106	17%	138	
Chromium*	21,048,818	20%	139	
Aluminum oxide (fibrous)	13,245,450	176%	1	Large releases were reported erratically by only 3 nickel and copper mines from 2009 to 2013.
Vanadium*	12,070,351	37%	66	High variability reflects higher levels in 2013, related to an atypically high release at one mine and reports from several mines that had not reported vanadium previously.
Barium*	11,795,449	155%	19	Reported only in TRI; anomalously high release by 1 mine raises it in the 2013 list.

Pollutant	Mean annual total releases and transfers (kg)	Coefficient of variation of the mean[1]	Facilities reporting in 2013	Notes
Top 25 by 2009-2013 mean				
Nitric acid/nitrates	5,766,289	7%	92	
Cobalt*	4,330,600	27%	67	
Aluminum (fume or dust)	3,874,971	57%	4	Large amounts were reported erratically by 6 mines of various types from 2009 to 2013.
Antimony*	3,602,351	37%	21	High variability reflects an atypically high total release in 2010, when 70% of antimony was reported from one gold mine.
Ammonia	3,308,483	22%	83	
Mercury*	2,334,709	8%	207	
Cyanides	1,544,136	47%	95	High variability reflects higher releases in 2013, in part due to a very high off-site release to disposal at a Mexican mine and a large one-time, on-site disposal by a Canadian gold mine.
Selenium*	1,061,618	38%	83	Variability is likely partly due to lower NPRI reporting thresholds introduced in 2011. Amounts were higher in 2013, mainly because of disposal of selenium by a Canadian mine/smelter complex that, prior to 2011, had not reported.
Cadmium*	770,066	68%	123	High variability is influenced by a large transfer to recycling by a Canadian base metals mine in 2010.
Methanol	699,119	33%	13	Variability reflects increasing trends in emissions and on-site disposal at 5 facilities.
Thallium*	652,180	117%	6	Fairly consistent amounts were reported by 5 gold and copper mines (2009-2013), and an anomalously large amount in 2013; thallium was reported only through the TRI during this time period.
Sulfuric acid	589,813	15%	31	
Chlorine	586,326	115%	7	Fairly consistently reported by 6 mines of various types (2009–2013).
Hydrochloric acid	523,599	26%	21	
Additional pollutants in top 25 for 2013				
Molybdenum trioxide	100,602	185%	2	A large amount was reported from a mine producing molybdenum; the mine had not reported molybdenum trioxide previously.
Silver*	202,768	31%	22	

1. The coefficient of variation is a measure of variability of the annual means (not the variability among facilities, which is far greater). The higher the number, the more variation. Highlighted (dark green) pollutants are included in Appendix 2: Main Pollutants Reported to the PRTRs by the North American Mining Sector (2009-2013).

Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

* and its compounds.

Certain types of pollutants that are not subject to reporting in all three PRTRs, and thus excluded from *Taking Stock* and the above table, are important to consider if we are to understand the pollution associated with North American mining. They include the following:

Greenhouse gases (GHGs). As in the case of other industries, GHG emissions are of increasing importance in strategies aimed at mitigating the scale and impacts of climate change. As mentioned in chapter 1 (box 1), GHG emissions are reported at the facility level in each country through different mechanisms, but are included only in Mexico's PRTR.

Criteria air contaminants (CACs). As discussed in the section on coal mining, CACs can be released in far greater quantities than other PRTR-reported pollutants. CAC emissions have been reported annually by facilities through the NPRI since 2002, but are reported with less frequency and through separate inventories in the United States and Mexico (CEC 2014, ECCC 2017). The exception is ammonia, which is included in the Canadian and U.S. PRTRs, but not the RETC. As noted in chapter 1, more facilities from each of the subsectors report to the NPRI; however, since they only report emissions of CACs, they are not included in the facility counts in this report (see chapter 1, box 1).

Radionuclides are not subject to reporting under any of the North American PRTRs. In 2013, uranium mining was only active in Canada, where it is under the management of the Canadian Nuclear Safety Commission (see chapter 2, section 2.3.1).

3.5.3 Spills at Mining Facilities

Spills and leaks at mines range from relatively minor spills, such as spills from vehicles or equipment malfunctions, to significant events such as those caused by breaches of tailings dams (see chapter 2, section 2.5.2). Spill prevention measures and remedial actions are taken by the respective responsible authorities in the three countries, as well as the mine facilities themselves. Equally important is ensuring the reporting of pollutants released during the event, as well as the timely provision of information to the public in the immediate aftermath of a major spill.

Canada's NPRI is the only PRTR system that clearly distinguishes spills from other releases. It has separate categories for reporting spills and leaks to air, water and land. In the TRI, air emissions resulting from accidents or malfunctions are reported in a category with other non-point-source air emissions. Spills and leaks to water are combined with all other water discharges. Spills or leaks to land are reported in the "other disposal" category. There is also a TRI reporting section that aggregates these quantities spilled, along with other one-time, non-production-related releases. In the RETC, spilled pollutants, where reported, would be combined with other releases in the air, water and land categories. Because *Taking Stock* combines data from all three PRTRs, it is only able to use the broadest categories. Spills are, therefore, combined with all other releases for air and water categories, and spills to land are combined with all other types of on-site disposal and land releases (chapter 2, table 13).

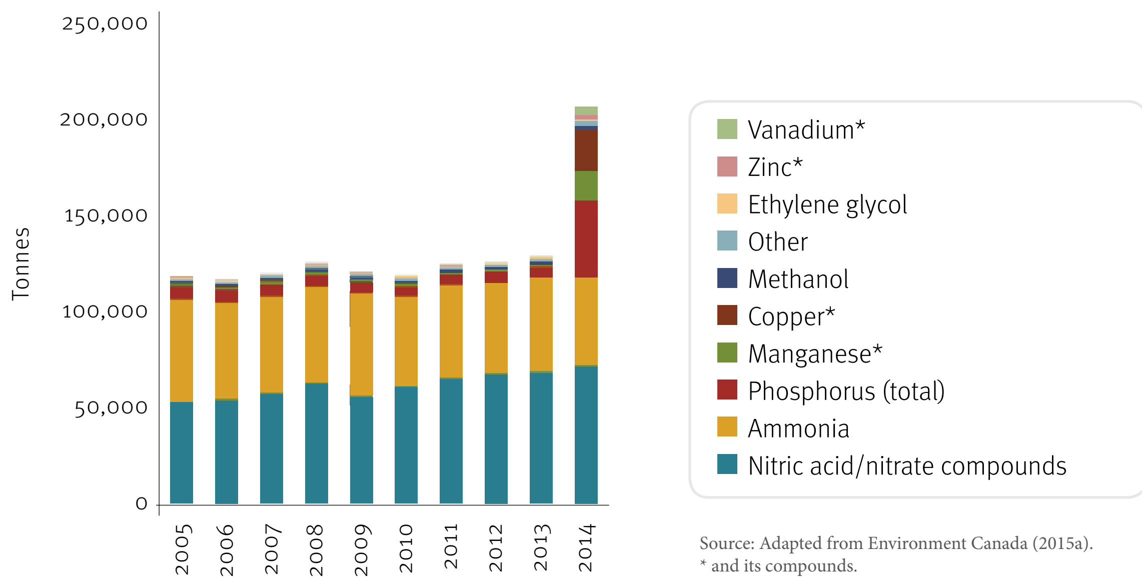
The NPRI data were examined in more detail, as the program distinguishes spills from other releases. NPRI data for 2013, 2014 and 2015 (ECCC 2016b, ECCC 2016a, ECCC 2016c) indicate that no leaks and few (albeit significant) spills were reported at Canadian mines. In all three years, only minor spill-related releases to air were reported by two mines (both in 2013). Two spills to water were reported for 2013, both related to dam failures: the major Obed coal mine spill (section 3.4.1) and a smaller spill of ammonia and metals to water from a gold mine in Quebec (Hecla Mining Company's Casa Berardi). The Casa Berardi spill was caused by a breach of an internal tailings dike that released material mainly to another pond in the tailings containment area, but also released an estimated 55,000 m^3 of fluid and 2,000 m^3 of solids to a stream (Caldwell 2014). The Obed mine reported pollutants spilled to land, as well as to water. In 2014, the only spill reported was the major Mount Polley mine spill, which was reported as a spill to water. In 2015, one spill, mainly of arsenic, was reported to land—meaning it was contained at the site (Teck Highland Valley Copper in British Columbia).

Information regarding recent major spills at operating and abandoned mining facilities in the three countries, based on available PRTR data and/or other sources, is summarized in table 22.

Table 22. **Major Spills at Operating and Abandoned Mines in North America in Relation to PRTR Reporting,** 2013–2015

Spill	PRTR context	Scope and impacts
***Grupo Minero Sa De C.V.* Bacis gold mine "El Herrero" processing plant** (Durango, Mexico) January 2013, from a tailings dam failure	Not reported through the RETC. The facility filed a report only for a transfer of lead offsite for recycling in 2013.	Release of 300,000 m^3 of material, affecting the Los Remedios and San Lorenzo Rivers downstream to a reservoir used for storing water for drinking water, livestock and irrigation. A study conducted 5 months after the spill showed elevated sediment levels of arsenic, zinc, lead, cadmium and mercury (Páez-Osuna et al. 2015, PROFEPA 2016).
Coal Valley Resources Obed coal mine (Alberta, Canada) October 2013, caused by a break in a settling pond wall	Reported through the NPRI. The initial report was incorrect; revisions were filed in 2015 and 2016. The 92,594 kg of pollutants reported released made up 39% of water releases for coal mining in 2013.	Release of 670,000 m^3 of coal slurry containing ammonia, total phosphorus and metals. The released material, plus erosion, resulted in a plume of fine sediment that extended 1100 km downstream to the mouth of the Athabasca River (Cooke et al. 2016).
Imperial Metals Mount Polley copper and gold mine, (British Columbia, Canada) August 2014, caused by a tailings dam failure	Reported through the NPRI. The spill accounted for 95% of all mining releases for Canada in 2014.	Release of 17 million m^3 of water and 8 million m^3 of tailings and construction materials to Polley Lake, Hazeltine Creek and Quesnel Lake (Government of British Columbia 2016). The debris flow scoured the creek and deposited tailings and sediment in its floodplain and in the lakes. Impacts include physical damage to stream, lake, riparian and terrestrial areas, destruction of biotic communities in these areas, and deposition of metals in sediments. Spilled material is not acid-generating and has low leaching potential (Golder Associates 2016, SRK Consulting 2015) but may incur ongoing risks (Petticrew et al. 2015).
Grupo Mexico's *Buenavista del Cobre* mine (Sonora, Mexico) August 2014, caused by a broken pipe for an acid copper tailings pond (Briseño 2017)	Not reportable through the RETC.	Spill of 40,000 m^3 of a metal-laden, highly acidic solution into Las Tinajas Stream, which flows into the Bacanuchi River and then the Sonora River. The spill's initial impacts extended 90 km downstream, raising concerns about effects on aquatic life, drinking water and economies of seven communities (Gobierno de Mexico 2014, Díaz-Caravantes et al. 2016, Jamasmie 2014, Gutiérrez Ruiz and Martín Romero 2015).
Gold King mine incident (Colorado, United States) August 2015	Not reportable through the TRI, as the spill was from a long-abandoned mine (last operating in 1923). The spill was in an area subject to ongoing ARD pollution from abandoned mines (and thus not reflective of modern mining practices).	During an attempt by the EPA to fix an ongoing leak, excavation resulted in a spill of 11,400 m^3 of acidic, metal-laden water and iron-rich sediments, eroding acid-generating waste rock and soil, flowing into the Animas and San Juan Rivers and reaching Lake Powell, Utah. The main metals entering the river were iron and aluminum—mostly scoured from the waste rock and stream bed (Gobla et al. 2015, US EPA 2017).

Figure 43. **Impacts of Mount Polley Mine Spill** (2014) **on Total Reported Releases to Water in Canada,** 2005-2014



Source: Adapted from Environment Canada (2015a).
* and its compounds.

The purpose of a PRTR is to make information on pollutant releases and transfers publicly accessible and to track the sources, releases and transfers of pollutants to aid in pollution prevention and reduction (CEC 2014). The inability, under the TRI and RETC programs, to distinguish spills from other types of releases is an important limitation. For the mining industry, spills are relatively rare but potentially major events that can lead to the rapid release of pollutants in quantities that far exceed the mine's normal annual pollutant releases. They are an important consideration when developing policies and programs to assess and address mine pollution.

Most mining-related spills of consequence are to water. The slug of pollution moves rapidly downstream, potentially affecting aquatic ecosystems and downstream communities. An important function of a PRTR is to provide access to information, immediately following a spill, about what potentially toxic substances were onsite and were likely to have been spilled. The NPRI was used for this purpose in the aftermath of the Mount Polley spill. Communications from the mining company (Imperial Metals) focused on dissolved substances in the tailings pond, not on pollutants in the spilled solids. The 2013 NPRI report on the disposal of pollutants in tailings was widely used as the source of public information on what had been spilled (Mining Watch Canada 2014, CBC News 2014, Paperny 2014). This was a reliable guide, as later downstream monitoring demonstrated. The mine's 2014 NPRI report on the spill closely matched their previous years' (2009–2013) reports on tailings disposal—i.e., the quantities of pollutants reported released into water when the dam breached were equivalent to the amounts deposited to tailings over about three years (ECCC 2016d).

3.6 Conclusion

This in-depth examination of the release and transfer data reported for 2013 by the North American mining industry reveals important differences in the amounts, pollutants, and types of releases and transfers reported by facilities. While factors such as incomplete reporting and non-compliance can play a role, this analysis has shown that differences among national PRTR reporting requirements, including differences in definitions of release and transfer categories, strongly affect the data from the mining sector.

These analyses provide insights into some PRTR program differences that are particularly important in the context of the mining sector—an industry that generates large quantities of waste containing pollutants that, depending on how they are managed, may or may not pose risks to environmental or human health. The most marked impact of these inconsistent reporting requirements, highlighted throughout this report, is that significantly smaller amounts of pollutants are reported by mines in Mexico than by mines in the United States and Canada. This is largely due to two characteristics of the RETC program: the lack of an on-site disposal reporting category; and the exclusion from the list of reportable substances of key pollutants typically associated with mining activities.[41]

Another issue that becomes clear by taking a closer look at the data (at the scale of mining types and individual mining facilities) is that releases and transfers reported under NAICS mining codes may also include smelting or other mineral refining activities that are covered by other NAICS codes. This is an artefact of the PRTR systems, which allow or require facilities to report releases and transfers from different industrial activities under one principal industry code. This combining of reporting of releases and transfers from different sources at the facility level introduces problems for data analysis and leads to a risk of making erroneous conclusions.

Table 23 summarizes important aspects of mining sector releases and transfers and the extent to which they are covered under the North American PRTR programs. It provides a basis for identifying potential enhancements to the national systems to better reflect the activities of the mining sector. For example, disposal of pollutants on site, mainly in tailings and waste rock, accounts for most of the total amount of pollutant releases and transfers reported by the mining sector. This category would provide better information for understanding patterns of pollutant releases and risks if tailings and waste rock data were reported more consistently and in distinct categories.

Minerals reported in waste rock and tailings occur naturally in the ore deposit and are contained and managed on-site. From a pollution stand-point, what is important is not the amounts stored on site, but the risk of these metals or other minerals eroding, leaching, spilling or being spread by other means into the surrounding environment. However, spills are not reported consistently among the national PRTRs and as a result, they are not able to be distinguished from other releases in the Taking Stock Online integrated, North American PRTR database. As spills are relatively rare, but potentially very major sources of pollutants, they need to be considered in any assessment of mine pollution and risks.

For some mining types, air pollutants that result from fossil fuel combustion and activities that produce dust (criteria air contaminants) are a significant aspect of the industry's emissions and pollutant issues. These pollutants, as well as greenhouse gas emissions, are monitored and reported in different ways in the three countries and are therefore excluded from *Taking Stock*. While it may be impractical to combine these into one reporting system, they should be considered in any in-depth look at air emissions from mining.

41. As mentioned earlier in this chapter and in chapter 2, as of the 2014 reporting year the RETC list has been expanded to include 200 substances, but this expansion does not add pollutants that are commonly released or transferred through mining (Semarnat 2014).

Table 23. **PRTR Coverage Relative to the North American Mining Sector**

Aspect of PRTR Reporting	Information Captured	Information partly captured (inconsistent across the 3 PRTRs, partial, or unclear)	Information Not Captured (or very inconsistent across the 3 PRTRs)
Discharges to Water	End-of-pipe discharges to surface water	Storm water runoff	Most non-point-source surface water pollution; pollutants released to groundwater
Air Emissions	Stack emissions	Fugitive air emissions, pollutants in dust	Important types of emissions (greenhouse gases and criteria air contaminants)
Disposal/Releases to Land		Tailings and waste rock in on-site disposal	Pollutants subsequently mobilized from tailings and waste rock
Spills		Spills and leaks, including from tailings dam failures	
Pollutant Types	Pollutants with high known toxicity and risk to human health	Pollutants with acute or sub-lethal, long-term environmental impacts; and pollutants released and deposited in highest quantities by mining sector (mainly metals)	Greenhouse gases, criteria air contaminants (including particulate matter), radionuclides, suspended solids (in water)
Mine Life Cycle	Operating phase	Decommissioning phase	Exploration, development, post-closure phases
Risks and Effects Measures		Information on toxic risks (scoring system for some pollutants in air and water releases)	Integrative measures of effects on human and environmental health

This feature analysis has revealed that total amounts of pollutant releases and transfers are often dominated by one or a few facilities and therefore, looking at totals, averages and changes over time may be misleading. Much more can be learned by examining the data for specific pollutants, mining types, regions and facilities. Additionally, other important sources of pollutants should be considered when looking at the broader picture of mining-associated pollution. These sources include accidental releases and non-point-source releases such as dust associated with extraction of minerals, vehicle emissions, and storm water runoff that may erode or leach pollutants from mine workings and from waste stored on-site.

The insights about the mining industry's waste management practices, and the potential issues that can arise when pollutants associated with these processes enter the environment, provide information that is useful for future enhancements to the North American PRTR programs to better reflect the activities of this important sector. The resulting data—more complete, accurate and comparable—can, in turn, inform pollution reduction policies and initiatives across the region.

References

Aneja, V.P., A. Isherwood, and P. Morgan. 2012. Characterization of particulate matter (PM 10) related to surface coal mining operations in Appalachia. *Atmospheric Environment* 54. Elsevier Ltd: 496–501

Briseño, O. 2017. Personal communication, March 2017. Grupo México

Caldwell, J.A. 2014. *Tailings facility failures in 2013/2014*. Vancouver: Infomine.com. Available at: http://www.infomine.com/library/publications/docs/Caldwell2014c.pdf

Canadian Mining Journal. 2013. *Carol Lake*. Available at: http://www.canadianminingjournal.com/features/carol-lake/

Canadian Nuclear Safety Commission. 2015. Uranium mines and mill waste. http://nuclearsafety.gc.ca/eng/waste/uranium-mines-and-millswaste/index.cfm. Consulted on 27 October 2016

CBC News. 2014. Mount Polley mine tailings spill: Imperial Metals could face $1M fine. Auust 6, 2014. http://www.cbc.ca/news/canada/british-columbia/mount-polley-mine-tailings-spill-imperial-metals-could-face-1m-fine-1.2728832. Consulted on 27 February 2017

CEC. 2014. *Taking stock vol. 14: Exploring changes in PRTR reporting, 2005-2010, with a focus on releases to air and water from pulp, paper and paperboard mills*. Montreal, QC: Commission for Environmental Cooperation

Clow, G.G., B. Salmon, M. Lavigne, B. Mcdonough, P. Pelletier, and D. Vallières. 2011. *Technical report on expansion options at the Niobec Mine, Quebec, Canada*. Roscoe Postle Associationes Inc. for Iam Gold Corporation

Cooke, C.A., C. Schwindt, M. Davies, W.F. Donahue, and E. Azim. 2016. Initial environmental impacts of the Obed Mountain coal mine process water spill into the Athabasca River (Alberta, Canada). *Science of the Total Environment* 557–558: 502–9

Díaz-Caravantes, R.E., H. Duarte-Tagles, and F.M. Durazo-Gálvez. 2016. Amenazas para la salud en el Río Sonora: análisis exploratorio de la calidad del agua reportada en la base de datos oficial de México. *Rev Univ Ind Santander Salud* 48 (1): 91–96

Eagles-Smith, C.A., J.G. Wiener, C. Eckley, J.J. Willacker, D.C. Evers, M. Marvin-DiPasquale, D. Obrist, et al. 2016. Mercury in western North America: An overview of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife. *Science of the Total Environment* 568 (January): 1213–26

EC. 2015a. *Overview of reviewed facility-reported data. National Pollutant Release Inventory (NPRI), 2014*. Environment Canada. Available at: https://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=386BAB5A-1&printfullpage=true

EC. 2015b. *Summary review of performance of metal mines subject to the melal Mining Effluent Regulations in 2013*. Environment Canada. Available at: http://ec.gc.ca/pollution/AD0FC9DC-6254-4CFA-9C13-E14F2ECFC5F5/15-011_Metal Mining_ANG_R3.pdf

ECCC. 2016a. National Pollutant Release Inventory (NPRI) - 2013 Pollutant release and transfer data reported by facilities, single year tabular format. Updated September 29 2016

ECCC. 2016b. National Pollutant Release Inventory (NPRI) - 2014 Pollutant release and transfer data reported by facilities, single year tabular format. Updated September 29 2016. Excel file for 2014 (2014-INRP-NPRI.xlsx). Data current to 8 September 2015). Environment and Climate Change Canada

ECCC. 2016c. National Pollutant Release Inventory (NPRI) - 2015 Pollutant release and transfer data reported by facilities, single year tabular format. Updated September 29 2016

ECCC. 2016d. National Pollutant Release Inventory (NPRI) - bulk data. NPRI-Substance-Comments-Normalized-Since1993. Excel file. Environment and Climate Change Canada. http://donnees.ec.gc.ca/data/substances/plansreports/national-pollutant-release-inventory-npri-pollutant-release-and-transfer-data-reported-by-facilities/national-pollutant-release-inventory-npri-bulk-data/?lang=en. Consulted on 8 September 2016

ECCC. 2016e. Performance agreement concerning air pollutants from the iron ore pellet sector. Environment and Climate Change Canada. https://www.ec.gc.ca/epe-epa/default.asp?lang=En&n=4ED7CF11-1. Consulted on 8 September 2016

ECCC. 2017. Criteria air contaminants and related pollutants. Environment and Climate Change Canada. https://www.ec.gc.ca/air/default.asp?lang=En&n=7C43740B-1. Consulted on 2 March 2017

Esteller, M.V., E. Domínguez-Mariani, S.E. Garrido, and M. Avilés. 2015. Groundwater pollution by arsenic and other toxic elements in an abandoned silver mine, Mexico. *Environmental Earth Sciences* 74 (4): 2893–2906

Gobierno de Mexico. 2014. *Derrame de sulfatao de cobre en en Rio Bancanuchi, (afluente del Ro Sonora)*. Available at: http://www.profepa.gob.mx/innovaportal/file/6251/1/presentacion_conferencia_derramesemarnat_profepa_260814.pdf

Gobla, M., C. Gemperline, and L. Stone. 2015. *Technical evaluation of the Gold King Mine Incident*. US Department of the Interior, Bureau of Reclamation. Available at: http://www.usbr.gov/docs/goldkingminereport.pdf

Golder Associates. 2016. *Mount Polley mine tailings storage facility, perimeter embankment breach. Update report: Post-event environmental impact assessment report*. Submitted to Mount Polley Mining Corporation

Government of British Columbia. 2016. Mount Polley Mine tailing dam breach. http://www2.gov.bc.ca/gov/content/environment/air-land-water/spills-environmental-emergencies/spill-incidents/past-spill-incidents/mt-polley

Gutiérrez Ruiz, M.E., and F. Martín Romero. 2015. Valoración del daño ambiental en la Cuenca del Río Sonora, asociado al derrame del 06 de agosto de 2014 de Buena Vista del Cobre. In *Memorias Trabajos Técnicos XXXI Convención Internacional de Minería Acapulco, Guerrero, México Octubre 7-10, 2015*, edited by Rogelio Monreal Saavedra, Leobardo Valenzuela García, and Francisco Cendejas Cruz, 604–16. Acapulco, Mexico

Hanchar, J.C., and A.D. Kerr. 2012. *Mineral commodities of Newfoundland and Labrador: Iron ore*. St John's, NL: Geological Survey Mineral Commodities Series Number 7. Newfoundland Labrador Natural Resources

Hauer, R., and E.K. Sexton. 2013. *Transboundary Flathead River: Water quality and aquatic life use: Final report*. Polson, MT: Prepared for Glacier National Park by Flathead Lake Biological Station, University of Montana

Hendry, M.J., A. Biswas, J. Essilfie-Dughan, N. Chen, S.J. Day, and S.L. Barbour. 2015. Reservoirs of selenium in coal waste rock: Elk Valley, British Columbia, Canada. *Environmental Science & Technology* 49 (13): 8228–36

Jamasmie, C. 2014. Mexico copper mine spill pollutes water supplies 40 km from US border. http://mining.com. Consulted on 1 December 2016

Jamieson, H.E. 2014. The legacy of arsenic contamination from mining and processing refractory gold ore at Giant Mine, Yellowknife, Northwest Territories, Canada. *Reviews in Mineralogy and Geochemistry* 79 (1): 533–51

Jaramillo, P., and N.Z. Muller. 2016. Air pollution emissions and damages from energy production in the U.S.: 2002-2011. *Energy Policy* 90 (x). Elsevier: 202–11

Kuchapski, K.A., and J.B. Rasmussen. 2015. Surface coal mining influences on macroinvertebrate assemblages in streams of the Canadian Rocky Mountains. *Environmental Toxicology and Chemistry* 34 (9): 2138–48

Mining Watch Canada. 2014. Catastrophic tailings spill at Mount Polley Mine. News item, 8 August 2014. http://miningwatch.ca/blog/2014/8/8/catastrophic-tailings-spill-mount-polley-mine. Consulted on 27 February 2017

Northwest Arctic Borough. 2009. Title 9 master plan permit no: 107-03-10 (issued to Teck Alaska, Inc.)

Páez-Osuna, F., H. Bojórquez-Leyva, M. Bergés-Tiznado, O.A. Rubio-Hernández, J.F. Fierro-Sañudo, J. Ramírez-Rochín, and J.A. Leon-Cañedo. 2015. Heavy metals in waters and suspended sediments affected by a mine tailing spill in the upper San Lorenzo River, northwestern Mexico. *Bulletin of Environmental Contamination and Toxicology* 94 (5): 583–88

Paperny, A.M. 2014. Mount Polley breach: What Thursday's tailings test won't tell you. Global News, August 7 2014. http://globalnews.ca/news/1496479/mount-polley-breach-what-thursdays-tailings-test-wont-tell-you/. Consulted on 27 February 2017

Petticrew, E.L., S.J. Albers, S.A. Baldwin, E.C. Carmack, S.J. Déry, N. Gantner, K.E. Graves, et al. 2015. The impact of a catastrophic mine tailings impoundment spill into one of North America's largest fjord lakes: Quesnel Lake, British Columbia, Canada. *Geophysical Research Letters*, 3347–56

Profepa. n.d. Ratifica Profepa que no hay contaminación en Río Los Remedios, en Sinaloa. Gobierno de México, Procuraduría Federal de Protección al Ambiente. http://www.profepa.gob.mx/innovaportal/v/6340/1/mx.wap/ratifica_profepa_que_no_hay_contaminacion_en_rio_%25E2%2580%259Clos_remedios%25E2%2580%259D_en_sinaloa.html. Consulted on 8 September 2016

Razo, I., L. Carrizales, J. Castro, F. Díaz-Barriga, and M. Monroy. 2004. Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. *Water, Air, & Soil Pollution* 152 (1–4): 129–52

Semarnat. 2014. *NORMA Oficial Mexicana NOM-165-SEMARNAT-2013, Que establece la lista de sustancias sujetas a reporte para el Registro de Emisiones y Transferencia de Contaminantes.* Diario Oficial Viernes 24 de Enero de 2014. Secretaría de Medio Ambiente y Recursos Naturales. Available at: http://www.profepa.gob.mx/innovaportal/file/6640/1/nom-165-semarnat-2013.pdf

SRK Consulting. 2015. *Mount Polley Mine tailings dam failure: Update on geochemical characterization of spilled tailings*. Prepared for Mount Polley Mining Corp.

Straskraba, V., and R.E. Moran. 1990. Environmental occurrence and impacts of arsenic at gold mining sites in the western United States. *International Journal of Mine Water* 9 (1–4). Springer-Verlag: 181–91

US EPA. 2011. *Final rule to reduce mercury emissions from gold mine ore processing and production sources (fact sheet)*. Environmental Protection Agency, Office of Air Quality Planning and Standards. Available at: https://www.epa.gov/sites/production/files/2016-01/documents/gold_mines_fs_121610.pdf

US EPA. 2015a. 2013 TRI National Analysis: Metal mining - Waste management by metal mines. https://www.epa.gov/toxics-release-inventory-tri-program/2013-tri-national-analysis-metal-mining-waste-management-metal. Consulted on 2 October 2016

US EPA. 2015b. *Factors to consider when using TRI data*. US Environmental Protection Agency. Available at: https://www.epa.gov/sites/production/files/2015-06/documents/factors_to_consider_6.15.15_final.pdf

US EPA. 2016. Toxics Release Inventory (TRI) Program: Is my facility's six-digit NAICS Code a TRI-covered industry?. https://www.epa.gov/toxics-release-inventory-tri-program/my-facilitys-six-digit-naics-code-tri-covered-industry. Consulted on 18 February 2017

US EPA. 2017. *Analysis of the transport and fate of metals released from the Gold King Mine in the Animas and San Juan Rivers*. Environmental Protection Agency. Available at: https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=325950

Wilson, A., D. Fox, G. Poole, and R. Bujoldy. 2011. Linking incineration to dioxins and furans in lakebed sediments (or, the case of the missing water license condition). *Integrated Environmental Assessment and Management* 7 (2): 302–4

Using and Understanding Taking Stock

For those new to pollutant release and transfer registers or to *Taking Stock*, this appendix describes the characteristics of the three national PRTRs, including the features that are unique to the system of each country. It also describes the scope of this report and the methodology and terminology used in it.

Features of the Three North American PRTRs

Taking Stock is based on information provided by North America's three national PRTR programs:

- **Canada's NPRI** (www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory.html)
- **Mexico's RETC** (http://apps1.semarnat.gob.mx/retc/index.html)
- **The U.S. TRI** (www.epa.gov/toxics-release-inventory-tri-program)

Each country's PRTR has evolved with its own list of pollutants, sector coverage, and reporting requirements. Table A-1 compares the main features of the three PRTRs.

Table A-1. **Features of the North American PRTRs**

Feature*	**Canada's National Pollutant Release Inventory (NPRI)**	**Mexico's *Registro de Emisiones y Transferencia de Contaminantes* (RETC)**	**United States' Toxics Release Inventory (TRI)**
First mandatory reporting year	1993	2004	1987
Industrial activities or sectors covered	Any facility manufacturing, processing or using a listed chemical (except for exempted activities—e.g., research, repair, retail sale, agriculture and forestry). Any facility releasing criteria air contaminants (CACs) to air in specified quantities	Facilities in 11 sectors under federal jurisdiction: petroleum; chemicals; paints and ink; primary and fabricated metals; automotive; pulp and paper; cement and limestone; asbestos; glass; electric utilities; and hazardous waste management. Also, facilities undertaking specific activities subject to federal jurisdiction—e.g., handling hazardous wastes, discharging pollutants to national water bodies	Manufacturing and federal facilities; electric utilities (oil- and coal-fired); coal and metal mines; hazardous waste management and solvent recovery facilities; chemical wholesalers; and petroleum bulk terminals
Number of pollutants subject to reporting	346 pollutants or pollutant groups	104 pollutants	675 pollutants and 30 pollutant categories
Employee threshold	Generally, 10 or more full-time employees. For certain activities (e.g., waste incineration, wastewater treatment) the 10-employee threshold does not apply	No employee thresholds	10 or more full-time employees (or equivalent number of hours)
Substance "activity" (manufacture, process or otherwise use) thresholds, or "release" thresholds	"Activity" thresholds of 10,000 kg for most chemicals. Lower thresholds for certain pollutants such as persistent, bioaccumulative and toxic (PBT) substances, polycyclic aromatic hydrocarbons, dioxins and furans. Air release thresholds for CACs	"Release" and "activity" thresholds for each pollutant (a facility must report if it meets or exceeds either threshold). Except for greenhouse gases, "release" thresholds range from 1 kg to 1,000 kg. "Activity" thresholds range from 5 kg to 5,000 kg. Any release of polychlorinated biphenyls (PCBs) and sulfur hexafluoride, and any release or activity involving dioxins and furans, is reportable	Activity" thresholds of 25,000 lbs, or 11,340 kg (with an "otherwise use" threshold of 4,356 kg); lower thresholds apply for certain pollutants (e.g., persistent bioaccumulative and toxic (PBT) chemicals and dioxins and furans)
Types of releases and transfers covered	On-site releases to air, water, land; disposal, including underground injection; transfers off-site for disposal, treatment prior to final disposal (including sewage), recycling or energy recovery	On-site releases to air, water and land; transfers off-site for disposal, recycling, re-utilization, energy recovery, treatment, co-processing (input from another production process) or sewage	On-site releases to air, water, land, and underground injection; off-site releases to disposal; off-site transfers to recycling, energy recovery, treatment, or sewage

* As of the 2013 reporting year.

PRTR Reporting Requirements

Which Pollutants Must Be Reported?

The pollutants subject to national PRTR reporting requirements are listed because they meet certain criteria for chemical toxicity and the potential for risk to human health and the environment. Each PRTR system covers a specific list of substances: NPRI spans almost 350 pollutants, TRI over 600, and RETC 104.[42]

As of April 2006, the Chemical Abstracts Service (CAS) listed more than 27 million chemical substances and identified more than 239,000 of them as regulated or covered by chemical inventories worldwide.

Facilities report the amounts of each pollutant they have released to the environment, or disposed of, at their own location (on site). They also report how much of the substance was sent off site for disposal, or transferred for recycling or other waste management.

Pollutant-based reporting thresholds exist, and certain pollutants have lower reporting thresholds due to their greater potential for risk to human health and the environment. In general, the PRTR pollutant thresholds are as follows:

- For Canada's NPRI and the U.S. TRI, a facility must report if it manufactures, processes, or otherwise uses (e.g., in cleaning industrial equipment) 10,000 kilograms (NPRI) or 11,340 kilograms (TRI) of a listed pollutant. The U.S.TRI also has an "otherwise use" threshold 4,356 kg (with the exception of PBTs).
- Mexico's RETC has both an "activity" threshold and a "release" threshold. A facility must report if it meets or exceeds either threshold. The RETC "activity" threshold is typically either 2,500 kilograms or 5,000 kilograms, depending on the substance; the typical "release" threshold is 1,000 kilograms.

For more information, see the List of Pollutants Reported to the North American PRTRs at **<PRTR Reporting Requirements>.**

Assessing potential harm to human health or the environment from particular releases of a pollutant is a complex task, because the potential of a substance to cause harm arises from various factors, including its inherent toxicity and the nature of the exposure to the substance (e.g., the potential risk posed by asbestos sent to a secure landfill is considered to be much lower than the risk posed by asbestos released to air). However, the reported data and information about a pollutant's chemical properties and toxicity can serve as a starting point for learning more about its potential impacts. For more information, see the text box in the report introduction, "Factors to Consider When Using PRTR Data to Evaluate Risk." Readers may wish to seek other sources for more information, such as:

- US Agency for Toxic Substances and Disease Registry, ToxFAQs,: <**www.atsdr.cdc.gov/toxfaqs/index.asp**>;
- State of New Jersey, Department of Health, *Right-to-Know Hazardous Substance Fact Sheets* (information also available in Spanish): <**http://web.doh.state.nj.us/rtkhsfs/indexFs.aspx**>.

Which Industries Report?

Each country requires PRTR reporting by facilities in specific industrial sectors, or undertaking specific industrial activities.

- In Canada, all facilities that meet reporting thresholds and requirements report to the NPRI, with the exception of a few resource-based sectors and certain activities such as research laboratories.
- In Mexico, all industrial sectors regulated under federal law are required to report to the RETC, along with facilities in other sectors that engage in activities subject to federal regulation. These include facilities that handle hazardous wastes, or discharge pollutants into national water bodies.

42. As of the 2014 reporting year, Mexico's RETC list has expanded to include 200 substances.

- In the United States, TRI requires reporting by federal facilities, most manufacturing facilities and industries that service manufacturing facilities (e.g., electric utilities and hazardous waste management facilities). A few resource-based sectors, such as oil and gas extraction, are exempt from reporting.

North American Industry Classification System

Canada, Mexico and the United States have adopted the North American Industry Classification System (NAICS), whose codes are used to categorize the industrial activities of a facility. NAICS codes were established in 1997 and since 2006 they have been incorporated into PRTR reporting to replace the standard industrial classification (SIC) codes used by each country. Although there is some variation among the three countries in the subsector categorizations and codes used, the breakdown of industrial sectors into general categories is the same (see the text box). For more information about the implementation of the NAICS system in each country, see:

- Canada: **https://www.statcan.gc.ca/eng/subjects/standard/naics/2017v2/index**
- Mexico: **http://www.inegi.org.mx/est/contenidos/proyectos/SCIAN/presentacion.aspx**
- United States: **www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007**

North American Industry Classification System

NAICS code	Industry
11	Agriculture, Forestry, Fishing and Hunting
21	Mining, Quarrying and Oil and Gas Extraction
22	Utilities (Electricity, Water and Gas Distribution)
23	Construction
31/32/33	Manufacturing
41/42/43	Wholesale Trade
44/45/46	Retail Trade
48/49	Transportation and Warehousing
51	Information and Cultural Industries
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support, Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
91/92/93	Public Administration

PRTR reporting requirements are based in part on the industrial activity undertaken within a facility, and not only the industry code assigned to that facility. Therefore, not all facilities within a given sector might have to report. For example, within the economic sector that includes dry-cleaning, only those facilities undertaking the actual dry-cleaning process, and not clothing drop-off points, might be required to report. Another example is a food processing plant that is required to report because it has its own power plant to generate electricity.

Employee Thresholds

Both NPRI and TRI have an employee threshold, generally corresponding to the equivalent of 10 full-time employees (with some exceptions for pollutants or certain types of facilities). Mexico's RETC does not have an employee threshold. More information on reporting instructions is available on the NPRI, RETC and TRI websites.

Taking Stock Terminology

Taking Stock uses the following categories for presenting information on pollutant releases and transfers (see figure A-1).

On-site releases or disposals occur at a facility. These include:

- Releases to air
- Releases to surface water
- Releases to underground injection
- Disposals or land releases.

Off-site disposal: describes pollutants sent to off-site locations for disposal.

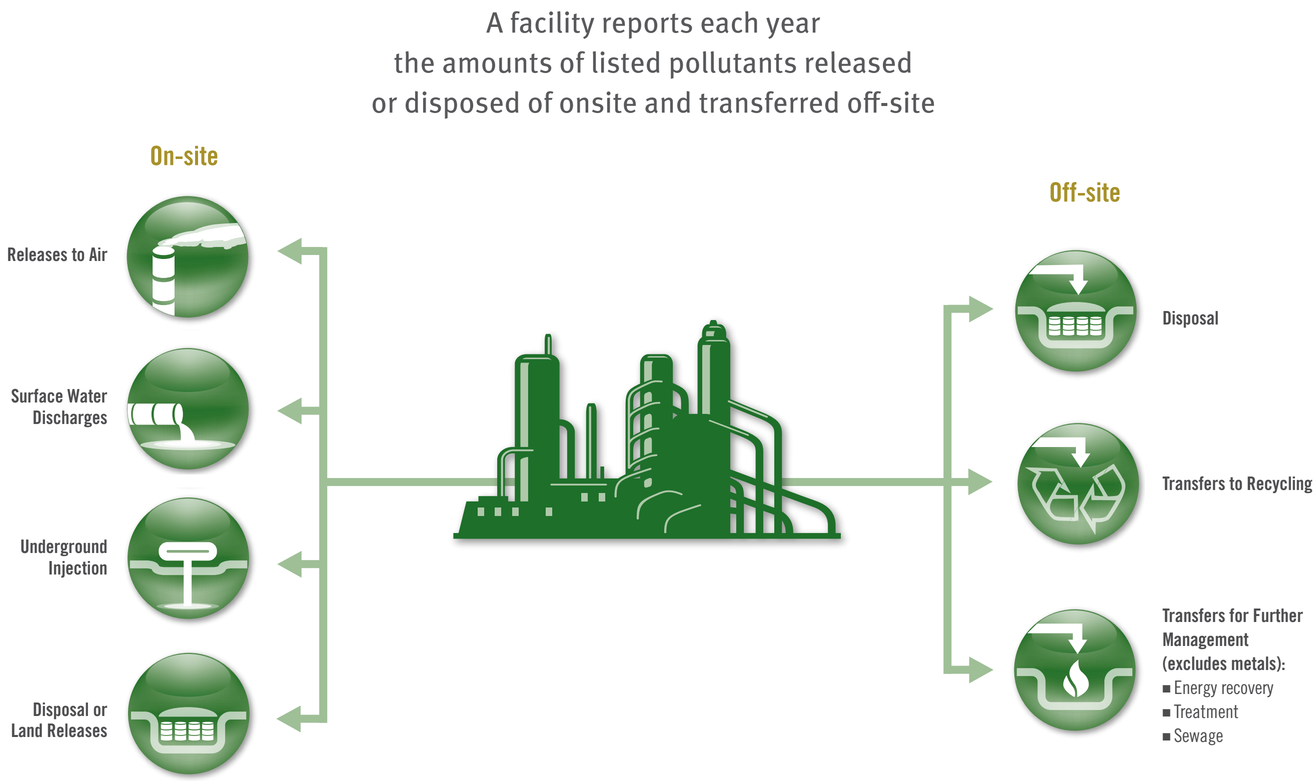
Transfers to recycling describes substances sent off-site for recycling.

Transfers for further management includes pollutants (other than metals*) sent off-site for treatment, energy recovery, or to sewage.

**A note about metals:* Quantities of metals reported as sent off-site for sewage, treatment or energy recovery are included in the *off-site disposal* category – since these metals may be captured and removed from waste and disposed of in landfills or by other methods. This approach recognizes the physical nature of metals and the fact that they are not likely to be destroyed through treatment.

Note: Because this terminology is specific to *Taking Stock,* the terms release and transfer as defined here may differ from their use in NPRI, RETC and TRI.

Figure A-1 Pollutant Releases and Transfers in North America



Limitations of PRTR Data

Because of national PRTR reporting requirements, including thresholds for pollutants and facilities, only a portion of all industrial pollution is being captured. Also, industrial facilities are not the only sources of pollution in North America.

North American PRTR data do not provide information on the following:

- *All potentially harmful substances.* The data provide information only on the pollutants reported to each country's PRTR.
- *All sources of contaminants.* The report includes only those facilities in the countries' industrial sectors, or undertaking specific industrial activities, that are subject to reporting to each national PRTR program. The North American PRTRs do not include emissions from automobiles or other mobile sources, from natural sources such as forest fires, or from agricultural sources. For some pollutants, these mobile, natural and agricultural sources can be large contributors to the overall amounts.
- *Releases and transfers of all pollutants from a facility.* Only those pollutants for which reporting thresholds are met are included.

- *All facilities within required reporting sectors.* In Canada and the United States, only facilities with the equivalent of 10 full-time employees must report (with certain exceptions). Mexico has no employee threshold.
- *Environmental fate of or risks* from the pollutants released or transferred.
- *Levels of exposure* of human or ecological populations to the pollutants.
- *Legal limits* of a pollutant from a facility. The data do not indicate whether a facility is in compliance with permits and other regulations.

Reporting of Criteria Air Contaminants and Greenhouse Gases

Data for releases of criteria air contaminants (CACs) and greenhouse gases (GHGs) are not included in *Taking Stock,* due to differences in national reporting requirements for these pollutants. CACs—including carbon monoxide, nitrogen oxides, particulate matter, sulfur oxides and volatile organic compounds—are a group of chemicals associated with environmental effects such as smog, acid rain and regional haze, and health effects such as respiratory illnesses. Major sources of CACs are the burning of fossil fuels, as well as natural resource extraction and a variety of manufacturing activities. GHGs contribute to climate change by trapping heat within the earth's atmosphere. The major GHGs include carbon dioxide, methane, nitrous oxide and three groups of fluorinated gases. Some of the main anthropogenic sources of GHGs are the burning of fossil fuels, deforestation and agricultural activities. CACs are reported to Canada's NPRI and GHGs are reported to Mexico's RETC, but these pollutants are not subject to US TRI reporting. However, there are other sources of information on emissions of these pollutants in all three countries:

Criteria Air Contaminants:

- Canada's National Pollutant Release Inventory: (**www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory.html**)
- Canada's Air Pollutant Emission Inventory: **www.ec.gc.ca/pollution/default.asp?lang=En&n=E96450C4-1**
- U.S. National Emissions Inventory: **https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei**
- *Inventario Nacional de Emisiones de México* (National Emissions Inventory of Mexico): **https://www.gob.mx/inecc/acciones-y-programas/emisiones-80133**>

Greenhouse Gases:

- Canada's Greenhouse Gas Reporting Program and National Inventory Report: **http://ec.gc.ca/ges-ghg/default.asp?lang=en&n=04**
- U.S. Greenhouse Gas Reporting Program: < **https://www.epa.gov/ghgreporting** >
- Mexico's RETC (facility-specific GHG data): (**http://apps1.semarnat.gob.mx/retc/index.html**)

Appendix 2

Main Pollutants Reported by the North American Mining Sector (2009–2013): Summary of On-site Release and Disposal Data, Sources and Potential Effects

The main pollutants included in tables A-2 and A-3 were selected and ranked based on release and transfer data available through the CEC's North American PRTR database for the years 2009 through 2013. During this period, there were few changes in reporting requirements that affected mining releases and transfers. A total of 93 pollutants were reported by the mining sector over this five-year period. Average annual total releases and transfers were under 10 kg for 14 of these substances.

Calculating ranks and selecting the main pollutants based on five-year averages, rather than on a single year, has the advantage of minimizing the year-to-year fluctuations caused by major facilities shutting down or coming on-stream or by anomalously large discharges from spills or other infrequent events occurring at one mine during one year. A few substances that were specific to one or a very small number of facilities over the five-year period were excluded from the list of main pollutants (see notes).

Guidelines for drinking water and for the protection of aquatic life in fresh water in the United States and Canada are also summarized in table A-2. While PRTR data do not provide any information about levels of pollutants in waters downstream of the mining facility, these guidelines are an indication of the risks posed to water supplies, public health and aquatic ecosystems by pollutant releases to water and by pollutant land disposal when the pollutant may be released to water later. Drinking water guidelines are maximum acceptable concentrations based on health considerations, unless noted otherwise. Guidelines for the protection of aquatic life are one or both of: 1) a maximum concentration for chronic or long-term exposure, and 2) a maximum concentration for acute or short-term exposure. Note that aquatic life guidelines are expressed in micrograms per liter (μg/L), equivalent to parts per billion, while drinking water standards are expressed in units that are 1000 times larger (mg/L, equivalent to parts per million).

Table A-2. Main Mining Pollutants Reported to the PRTRs (2009-2013): Summary of On-site Release and Disposal Data, Sources and Potential Effects

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	**On-site Mining Releases/ Disposals,** (Rank by 2009-2013 Average)			**Mining-related sources**	**Potential effects**	**Water quality guidelines**
	Air	**Water**	**Land**			
Ammonia CA, US **Ranking:** **All sectors: 9** **Mining: 14**	1	2	17	Mineral processing from many types of mining led to ammonia releases. The highest ammonia air emissions in 2013 were from a vanadium mine and several ceramics facilities. Highest water discharges were from metal ore mines. Ammonia also occurs naturally as a waste product of animal and microbial metabolism.	Ammonia discharged to water can be acutely toxic to aquatic life and can have long-term detrimental effects. Concerns about effects on drinking water, though, are based on aesthetic (taste and odor), not health, considerations. Inhalation of corrosive ammonia fumes can cause irritation and burns. Ammonia can combine with sulfates and nitrates to form fine particulate matter in air (and in this role, is considered a criteria air contaminant). Ammonia emissions and water discharges can also be a source of nutrients to plants and bacteria, leading to eutrophication.	There are no set guidelines for drinking water. Guidelines for toxicity to aquatic life vary with pH and temperature (US EPA 2013).
Antimony* CA, US **Ranking:** **All sectors: 45** **Mining: 13**	38	18	13	Release of antimony was mainly through disposal in tailings and waste rock and in water discharges from metal mines, especially gold mines. Antimony is often present in gold ores. It is a metalloid, exhibiting similar properties to arsenic and often occurring with arsenic.	Antimony exposure causes microscopic changes to human organs and tissues. There is evidence that antimony bioaccumulates in aquatic organisms but does not become magnified in food chains (Dovick et al. 2016). There is little information on toxicity available.	Drinking water guideline: 0.006 mg/L for US and Canada. No guidelines are set for protection of aquatic life due to insufficient data.

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	On-site Mining Releases/ Disposals, (Rank by 2009-2013 Average) Air	Water	Land	Mining-related sources	Potential effects	Water quality guidelines
Arsenic* CA, MX, US **Ranking:** **All sectors: 15** **Mining: 5**	17	13	5	A main source is disposal in tailings and waste rock, especially from gold mines. Arsenic occurs naturally in rock and soil and is sometimes naturally elevated in water to levels that exceed drinking water guidelines. Arsenic can be dissolved from rock under neutral pH conditions, meaning arsenic disposed of on land may later be released into water independently of acid rock drainage.	Arsenic is a carcinogen. Long-term exposure has additional risks to health (including skin damage and impairment of the circulatory system) and to reproduction and fetal and child development. It is generally in the form of inorganic or organic compounds, some of which bioaccumulate. Arsenic has high acute toxicity to aquatic life.	Drinking water guideline: 0.010 mg/L for the United States and Canada. Guidelines for protection of aquatic life: US–340 µg/L acute and 150 µg/L chronic; Canada–5 µg/L long-term.
Barium* US **Ranking:** **All sectors: 14** **Mining: 10**	32	19	10	Barium on-site disposal was mainly from coal mines and some metal mines. In 2013, 95 percent of barium releases and disposal was from decommissioning a heap leach pad at one gold mine in Utah. Total barium releases will be underestimated as barium is only reported in the United States.	Barium in drinking water can cause elevated blood pressure. Human health concerns for air emissions are related to inhalation where barium compounds are used in sectors such as manufacturing. Barium compounds have varying degrees of solubility in water, with the natural barium compounds in mineral deposits being not as soluble as industrial barium compounds.	US drinking water guideline: 2 mg/L; no guideline set for Canada. No guidelines are set for protection of aquatic life.
Cadmium* CA, MX, US **Ranking:** **All sectors: 52** **Mining: 18**	27	17	23	Cadmium was released to air mainly through base metal mining (85 percent of emissions from 2009 to 2013), with gold and silver mines also contributing. Water discharges and land disposal were reported by a wider range of mining types, but still dominated by metal mines. Cadmium disposed of on land may later be released to water as cadmium is often a component of acid rock drainage. Cadmium occurs naturally in rock and soil.	Cadmium in drinking water can lead to kidney and bone damage in humans. Unlike many metals, cadmium is not an essential part of the diet for freshwater organisms. It blocks the uptake of calcium in aquatic organisms, leading to calcium deficiency. Toxicity is affected by water hardness, with cadmium being more toxic in softer water.	Drinking water guideline: 0.005 mg/L for the United States and Canada. Guidelines for protection of aquatic life: US–1.8 µg/L acute and 0.72 µg/L chronic; Canada–1 µg/L short-term and 0.09 µg/L long-term.
Chromium* CA, MX, US **Ranking:** **All sectors: 13** **Mining: 8**	23	16	8	Though amounts released varied greatly from year to year, chromium was a common constituent reported in disposal through tailings and waste rock by metal ore mines. Chromium occurs naturally in rock and soil.	All chemical forms of chromium can be toxic to humans at high levels. Lower levels can cause allergic reactions including asthma and skin irritations. Chromium is toxic to aquatic life, though toxicity varies considerably with the chemical form. Most chromium entering water remains attached to sediment particles. Hexavalent chromium (Cr^{6+}) compounds (not generally associated with mining) have the highest toxicity and bioaccumulate in fish tissues.	Drinking water guideline: 0.1 mg/L for US; 0.05 for Canada. Guidelines for protection of aquatic life: US–570 µg/L acute and 74 µg/L chronic; guidelines are specific to the chemical form of chromium in Canada.
Cobalt* CA, US **Ranking:** **All sectors: 33** **Mining: 12**	29	15	11	Cobalt was released to all media by mines of several types, with 84 percent of releases to air (2009 to 2013) from base metal mines, and 69 percent of water discharges from gold and silver mines. Land disposal was reported by a wide range of metal and non-metallic mines. Cobalt occurs naturally in rocks and soil.	Cobalt is beneficial to health as it is a constituent of vitamin B12, but exposure to high levels can affect the lungs and heart and can cause skin problems in humans. Cobalt exhibits acute and chronic toxicity to aquatic life, but indications are that it does not significantly bioaccumulate in the tissues of fish (Australian Government 2014) (EC 2013a). Toxicity varies with water hardness (Pourkhabbaz et al. 2011).	No water quality guidelines are set for cobalt in the US and Canada due to insufficient data.

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	On-site Mining Releases/ Disposals, (Rank by 2009-2013 Average) Air	Water	Land	Mining-related sources	Potential effects	Water quality guidelines
Copper* CA, US **Ranking:** **All sectors: 5** **Mining: 4**	7	10	4	Copper is a common constituent of releases to air and land disposal to tailings and waste rock for metal ore mines, especially base metal mines. Copper occurs naturally in rock, soil and water. Copper disposed of on land may later be released to water as it is often a component of acid rock drainage.	Copper is a required nutrient at low levels, but high levels can be harmful to human health, causing liver or kidney damage. Copper in drinking water affects water taste and causes staining of laundry. Copper is also essential for plants and animals, but in some chemical forms it is highly toxic to aquatic life. Water quality characteristics such as pH, hardness and amount of dissolved organic matter have a major effect on its toxicity.	Drinking water guidelines are based on aesthetic criteria: 1.3 mg/L for US and 1.0 mg/L for Canada. Guidelines for protection of aquatic life: US–guidelines are calculated based on how available the copper would be to aquatic life; Canada–the guideline varies with water hardness. If hardness is not known, the long-term guideline is 2 µg/L.
Cyanides CA, MX, US **Ranking:** **All sectors: 57** **Mining: 16**	8	14	18	All cyanide emissions (and most other cyanide releases) were from gold mines and are related to beneficiation. Cyanide (CN^-) is found in compounds with other chemicals, such as hydrogen (forming a gas), and sodium or potassium (forming salts that are water soluble). Hydrogen cyanide released to air is very stable, taking years to break down. Cyanides can also occur naturally.	Although very small amounts of cyanide form part of the human diet (vitamin B12), cyanide is a rapidly acting poison to humans if inhaled or ingested. Long-term exposure at lower levels causes health problems, including thyroid and nerve damage. Cyanide has a high acute and chronic toxicity to aquatic life.	Drinking water guideline: 0.2 mg/L for the United States and Canada. Guidelines for protection of aquatic life: US–22 µg/L acute and 5.2 µg/L chronic; Canada–5 µg/L long-term.
Hydrochloric acid CA, US **Ranking:** **All sectors: 16** **Mining: 22**	3	–	41	Hydrochloric acid was emitted by mines in several categories through beneficiation processes. Most (84 percent) of the total air emissions was from iron ore mines (which are exempt from reporting in the United States). Hydrochloric acid released to air is generally rapidly neutralized when it contacts soil, though it can contaminate groundwater.	High concentrations of hydrochloric acid in air are toxic to humans when inhaled. It is acutely toxic to all forms of life and contributes to production of smog.	Not applicable (not released to water, and no guidelines).
Hydrogen fluoride CA, US **Ranking:** **All sectors: 25** **Mining: 24**	5	–	30	Hydrogen fluoride was emitted from several US ceramics facilities and two Canadian iron ore mines. Fluoride compounds are found naturally at low levels in the environment.	Hydrogen fluoride (hydrogen combined with fluorine) is a gas that dissolves in water to form an acid. Inhaling high levels of hydrogen fluoride can harm the heart and lungs and can cause death. Lower levels are associated with eye irritation, and chronic exposure leads to bone damage.	Not applicable (not released to water, and no guidelines).
Lead* CA, MX, US **Ranking:** **All sectors: 2** **Mining: 2**	10	11	2	Disposed of in tailings and waste rock and released to air and water by mines in most categories—but especially base metal mines. Lead disposed of on land may later be released to water as it is often a component of acid rock drainage. Lead occurs naturally in rock and soil.	Exposure to lead causes physical, mental and behavioral developmental impairment in infants and children. Lead exposure causes kidney damage and raised blood pressure in adults. Lead is acutely toxic to fish and aquatic invertebrates and lower levels have effects on survival and reproduction.	Drinking water guidelines: 0.015 mg/L for the United States (Treatment Technique action level); 0.010 mg/L for Canada. Guidelines for protection of aquatic life: US–65 µg/L acute and 2.5 µg/L chronic; Canada–the guideline varies with water hardness. If hardness is not known, the long-term guideline is 1 µg/L.

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	On-site Mining Releases/ Disposals, (Rank by 2009-2013 Average)			Mining-related sources	Potential effects	Water quality guidelines
	Air	Water	Land			
Manganese* CA, US **Ranking:** **All sectors: 4** **Mining: 3**	9	3	3	Manganese releases to all media were highest from iron ore mining, which accounted for 58, 50 and 57 percent, respectively, of air, water and land releases and disposal in 2013. As iron ore mining is exempt from reporting in the United States, manganese releases will be underestimated.	Manganese is an essential element in the human diet. Occupational exposure to dust and fumes is a serious health risk, causing lung irritation and reproductive effects. Manganese is also an essential element for plants, animals and bacteria, but some manganese compounds can have moderate acute and moderate chronic toxicity to aquatic life.	Drinking water guideline: 5 mg/L for the United States and Canada, based on taste and staining of laundry. No guidelines for the protection of aquatic life.
Mercury* CA, MX, US **Ranking:** **All sectors: 69** **Mining: 15**	28	25	15	Mercury occurs naturally in rock and soils, but significant amounts also enter ecosystems from anthropogenic sources. Air emissions were from gold, silver, base metal and iron operations—but consistently close to 80 percent from gold mining. Water discharges and land disposal of mercury were reported by a range of mining types, with high year-to-year variation. Inorganic mercury can be transformed into methylmercury through chemical and biological processes. Methylmercury is the form that is very toxic and accumulates in aquatic biota.	Exposure to all forms of mercury causes brain and other nerve damage and kidney damage in humans. Young children and developing fetuses are more sensitive than adults. Both inorganic and methylmercury forms are toxic to aquatic plants and animals, with a range of effects including reproductive impairment and reduced growth. Methylmercury becomes concentrated through food chains, so that even when it is low in water it may become elevated in fish and exceed guidelines for fish consumption.	Drinking water guideline: 0.002 mg/L for US; 0.001 mg/L for Canada. Guidelines for protection of aquatic life: US–1.4 µg/L acute and 0.77 µg/L chronic for methylmercury; Canada–0.026 µg/L long-term for inorganic mercury and 0.004 µg/L long-term for methylmercury.
Methanol CA, US **Ranking:** **All sectors: 7** **Mining: 19**	6	23	22	Emissions were from a few diverse types of facilities, including potash and ceramics producers. An Alaskan lead-zinc mine accounted for 86 percent of methanol emissions in 2013. These were fugitive emissions from quarrying operations, reflecting winter use of methanol as antifreeze in dust control water (Northwest Arctic Borough 2009).	Methanol in air is an eye, nose and throat irritant. Exposure through any route can lead to any of multiple afflictions, including liver damage, blindness and death. Methanol released to air is carried long distances, eventually breaking down or entering water. Long-term exposure to methanol can affect fertility of aquatic biota. Methanol does not accumulate in fish.	No water quality guidelines are set for cobalt in the United States and Canada.
Nickel* CA, MX, US **Ranking:** **All sectors: 12** **Mining: 7**	13	7	7	Discharged to water and disposed of through tailings and waste rock at many facilities, primarily metal ore, coal and iron ore mines. Five Canadian nickel mines accounted for 62 percent of water discharges and 64 percent of land disposal in 2013. Nickel disposed of on land may later be released to water as it is often a component of acid rock drainage. Nickel occurs naturally in rock and soil.	Nickel can cause an allergic reaction in humans, through skin contact, inhalation or ingestion. Occupational risks of high exposure include cancer. Nickel toxicity to aquatic organisms varies with water hardness, with nickel being more toxic in softer water.	No drinking water guidelines. Guidelines for the protection of aquatic life: US–470 µg/L acute and 52 µg/L chronic; Canada–the guideline varies with water hardness. If hardness is not known, the long-term guideline is 25 µg/L.

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	On-site Mining Releases/ Disposals, (Rank by 2009-2013 Average)			Mining-related sources	Potential effects	Water quality guidelines
	Air	Water	Land			
Nitric acid/ nitrates CA, US **Ranking:** **All sectors: 6** **Mining: 11**	26	1	14	Explosives are a source of nitrates in mine water discharges. Nitric acid/nitrate was discharged to water from many facilities, mainly metal ore and iron ore mines. Mines in the "gold and silver" category accounted for 46 percent of water discharges. Nitrate compounds are common in the environment.	Nitric acid and nitrate compounds released to water dissociate to nitrate ions. Nitrate in drinking water is particularly toxic to infants. Nitrate can have a direct toxicity to aquatic life (though much lower than ammonia). Nitrate is a nutrient and its anthropogenic enrichment in surface waters can lead to eutrophication (Government of Canada 2014, CCME 2012). Nitric acid is a health risk when emitted to air. It is corrosive and high concentrations in liquid forms cause burns.	Drinking water guideline for nitrate: 10 mg/L (as nitrogen) for the United States and Canada, and 45 mg/L when measured as nitrate for Canada. Guidelines for protection of aquatic life: no US guidelines; Canada–550,000 µg/L short-term and 13,000 µg/L long-term for nitrate.
Phosphorus (total) CA **Ranking:** **All sectors: 11** **Mining: 6**	16	8	6	Releases to water and land releases and disposal were reported at mines in several categories. Coal mining accounted for 93 percent of phosphorus water discharges in 2013. The one phosphate rock mine reporting that year accounted for 82 percent of phosphorus air emissions. The extent of releases will be underestimated, as phosphorus is only reported in Canada. Phosphorus occurs naturally in rock and soil.	Phosphorus is a nutrient and can lead to eutrophication, causing changes to aquatic ecosystems that affect water use, drinking water quality and aquatic life. Phosphorus only has direct toxicity at very high levels. All forms of phosphorus are required to be reported in Canada because phosphorus can enter water by being deposited from air releases and leached from land deposits and change into chemical forms that are available for biological growth (EC 2013b).	No specific water quality guidelines. Both Canada and the United States have guidance frameworks for addition of nutrients (including phosphorus) to freshwater bodies (CCME 2004, US EPA 2016b).
Selenium* CA, US **Ranking:** **All sectors: 70** **Mining: 17**	31	9	19	Selenium releases to water in 2013 were mainly (85 percent) from coal mining. Mines in the metal ore categories also released selenium to water and accounted for most (95 percent) of land disposal from mining. Selenium occurs naturally and is often associated with sulfide mineral deposits.	Selenium exposure can lead to hair or fingernail loss and circulatory problems in humans. Selenium is an essential nutrient for animals at low levels, but it has a high acute toxicity to aquatic life and causes reproductive impairment. Because it bioaccumulates in the food chain, selenium is a risk especially to predatory fish.	Drinking water guideline: 0.05 mg/L for the United States and Canada. Guidelines for protection of aquatic life: US–1.5 µg/L in streams for chronic exposure plus guidelines for selenium in aquatic animal tissues (US EPA 2016a); Canada–1 µg/L long-term.
Silver* CA, US **Ranking:** **All sectors: 80** **Mining: 23**	41	20	25	Silver was released and disposed of by gold, silver and base metal mines. Silver occurs naturally in rock but is not abundant, and this is reflected in the relatively few facilities reporting silver releases.	Chronic exposure to high levels of silver leads to skin discoloration in humans. Silver is not an essential nutrient. It is accumulated by algae and filter-feeders, and in some fish. It can accumulate to high levels in biota, but, depending on the form, may not have adverse effects. It can be acutely toxic through uptake through gills.	No drinking water guidelines (as drinking water contributes only a small amount to daily intake of silver). Guidelines for protection of aquatic life: US–3.2 µg/L acute; Canada–0.25 µg/L long-term.

Pollutant and Ranking (by 2009-2013 Average of Total Releases & Transfers)	**On-site Mining Releases/ Disposals,** (Rank by 2009-2013 Average) Air	Water	Land	Mining-related sources	Potential effects	Water quality guidelines
Sulfuric acid CA, US **Ranking:** **All sectors: 8** **Mining: 21**	2	–	61	Sulfuric acid was only released to air (not to water or land). Mines in several categories were sources, but 60 percent of emissions in 2013 were from base metal mines. Sulfuric acid is a common industrial chemical for many industries.	Inhaling sulfuric acid affects teeth and eyes and is a respiratory tract irritant. Sulfuric acid emissions are of environmental concern as they contribute to acidification of lakes and streams through acid rain.	Not applicable (not released to water) – though water is affected through acid rain.
Thallium*† US **Ranking:** **All sectors: 86** **Mining: 20**	46	24	20	Thallium is rare but widespread and may be present in metal sulfide ores and coal. It was released mainly by one copper mine and several gold mines. Total thallium releases may be underestimated as thallium is only reported in the United States.	Thallium exposure can cause liver problems, changes in blood, kidneys and intestines, and hair loss in humans. Thallium may bioaccumulate in aquatic organisms and it can be toxic to fish, invertebrates and aquatic plants.	Drinking water guidelines: 0.002 mg/L in US; no Canadian guideline. Guidelines for protection of aquatic life: no US guideline; Canada–0.8 µg/L long-term.
Vanadium* CA, US **Ranking:** **All sectors: 20** **Mining: 9**	24	4	9	Most air and water releases of vanadium from 2009 to 2013 were from one US vanadium mine, while on-site disposal was reported by many metal, non-metallic and coal mines. Vanadium, though not abundant, occurs naturally in rock and soil.	Exposure to high levels of some forms of vanadium in air can result in lung damage in humans. Known effects of vanadium in aquatic environments include decreased photosynthesis of algae and reduction of growth and feeding response in fish (Costigan et al. 2001).	There are no water quality guidelines for vanadium.
Zinc* CA, US **Ranking:** **All sectors: 1** **Mining: 1**	4	5	1	Zinc's high ranking in all categories of releases reflects its natural abundance in the environment. In 2013, 99 percent of air emissions, 59 percent of water discharges and 98 percent of land disposal was from gold, silver and base metal mines. Iron ore mines and coal mines also contributed to zinc water discharges. Zinc disposed of on land may later be released to water as it is often a component of acid rock drainage.	Zinc is essential in the human diet, but as the main source is through food, not drinking water, elevated zinc in water is not considered a health concern. Inhalation of some zinc compounds can be damaging to human health, affecting the lungs. Zinc in water at high concentrations is acutely lethal to fish because it causes irreversible damage to their gills. At lower concentrations, zinc blocks uptake of calcium, leading to calcium deficiency in fish and invertebrates. Zinc also has toxic effects on algae.	Drinking water guidelines: 5 mg/L for the United States and Canada, based on taste and other aesthetic considerations. Guidelines for protection of aquatic life: US–120 µg/L acute and chronic; Canada–30 µg/L long-term.

CA=Canada's National Pollutant Release Inventory (NPRI); MX=Mexico's *Registro de Emisiones y Transferencia de Contaminantes* (RETC); US= United States' Toxics Release Inventory (TRI)
† Added to the substance list of the NPRI in 2014. * and its compounds.
Sources: Several national pollutant information series (Australian Government 2014, Scottish Environment Protection Agency, ECCC 2016, ATSDR 2016, CCME 2014a), augmented with other references as noted. Water quality guidelines are from CCME (2014b), Health Canada (2017), US EPA (2017) and US EPA (2016c).
Note: Differences among national reporting requirements need to be taken into account when interpreting North American PRTR data.

Table A-3. Main Mining Pollutants (based on mean annual releases or disposals, 2009-2013)

Air Emissions

Pollutant	% of total
Ammonia	34%
Sulfuric acid	17%
Hydrochloric acid	15%
Zinc*	8%
Hydrogen fluoride	5%
Methanol	4%
Copper*	2%
Cyanides	2%
Manganese*	2%
Lead*	1%

Water Discharges

Pollutant	% of total
Nitric acid/nitrates	66%
Ammonia	22%
Manganese*	4%
Vanadium*	2%
Zinc*	1%
Nickel*	1%
Phosphorus (total)	1%
Selenium*	0.3%
Copper*	0.3%
Lead*	0.3%

Disposal/Releases to Land

Pollutant	% of total
Zinc*	24%
Lead*	22%
Manganese*	20%
Copper*	9%
Arsenic*	8%
Phosphorus (total)	8%
Nickel*	3%
Chromium*	2%
Vanadium*	1%
Barium*	1%

* and its compounds.

Additional pollutants of note (with significant total disposals or releases, but not included in the above tables because they are specific to one or a small number of facilities):

Air:

- **Aluminum (fume or dust)** formed 2% of the total air emissions (2009–2013), but this was all from two Canadian facilities, an iron ore mine and a gold mine. The high annual average was due to an anomalously large release to air in 2010 from the gold mine.
- **Carbon disulfide** formed 3% of the total air emissions (2009–2013), all from three Canadian metal mining and processing facilities. Emissions are likely to be related to smelters located with the mines (see the note on TRS in the methodology section).
- **Chlorine** formed 0.6% of air emissions, mainly from one Canadian nickel mining and smelting facility.

Water:

- **Fluorine** formed 1% of total water releases (2009–2013), but it was associated with only one facility in 2013, a Canadian niobium mine, where fluorine is a constituent of the ore body (Clow et al. 2011).

Land:

- **Aluminum oxide (fibrous forms):** large amounts of this substance disposed of on-site by one Canadian nickel mine in 2009 and 2010 account for it making up 1% of land releases and on-site disposal (2009–2013).

References

ATSDR. 2016. "Toxic substances portal: Toxicological profiles and ToxFAQs". Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/toxprofiles/index.asp. Consulted on 15 October 2016

Australian Government. 2014. "Substance fact sheets". Australian National Pollutant Inventory. http://www.npi.gov.au/substances/fact-sheets. Consulted on 15 October 2016

CCME. 2004. *Phosphorus: Canadian guidance framework for the management of freshwater systems*. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment. ISBN: 1-896997-34-1

CCME. 2012. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: Nitrate ion*. Canadian Council of Ministers of the Environment. ISBN: 1-896997-34-1

CCME. 2014a. "Canadian environmental quality guidelines (factsheets)". http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/. Consulted on 1 February 2017

CCME. 2014b. "Water quality guidelines for the protection of aquatic life: Summary table". Canadian Council of Ministers of the Environment. http://st-ts.ccme.ca/en/index.html

Clow, G.G., B. Salmon, M. Lavigne, B. Mcdonough, P. Pelletier, and D. Vallières. 2011. *Technical report on expansion options at the Niobec Mine, Quebec, Canada*. Roscoe Postle Associationes Inc. for Iam Gold Corporation

Costigan, M., R. Cary, and S. Dobson. 2001. *Vanadium pentoxide and other inorganic vanadium compounds. Word Healt Organization*. Concise International Chemical Assessment Document 29. United Nations Environment Programme, Internatioal Labour Organization and World Heath Organization. Available at: http://apps.who.int/iris/bitstream/10665/42365/1/9241530294.pdf

Dovick, M.A., T.R. Kulp, R.S. Arkle, and D.S. Pilliod. 2016. Bioaccumulation trends of arsenic and antimony in a freshwater ecosystem affected by mine drainage. *Environmental Chemistry* 13 (1): 149–59

EC. 2013a. *Canadian Environmental Protection Act, 1999-Federal Environmental Quality Guidelines- Cobalt*. Environment Canada. Available at: http://www.ec.gc.ca/ese-ees/92F47C5D-24F5-4601-AEC0-390514B3ED75/FEQG_Cobalt_EN.pdf

EC. 2013b. «Phosphorus guidance». Environment Canada. https://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=46C694F1-1. Consulted on 17 August 2016

ECCC. 2016. "Substances (managed under CEPA Schedule 1)". Environment and Climate Change Canada. www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=6B9B6B28-1. Consulted on 7 October 2016

Government of Canada. 2014. "Guidelines for Canadian drinking water quality: Guideline technical document - nitrate and nitrite". http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/water-nitrate-nitrite-eau/index-eng.php?page=2#a2. Consulted on 20 October 2016

Health Canada. 2017. *Guidelines for Canadian drinking water quality - summary table.* Ottawa, ON: Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada

Northwest Arctic Borough. 2009. Title 9 master plan permit no: 107-03-10 (issued to Teck Alaska, Inc.)

Pourkhabbaz, A., T. Khazaei, S. Behravesh, M. Ebrahimpour, and H. Pourkhabbaz. 2011. Effect of water hardness on the toxicity of cobalt and nickel to a freshwater fish, *Capoeta fusca*. *Biomedical and Environmental Sciences* 24 (6): 656–60

Scottish Environment Protection Agency. n.d. "Pollutant fact sheets (Scottish Pollutant Release Inventory)". http://apps.sepa.org.uk/spripa/Pages/SubstanceSearch.aspx

US EPA. 2013. *Aquatic life ambient water quality criteria for ammonia—freshwater*. EPA-822-R-13-001. US Environmental Protection Agency. Available at: https://www.epa.gov/sites/production/files/2015-08/documents/aquatic-life-ambient-water-quality-criteria-for-ammonia-freshwater-2013.pdf. ISBN: EPA-822-R-13-001

US EPA. 2016a. *Aquatic life ambient water quality criterion for selenium in freshwater 2016—fact sheet*. US Environmental Protection Agency. Available at: https://www.epa.gov/sites/production/files/2016-06/documents/se_2016_fact_sheet_final.pdf

US EPA. 2016b. "Ecoregional criteria". US Environmental Protection Agency. https://www.epa.gov/nutrient-policy-data/ecoregional-criteria

US EPA. 2016c. "National primary drinking water regulations and national secondary drinking water regulation". US Environmental Protection Agency. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulation-table

US EPA. 2017. "National recommended water quality criteria - aquatic life criteria table". https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table

Commission for Environmental Cooperation
393, rue St-Jacques Ouest, bureau 200
Montreal (Quebec)
H2Y 1N9 Canada
t 514.350.4300 f 514.350.4314
info@cec.org / www.cec.org