This lesson focuses on conflicts arising due to the importance of water. Students will skim and then read a short article, analyze and discuss a map and graph, create a timeline, classify and use new vocabulary, and write a short research report. Some of the academic tasks are: skimming, extracting relevant information, making notes, drawing conclusions, summarizing, quoting directly, citing sources, paraphrasing, pronouncing properly, deducing the meanings of unfamiliar words and groups of words, and listening selectively.
Outcomes

| SLO 1.3 | Develop and express a personal position in a variety of ways… |
| SLO 1.4 | Show an awareness of organizational patterns… |
| SLO 1.7 | Evaluate a given text… |
| SLO 2.1 | Show sufficient control over linguistic structures… |
| SLO 2.3.1 | Use the structures and language features… |
| SLO 4.1 | Use language to encourage… |
| SLO 6.1.5 | Use selective attention… |
| SLO 6.2.7 | Use elaboration… |
| SLO 6.3.2 | Use cooperation… |

Instructional and Learning Sequence

Sequence 1

Activation

Play a tape of appealing water sounds as a tanka and a haiku about water are read. Ask students to comment on the emotional response to the sounds of water. Have them discuss this tanka as a poem in which the words are complemented by the sounds of the water, and the haiku as a poem in which the words act as a contrast.

Ask a student to read Matsuura’s statement in Handout 2-17: “Water Poetry.” Have class members list reasons for the comment, and then brainstorm known water problems in their countries of origin and globally, comparing and contrasting.

Suggested questions for discussion: Is water a plentiful commodity in the world? What about in your country of origin? What do you think the situation regarding water was 50 years ago? Why has it worsened over time? Predict what the situation will be in another 50 years. Suggest some of the causes of our water problems (supply and demand, pollution, poor management, et cetera).

Record a list on the board, the overhead, or on chart paper.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjectives to describe the sounds of water: peaceful, clean, spiritual, soothing, etc.</td>
<td></td>
</tr>
<tr>
<td>Articles: appropriate use with names of places and bodies of water (definite article with names of rivers [e.g., the Winnipeg River]; no definite article with the names of lakes [e.g., Lake Winnipeg])</td>
<td></td>
</tr>
<tr>
<td>Pronunciation</td>
<td></td>
</tr>
<tr>
<td>r, l, th, cl, pl, gr, cal (focus on any sounds that are problematic in terms of intelligibility)</td>
<td></td>
</tr>
<tr>
<td>Discourse Features</td>
<td></td>
</tr>
<tr>
<td>contrast markers, comparison markers, structure of tanka and haiku</td>
<td></td>
</tr>
</tbody>
</table>
**Assignment**

Comment on the emotional response to the sounds of water in the tanka, where the words are complemented by the sounds of the water, and the haiku as a poem in which the words act as a contrast. (C)

As one student reads Matsuura’s statement in **Handout 2-17**: “Water Poetry,” class members list reasons for the comment, then brainstorm known water problems in their countries and globally, comparing and contrasting. (C)

Contribute to the discussion by commenting on the questions posed. (I) (C)

---

**Teacher Notes and References**

- Short tape of pleasant water sounds (teacher-provided)
- **Handout 2-17**: “Water Poetry” (tanka, haiku, and statement from General Koichiro Matsuura)

The word Manitoba means “the spirit who speaks.” The name originated from the Aboriginal belief that a spirit spoke through the rushing waters of the currents of Lake Manitoba Narrows against the shore of Manitou Island.
Sequence 2

Because of its importance, people have had numerous conflicts over access to water. Students work individually or in groups with the suggested reading. Because so many conflicts are listed, you may want to do this as a Jigsaw activity, dividing the timeline into parts, one part per group.

Students skim their sections, noting the reasons for the conflicts and the areas of the world in which they took place. Each group chooses from its area three to five conflicts the group members feel are important, and the group prepares to discuss them. Students note vocabulary, especially vocabulary that describes conflicts and solutions. They may discover this vocabulary as they read, or you may want to introduce this first. Vocabulary will be recycled throughout the module.

Next, students create a timeline to record the main dates and descriptions of conflicts they have chosen. They will add any additional conflicts with which they may be familiar. (Point out the use of simple present tense in the list of conflicts and their dates—historical information.) Ask students to come together to create a master timeline of their chosen conflicts, and to discuss events. What have been the main causes for conflict over water? What have they been in the students’ countries of origin? Have these causes changed over time?

Vocabulary

**Water vocabulary:** irrigation, river basins, watersheds, sanitation, desalination plans, canals, floods, aqueduct, gate valve, dikes, dams, reservoirs

**Conflict/solution vocabulary:** controversy, clashed, arbitrary, disputes, conflicts, escalated, inequitable, strife, competition, scarce, intensifies, contested, erupt, disrupting

**Solutions:** negotiations, ease of tensions, coalition, diplomacy, rule out, settlement, long-/short-term agreement, quell opposition

**Idioms:** cut off (water supply), rule out (solutions)

**Structures**

use of simple present in presenting conflicts and dates
**Student Learning Tasks**

**Jigsaw Activity**

Skim your section, noting the reasons for the conflicts and the areas of the world in which they took place. (I)

Form a group with three or four other classmates. Each group chooses from their area three to five conflicts that group members feel are important. Be ready to discuss them and note vocabulary, especially vocabulary that describes conflicts and solutions.

Create a timeline to record the main dates and descriptions of conflicts your group has chosen. Add any additional conflicts you may be familiar with. (G)

Create a master timeline of your chosen conflicts, and discuss questions posed by the teacher. (C)

---

**Teacher Notes and References**

**Suggested Reading:** “Water Conflict Chronology” at: [http://worldwater.org/conflict.htm](http://worldwater.org/conflict.htm)
### Outcomes

| SLO 1.1 Engage with increasingly difficult oral and/or visual texts… |
| SLO 1.4 Show an awareness of organizational patterns… |
| SLO 2.1.3 Use developing control of grammatical features… |
| SLO 2.2 Use several visual techniques… |
| SLO 4.2 Communicate effectively to work with others… |
| SLO 6.2.5 Use deduction and induction… |
| SLO 6.2.7 Use elaboration… |
| SLO 6.2.8 Use imagery in the form of mental or actual pictures… |
| SLO 6.2.12 Use inferencing to guess the meanings… |
| SLO 6.3.2 Use co-operation… |

### Instructional and Learning Sequence

#### Sequence 3

Ask students: Where will the water shortages be in the future? Students examine the graphics in **Handout 2-18**: “The World’s Freshwater Supplies” and **Handout 2-19**: “Water Stress,” using imagery to help understand the magnitude of the projected water shortages by 2025. In groups of two or three, they analyze the maps. Ask students to create and share sentences to explain the pictorial information presented on the maps.

Question students about possible causes of these water shortages. Ask them about possible and specific impacts of this problem in their own countries, and record answers.

Students explain the maps in as many ways as they can, using newly acquired language from this lesson. Students also use the chart to make predictions and inferences in order to draw some conclusions.

### Language Features

#### Vocabulary

**Map terms**: directions, abundant, limited, scarce, stressed, aquifers, concentrated, isolated, arid, Third World, industrialized, declined, increased, depleted, natural sources, per capita, access, positive trend, mismanagement, economic, political, abundant, shortages, etc.

**Math terms**: doubled, tripled, increased, decreased

#### Structures

Future tense, comparative, superlative forms, hypothetical expressions: if~then; modals: might, could, etc.
<table>
<thead>
<tr>
<th><strong>Student Learning Tasks</strong></th>
<th><strong>Teacher Notes and References</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assignment</strong></td>
<td></td>
</tr>
<tr>
<td>a) In groups of two or three, analyze the maps in <strong>Handout 2-18</strong>: “The World’s Freshwater Supplies: Annual Renewable Supplies per Capita per River Basin,” and <strong>Handout 2-19</strong>: “Water Stress,” using imagery to help understand the magnitude of the projected water shortages by 2025.</td>
<td></td>
</tr>
<tr>
<td>b) Create and share sentences to explain the pictorial information presented on the maps. (G)</td>
<td></td>
</tr>
<tr>
<td>c) Discuss the possible and specific impacts of this problem in your own home countries. (C)</td>
<td></td>
</tr>
<tr>
<td>d) Explain the map in as many ways as you can using newly acquired language from this lesson. Make predictions and inferences, using the chart in order to draw some conclusions. (C)</td>
<td></td>
</tr>
</tbody>
</table>

**Handout 2-18**: “The World’s Freshwater Supplies”
**Handout 2-19**: “Water Stress”
Writing Activity

Students research one water conflict that interests them or that has occurred in their country of origin, and write a 250- to 300-word summary report on that topic. They should briefly cover the following areas: problem, possible solutions, and the future. Students are required to use at least seven new vocabulary words and include at least three statistics. They must appropriately quote from and cite their sources. Use the writing process.

Language Features

<table>
<thead>
<tr>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>format of a summary</td>
</tr>
<tr>
<td>paragraph structure (review)</td>
</tr>
<tr>
<td>citation rules (review)</td>
</tr>
</tbody>
</table>
Student Learning Tasks

**Assignment**

a) Research one water conflict that interests you or that has occurred in your home country.
b) Write a 250- to 300-word summary report.

Cover the following areas: problem, possible solutions, and the future.

Use at least seven new vocabulary words and include at least three statistics.

Quote from and cite your sources, and use the writing process.

Teacher Notes and References

**Appendix 2: How to Create a Summary**

Prepare a list of possible links for students to use for their research.

Review how to quote and cite sources. Remind students how to collect information without plagiarizing.
Tanka
The Natives tell us,
“We hear the Spirit who speaks
In rushing waters
Powerful and mystical
We call it Manitoba.”

Haiku
Water, plentiful
Flowing oh so gracefully
Ours forever? No.

Statement:
“Of all the social and natural crises we humans face, the water crisis is the one that lies at the heart of our survival and that of our planet earth.”

UNESCO Director: General Koichiro Matsuura
Although the absolute quantities of freshwater on Earth have remained approximately the same, the uneven distribution of water and human settlement continues to create growing problems of freshwater availability and accessibility.

According to Population Action International, based upon the UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025. Of these countries, 40 are in West Asia, North Africa or Sub-Saharan Africa. Over the next two decades, population increases and growing demands are projected to push all the West Asian countries into water scarcity conditions. By 2050, the number of countries facing water stress or scarcity could rise to 54, with their combined population being 4 billion people—about 40% of the projected global population of 9.4 billion (Gardner-Outlaw and Engleman, 1997; UNFPA, 1997).

- Many African countries, with a population of nearly 200 million people, are facing serious water shortages. By the year 2025, it is estimated that nearly 230 million Africans will be facing water scarcity, and 460 million will live in water-stressed countries (Falkenmark, 1989).

- Today 31 countries, accounting for less than 8% of the world’s population, face chronic freshwater shortages. Among the countries likely to run short of water in the next 25 years are Ethiopia, India, Kenya, Nigeria and Peru. Parts of other large countries (e.g., China) already face chronic water problems (Hinrichsen et al., 1998; Tibbetts, 2000).

- Bahrain, Kuwait, Saudi Arabia and the United Arab Emirates have resorted to the desalinization of seawater from the Gulf. Bahrain has virtually no freshwater (Riviere, 1989). Three-quarters of Saudi Arabia’s freshwater comes from fossil groundwater, which is reportedly being depleted at an average of 5.2 km³ per year (Postel, 1997).
Some 460 million people—more than 8% of the world’s population—live in countries using so much of their freshwater resources that they can be considered highly water stressed (UNCSD, 1999; WMO 1997). A further 25% of the population lives in countries approaching a position of serious water stress (WMO, 1997). Water scarcity occurs when the amount of water withdrawn from lakes, rivers or groundwater is so great that water supplies are no longer adequate to satisfy all human or ecosystem requirements, resulting in increased competition between water users and demands.

**Definitions of Water Stress and Scarcity**

An area is experiencing water stress when annual water supplies drop below 1,700 m³ per person. When annual water supplies drop below 1,000 m³ per person, the population faces water scarcity.

Sources: UNPD, UNEP, World Bank, and WRI. 2000.
This lesson focuses on four different solutions to the problem of available clean water. Students will review information introduced in the last lesson, use a map to suggest possible solutions to water problems, complete a Jigsaw activity composed of reading and answering questions about water problem solutions, and write to express a personal opinion concerning the best solution. Some of the academic tasks are: skimming and scanning; making notes; pronunciation; defining terms; illustrating a point; giving examples; explaining, describing, and comparing ideas; noting important markers; selectively extracting important points; and listening critically.
Sequence 1

Activation

Students have discussed the shortage of clean, available water and have hypothesized about what some of the effects of this shortage might be. Post their main ideas and the timeline from the previous lesson. Ask students to look once again at the map from the previous lesson. Which word introduced in the last lesson will describe the water situation projected year 2025 in their country of origin: abundant, limited, scarce, or stressed?

Ask students to suggest any possible solutions for water-stressed areas of the world. Discuss.

<table>
<thead>
<tr>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terms related to the amount of available water: abundant, limited, scarce, stressed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>markers to show problem/cause—impact/effect, and solutions</td>
</tr>
</tbody>
</table>
## Student Learning Tasks

### Assignment

a) Review the map **Handout 2-18**: “The World’s Freshwater Supplies” to describe your home country’s projected water situation in the year 2025: abundant, limited, scarce, or stressed.

b) Suggest and discuss any possible solutions for water-stressed areas of the world. (C)

## Teacher Notes and References

Map from the previous lesson (**Handout 2-18**: “The World’s Freshwater Supplies”)
### Outcomes

<table>
<thead>
<tr>
<th>Instructional and Learning Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SLO 1.1</strong> Engage with increasingly difficult oral and/or visual texts…</td>
</tr>
<tr>
<td><strong>SLO 1.2</strong> Respond to texts with increasing independence…</td>
</tr>
<tr>
<td><strong>SLO 1.4</strong> Show an awareness of organizational patterns…</td>
</tr>
<tr>
<td><strong>SLO 2.1.1</strong> Analyze and edit texts…</td>
</tr>
<tr>
<td><strong>SLO 2.1.2</strong> Use standard Canadian spelling…</td>
</tr>
<tr>
<td><strong>SLO 2.1.3</strong> Use developing control of grammatical features…</td>
</tr>
<tr>
<td><strong>SLO 2.3.1</strong> Use the structures and language features…</td>
</tr>
<tr>
<td><strong>SLO 4.1</strong> Use language to encourage…</td>
</tr>
<tr>
<td><strong>SLO 4.2</strong> Communicate effectively to work with others…</td>
</tr>
<tr>
<td><strong>SLO 6.1.2</strong> Use organizational planning…</td>
</tr>
<tr>
<td><strong>SLO 6.1.5</strong> Use selective attention…</td>
</tr>
<tr>
<td><strong>SLO 6.1.6</strong> Use self-monitoring to check…</td>
</tr>
<tr>
<td><strong>SLO 6.1.8</strong> Use self-evaluation to check…</td>
</tr>
<tr>
<td><strong>SLO 6.2.1</strong> Use resourcing to access…</td>
</tr>
<tr>
<td><strong>SLO 6.2.7</strong> Use elaboration…</td>
</tr>
<tr>
<td><strong>SLO 6.2.11</strong> Use transfer…</td>
</tr>
<tr>
<td><strong>SLO 6.2.12</strong> Use inferencing to guess the meanings…</td>
</tr>
<tr>
<td><strong>SLO 6.3.2</strong> Use co-operation…</td>
</tr>
</tbody>
</table>

### Jigsaw: Part 1.
Tell students they will be completing a Jigsaw activity. Divide the students into four equal Home Groups. Each group will get a complete list of focus questions and one of the handouts, each of which contains one solution to the water problems. Each group’s solution will be different. To complete the whole list of focus questions, information from all the handouts must be shared among groups.

### Jigsaw: Part 2.
Have students regroup into Expert Groups to read all the focus questions and (by previewing the article) decide which questions they think their article might answer. Reading aloud, they skim their solution, reading the title, the whole introduction and conclusion, and the topic sentences of all the other paragraphs, predicting in which sections of the article they will find the answers to their focus questions.

Next, have students scan the article using the focus questions to help them locate the key words that will help them find the answers, coming to an agreement on the answers. Finally, they answer the focus questions related to their article in complete sentences/short paragraphs.

### Language Features

#### Vocabulary

**Imperative verbs used in focus questions:** define, explain, describe, evaluate, list, hypothesize

**Idioms:** waste not, want not; sweating the small stuff; go green

**From the focus questions:** imminent, implement, concurrently, conservation, reclaimed water, desalination, reverse osmosis, initial

Specific vocabulary from articles needed to answer questions

#### Pronunciation

Focus on pronunciation (sounds, linkage, reduction) that is problematic for students

#### Discourse Features

Expressions to acknowledge, to agree, to disagree, to ask for clarification
**Student Learning Tasks**

**Assignment**

**Jigsaw Activity: Four Equal Home Groups:**

a) Read the focus questions and preview the article to decide which questions you think your article might answer.

(They regroup into Expert Groups here)

b) Read aloud, skimming the title, the whole introduction and conclusion, and the topic sentences of all the other paragraphs, predicting in which sections of the article the answers to your focus questions will be found.

c) Scan the article using the focus questions to locate the key words leading to the answers, coming to an agreement on the answers.

d) Answer the focus questions related to your article in complete sentences/short paragraphs. (↻)

**Teacher Notes and References**

**Handout 2-20:** “Approach #1: Seek New Sources: Sweating the Small Stuff”

**Handout 2-21:** “Approach #2: Redistribute Supplies: Bagged and Dragged”

**Handout 2-22:** “Approach #3: Leaking Away”

**Handout 2-23:** “Approach #4: Recycle: Waste Not, Want Not” (one article per group)

**Handout 2-24:** “Examples of Focus Questions: Water: Some Solutions”

The focus questions are suggestions only. They are designed to give more practice in academic writing tasks such as explaining cause/effect, describing positive and negative aspects, writing definitions, explaining a process, giving examples, et cetera.

The solutions are written at a very advanced level. In this part of the lesson, students will focus on the fact that it is not always necessary to understand an article in detail to complete certain academic tasks. For the academic task of this lesson, they are only required to skim and scan.
### Outcomes

| SLO 1.1 | Engage with increasingly difficult oral and/or visual texts... |
| SLO 1.2 | Respond to texts with increasing independence... |
| SLO 2.3.1 | Use the structures and language features... |
| SLO 2.3.3 | Produce effective oral presentations. |
| SLO 4.1 | Use language to encourage... |
| SLO 4.2 | Communicate effectively to work with others... |
| SLO 4.4 | Manage group action... |
| SLO 6.1.3 | Use directed attention... |
| SLO 6.2.4 | Use note taking... |
| SLO 6.3.1 | Use questioning for clarification... |

### Instructional and Learning Sequence

Have the Home Groups work to complete all the focus questions in point form. New vocabulary necessary to answer the questions should be shared and explained. Ask students to listen to each other to get the information they need to answer their questions. Finally, have students answer all the questions in sentences or short paragraphs.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>expressions for hesitating, for asking for restatement, for probing, for agreeing, for disagreeing</td>
</tr>
</tbody>
</table>
### Student Learning Tasks

**Assignment**

a) Listen and take notes as each member shares information needed to answer the focus questions. (B)

b) Answer all questions in complete sentences or short paragraphs. (I)

### Teacher Notes and References

Once all the groups have completed their tasks, divide the class into new groups of four. Each member of the new group has the answers from a different solution.

The following SLOs from the previous part of the assignment should also be considered here: SLOs: 6.1.5, 6.1.6, 6.1.8, 6.2.12
Outcomes

| SLO 2.1.1 | Analyze and edit texts… |
| SLO 2.1.2 | Use standard Canadian spelling… |
| SLO 2.1.3 | Use developing control of grammatical features… |
| SLO 2.3.1 | Use the structures and language features… |
| SLO 2.4 | Use the steps of the writing process… |
| SLO 4.1 | Use language to encourage… |
| SLO 6.1.1 | Use advanced organization… |
| SLO 6.1.6 | Use self-monitoring to check… |
| SLO 6.1.7 | Use problem identification… |
| SLO 6.1.8 | Use self-evaluation to check… |
| SLO 6.2.5 | Use deduction and induction… |
| SLO 6.3.2 | Use co-operation… |

Instructional and Learning Sequence

Writing Task

Personal opinion: Which of the solutions to the water crisis is most important and why? Have each student choose a solution that is important to him or her and answer the question in a formal paragraph, using at least five new vocabulary words from this or other lessons. Ask students to use writing process strategies.

The skills required for this activity should help prepare students for the culminating task of the module.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>topic sentence</td>
</tr>
<tr>
<td></td>
<td>organizing markers</td>
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<tr>
<td></td>
<td>concluding sentence</td>
</tr>
<tr>
<td></td>
<td>well-chosen vocabulary</td>
</tr>
<tr>
<td></td>
<td>appropriate transition markers</td>
</tr>
<tr>
<td>Student Learning Tasks</td>
<td>Teacher Notes and References</td>
</tr>
<tr>
<td>------------------------</td>
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</tr>
</tbody>
</table>

**Assignment**

Choose a solution that is important to you.

a) Answer the question in a formal paragraph.

b) Use at least five new vocabulary words from this or other lessons.

c) Use writing process strategies. (I)
A water-covered planet facing a water crisis seems paradoxical. And yet that is exactly the reality on planet Earth, where 97 percent of the water is too salty to quench human thirst or to irrigate crops. Tackling water shortage issues with desalination—drawing fresh, drinkable water out of salty seawater—is common in the desert nations of the Middle East, the Caribbean and the Mediterranean. But as the cost of desalination drops and the price and demand for water climb, countries in temperate regions are turning more and more to the sea.

Large-scale desalination facilities are even turning up in the U.S., one of the world’s most water-rich countries. As part of an ambitious plan to reduce pumping from depleted underground aquifers, water officials in the Tampa Bay, Fla., area are contracting the construction of a desalination plant capable of producing 25 million gallons of desalted water a day. They are relying on desalination to supplement the region’s future water demands. Houston is also looking at desalinating water from the Gulf of Mexico to keep from going dry.

People have been pulling freshwater out of the oceans for centuries using technologies that involve evaporation, which leaves the salts and other unwanted constituents behind. Salty source water is heated to speed evaporation, and the evaporated water is then trapped and distilled.

This process works well but requires large quantities of heat energy, and costs have been prohibitive for nearly all but the wealthiest nations, such as Kuwait and Saudi Arabia. (One exception is the island of Curaçao in the Netherlands Antilles, which has provided continuous municipal supplies using desalination since 1928.) To make the process more affordable, modern distillation plans recycle heat from the evaporation step.

A potentially cheaper technology called membrane desalination may expand the role of desalination worldwide, which today accounts for less than 0.2 percent of the water withdrawn from natural sources. Membrane desalination relies on reverse osmosis—a process in which a thin, semipermeable membrane is placed between a volume of saltwater and a volume of freshwater. The water on the salty side is highly pressurized to drive water molecules, but not salt and other impurities, to the pure side. In essence, this process pushes freshwater out of saltwater.

Most desalination research over the past few years has focused on reverse osmosis, because the filters and other components are much smaller than the evaporation chambers used in distillation plants. Reverse osmosis plants are also more compact and energy-efficient.

Although reverse osmosis plants can offer energy savings, the earliest membranes, made from either polyimide fibers or cellulose acetate sheets, were fragile and had short life spans, often no longer than three years. These materials are highly susceptible to contaminants in the source water—particularly chlorine, which hardens the membranes, and microbes, which clog them. Pretreatment regimes, such as filtering out sediments and bacteria, must be extremely rigorous. A new generation of so-called thin composite membranes, made from polyimide films, promises to eliminate these problems. Though still susceptible to contamination, these new membranes are sturdier, provide better filtration and may last up to 70 years.

Technical performance is important, but it alone does not drive the adoption of desalination as a source of clean water. With or without technical improvements, the market for desalination equipment will very likely show healthy growth in the next 10 years as cities and other consumers realize the potential and favourable economics of existing equipment, according to James D. Birkett, who runs West Neck Strategies, a private desalination consulting company based in Nobleboro, Me.

 Hundreds of suppliers are already selling many thousands of pieces of equipment annually. These desalination units range in capacity from a few gallons a day (small emergency units for life rafts) to several million gallons a day (municipal systems).

“So confident are the suppliers that they enter into

(continued)
long-term contracts with their customers,” Birkett
says, “thus assuming themselves the risks of
performance and economics.” The desalination plant
on Tampa Bay, scheduled to be operational by the
end of 2002, will be funded and operated in such a
manner.

Today the best estimate is that about 1 percent of the
world’s drinking water is supplied by 12,500
desalination plants. No doubt, this is only the
beginning. In the future, the water in your glass may
have originated in the seas.
pipelines make it possible to move freshwater cheaply over vast distances of land. If only the same were possible over the oceans. Dragging waterproof plastic or fabric containers behind tugboats may be the answer.

Beginning in 1997, the English company Aquarius Water Trading and Transportation Ltd. has towed water from mainland Greece to nearby resort islands in enormous polyurethane bags, helping the tourist destinations deal with increased demand for drinking water during the peak season. Another company, Nordic Water Supply in Oslo, Norway, has made similar deliveries from Turkey to northern Cyprus using their own fabric containers.

The seemingly far-fetched concept of water bags was born in the early 1980s out of the desire to move large amounts of water more cheaply than modified oil tankers can do. For many years, tankers and barges have been making deliveries to regions willing to pay premium prices for small amounts of freshwater, such as the Bahamas, Cyprus and other islands with inadequate sources. Tankers have also supplied water during short-term droughts and disasters such as the 1995 Kobe earthquake in Japan.

Aquarius has manufactured eight 790-ton bags and two 2,200-ton versions; the latter hold about half a million gallons of water each. Aquarius has also developed models that are 10 times larger than the ones in use today, and last year Nordic began manufacturing bags that can hold nearly eight million gallons.

Water bags could offer a less expensive alternative to tankers—bags in the Aquarius fleet cost anywhere from $125,000 to $275,000—but some technical problems remain. In particular, making such large bags that are capable of withstanding the strains of an ocean voyage is difficult. For freshwater deliveries to the Greek isles and to Cyprus, bags need be dragged no farther than 60 miles. The piping systems needed to connect the bags to water supplies on land can be built from existing technology, but bags have ripped during transport on several occasions.

A third water-bag inventor, Terry G. Spragg of Manhattan Beach, Calif., is solving the problems of both volume and towing in a different way. With the support of privately hired scientists and consultants, Spragg has patented specialized zippers, with teeth more than an inch long, that can link water bags like boxcars. He has demonstrated the technology but has yet to sell it for commercial use.

Thus far this technology has been used only for freshwater deliveries to emergency situations and to extremely water-scarce coastal regions with a reliable demand for expensive water. But for some communities with no other option, water bags may offer a new and clever solution.
New York City is a metropolis of flamboyant excess, except when it comes to water. No one would suspect it, but the Big Apple has clamped down on water wasters, and after 10 years of patching leaky pipes and replacing millions of water-guzzling toilets, the city is now saving billions of gallons of water every year.

Back in the early 1990s New York City faced an imminent water shortage, and it was getting worse with every flush, shower and tooth brushing. With an influx of new residents and an increase in the number of drought years, the city needed to find an extra 90 million gallons of water a day—about 7 percent of the city’s total water use. Instead of spending nearly $1 billion for a new pumping station along the Hudson River, city officials opted for a cheaper alternative: reduce the demand on the current water supply, which was piped in from the Catskill Mountains.

Officials knew that persuading New Yorkers to go green and conserve water would require some enticement—free toilets. The city’s Department of Environmental Protection (DEP) stepped in with a three-year toilet rebate program which began in 1994. With a budget of $295 million for up to 1.5 million rebates, the ambitious scheme set out to replace one third of the city’s inefficient toilets—those using more than five gallons of water per flush—with water-saving models that do the same job with only 1.6 gallons per flush. With the rebate program, the DEP hoped to meet the largest part of its water-savings goal.

New Yorkers embraced the plan. Some 20,000 applications arrived within three days of its start. By the time the program ended in 1997, low-flow toilets had replaced 1.33 million inefficient ones in 11,000 buildings. The result: a 29 percent reduction in water use per building per year. The DEP estimates that low-flow toilets save 70 million to 90 million gallons a day citywide—enough to fill about 6,700 Olympic-size swimming pools.

But more efficient flushes weren’t enough. The toilet rebate program happened concurrently with the city’s water audit program, which continues today. For much of the city’s history, the amount building owners paid for water was based on the size of their property. Following a law passed in 1985, however, the city began keeping tabs on water use and charging accordingly. The law dictated that water meters be installed during building renovations, and the same requirement was applied to construction of new homes and apartments beginning in 1988. As of 1998, all properties in the city must be metered.

Homeowners who want to keep their water bills down under the new laws can request a free water-efficiency survey from Volt VIEWtech, the company that oversees the city’s audit program. Inspectors check for leaky plumbing, offer advice on retrofitting with water-efficient fixtures and distribute free faucet aerators and low-flow showerheads.

Low-flow showerheads use about half as much water as the old ones, and faucet aerators, which replace the screen in the faucet head and add air to the spray, can lower the flow of water from four gallons a minute to less than one gallon a minute. Volt VIEWtech has made several hundred thousand of these inspections, saving an estimated 11 million gallons of water a day in eliminated leaks and increased efficiency.

In efforts to save even more water, New York City has gone outside the home and into the streets. Water officials have installed magnetic locking caps on fire hydrants to keep people from turning them on in the summer. The city is also keeping an eye underground by using computerized sonar equipment to scan for leaks along all 32.6 million feet (6,174 miles) of its water mains.

Although the city’s population continues to grow, per person water use in New York dropped from 195 to 169 gallons a day between 1991 and 1999. From all indications, this trend is following its upward path. Water conservation works. And New Yorkers are proving that every flush makes a difference.
Namibia is the driest African country south of the Sahara Desert. Blistering heat evaporates water faster than rains can rejuvenate the parched landscape, and there are no year-round rivers. Residents of the capital city, Windhoek, must do more than just conserve water to secure a permanent supply. They must reuse the precious little they have.

By the end of the 1960s, most underground aquifers and reservoirs on seasonal rivers near Windhoek had been tapped dry by the capital’s burgeoning population, which has grown from 61,000 to more than 230,000 in the past 30 years. Transporting water from the closest permanent river, the Okavango—some 400 miles away—was too expensive. This crisis inspired city officials to implement a strict water conservation scheme that includes reclaiming domestic sewage and raising it once again to drinkable standards.

The city’s first reclamation plant, initially capable of producing only 460 million gallons of clean water per year when it went on line in 1968, is now pumping out double that amount enough to provide about 23 percent of the city’s yearly water demands. Officials hope to boost that supply number to 51 percent with an upcoming facility now under construction.

To make wastewater drinkable, it must undergo a rigorous cleaning regimen. First, large solids are allowed to settle out while biofilters remove smaller organic particles. Advanced treatments remove ammonia, and carbon and sand filters ensure that the last traces of dissolved organic material are eliminated. The final step is to purify the water by adding chlorine and lime. To guarantee a safe drinking supply, the reclaimed water is tested once a week for the presence of harmful bacteria, viruses and heavy metals. (Industrial effluent laden with toxic chemicals is diverted to separate treatment plants.) Compared with local freshwater sources, the reclaimed water is equal or better in quality.

Despite 32 years of access to high-quality recycled water, the residents of Windhoek still doggedly oppose its use for personal consumption. For this reason, most of this purified wastewater irrigates parks and gardens. But sometimes people don’t have a choice about their water source. In times of peak summer demand or during emergencies such as drought, local freshwater reservoirs are strained, and Windhoek relies heavily on treated effluent to boost supply. During the drought of 1995, for instance, reclaimed water accounted for more than 30 percent of the clean water piped into homes.

Officials hope to bolster support for the recycling program through enhanced public education—like letting the word slip that besides irrigating the city’s greenery, treated wastewater is the secret ingredient in the prized local brew.

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Examples of Focus Questions:
Water: Some Solutions

1. Explain why there was an imminent water shortage in New York in the early 1990s.

2. How were New Yorkers convinced to “go green?” Discuss the plan in a few sentences.

3. What else did the city do concurrently to help conserve water? Explain the program.

4. What is Volt VIEWtech?

5. What statistical evidence is there that New York’s water conservation plans were successful?

6. Although 97 percent of the earth is water, much of it cannot be used. Why not?

7. Define the term desalination. Describe the process.

8. What is reverse osmosis? What are the pros and cons of this process?

9. Eventually, what percentage of the world’s drinking water will be supplied by desalination?

10. After skimming and scanning the article, what do you think “Sweating the Small Stuff” means?

11. What does the expression “bagged and dragged” refer to? Where has this process begun to occur? Why?

12. Explain the initial reason for the development of water bags.

13. Evaluate these water bags as a useful invention.

14. What do you think the expression “waste not, want not” means?

15. Describe the water problems facing Namibia, Africa.

16. Explain their solution to their problem.

17. What is the quality level of the reclaimed water? What has been the response of the people? Hypothesize why this is so.
This lesson requires students to work with charts, make a graphic organizer, pronounce the names of chemical compounds, find the organizing features of a long reading, discuss or debate a controversial topic, paraphrase, express predictions, and solve mathematical word problems. Language features include a number of words from the Academic Word List, as well as content words related to air pollution; definition pattern using relative clauses; synonyms; and structures for expressing the future, cause and effect, and possibilities.
## Outcomes

<table>
<thead>
<tr>
<th>SLO 4.1</th>
<th>Use language to encourage…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 6.1.7</td>
<td>Use problem identification…</td>
</tr>
<tr>
<td>SLO 6.2.7</td>
<td>Use elaboration…</td>
</tr>
<tr>
<td>SLO 6.3.2</td>
<td>Use co-operation…</td>
</tr>
</tbody>
</table>

## Instructional and Learning Sequence

### Sequence 1

#### Activation

This lesson will focus on some solutions for air pollution. Before we can solve the problem, we need to know exactly what the problem is. Discuss students’ possible personal experiences with smog, and the causes of smog. Ask: What are the chemical components of urban air pollution? What do individuals do to avoid air pollution (e.g., masks, alerts, go to countryside)? What needs to be done to solve the problem for the long term?

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good definitions of terms associated with air pollution are found at <a href="http://www.epa.gov/otaq/inventory/overview/definitions.htm">www.epa.gov/otaq/inventory/overview/definitions.htm</a>.</td>
<td></td>
</tr>
<tr>
<td>Good definitions of terms associated with pollution in general are found at <a href="http://www.marine.usf.edu/pjocean/packets/f00/f00u1vocab.pdf">www.marine.usf.edu/pjocean/packets/f00/f00u1vocab.pdf</a>.</td>
<td></td>
</tr>
</tbody>
</table>

Examine the chart and pie charts in **Handout 2-25**: “Major Air Pollutants.”

Using the definition pattern given, have students make sentences about each pollutant listed in the first chart. Evaluate for information and language accuracy.

**OR**

The following activity may be done as a listening or a reading exercise, using **Handout 2-26**: “Urban Air Pollution.”

**Preparation:** When we talk about the components of air pollution, what kinds of information do you expect to hear (e.g., effects, names of chemicals)?
Student Learning Tasks

Discuss personal experiences with smog, and the causes of smog. (C)

Teacher Notes and References

Visual: City with smog—many good pictures are available on the Internet (teacher-provided)

Using the definition pattern given in Handout 2-25: “Major Air Pollutants,” make sentences about each pollutant listed in the first chart. (I)

OR

Before listening to or reading Handout 2-26: “Urban Air Pollution,” predict the answer to the following question: When we talk about the components of air pollution, what kinds of information do you expect to hear? (I)

Handout 2-25: “Major Air Pollutants”

Handout 2-26: “Urban Air Pollution”

If necessary, model the first one: “Sulphur dioxide (SO₂) is a colourless gas with a pungent odour that causes irritation of the upper respiratory tract and eyes. It may lead to an increase in respiratory diseases.”
### Outcomes

<table>
<thead>
<tr>
<th>SLO 2.1.1</th>
<th>Analyze and edit texts…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 2.1.4</td>
<td>Refine pronunciation to increase intelligibility…</td>
</tr>
<tr>
<td>SLO 6.1.8</td>
<td>Use self-evaluation to check…</td>
</tr>
<tr>
<td>SLO 6.2.2</td>
<td>Use repetition to imitate a language model…</td>
</tr>
</tbody>
</table>

### Instructional and Learning Sequence

Draw a chart and let students decide how to label it (likely Pollutant, Description, and Effect on Health). Reread the paragraph and complete the chart. Compare the finished chart to the model, noting the omission of “small words” (articles, connectors, transition words, linking verbs) from the notes.

**Optional:** Add a column for the chemistry of each pollutant. Have students practise reading chemical equations.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Pronunciation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>chemical compounds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discourse Features</th>
<th>point-form notes (for chart)</th>
</tr>
</thead>
</table>

Read aloud, or have students skim the text in **Handout 2-26:** “Urban Air Pollution.” Ask students what type of graphic organizer would help them take notes on the information (chart) Have students make notes on a chart.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>effects, components, pollutants, SO(^2) and other chemicals, components, compounds, suspended, visibility, particulates, significantly suffixes: -less; -tion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structures</th>
<th>reduced adjective phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sentence combining</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pronunciation</th>
<th>chemical compound names (e.g., SO(^2))</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Discourse Features</th>
<th>definition markers: x is/are a ___________ that ________________; ________________, also known as ________________; or ________________</th>
</tr>
</thead>
</table>
### Student Learning Tasks

a) Decide on the labels for the chart, then compare the finished chart to the model, noting the omission of “small words.”

b) Practise reading chemical equations. (C)

Listen to or skim **Handout 2-26:** “Urban Air Pollution,” for information. Decide on an appropriate type of graphic organizer that would help to record notes. (I) (C)

### Teacher Notes and References

**Handout 2-25:** “Major Air Pollutants”

Hydrocarbons come from fossil fuels such as gasoline.

**Handout 2-26:** “Urban Air Pollution”

This reading is at Flesch-Kincaid Grade 12 level. Students will know the chemical compounds involved, but may not know how to say them in English.
Ask students: Where do these pollutants come from? With a partner, students analyze **Handout 2-27**: “Projections and Analysis Chart.”

What is the major source of each pollutant? Ask students to make three statements based on the chart and share them with the class. What is the biggest single source of air pollution in Canada? (transportation)

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 6.2.2 Use repetition to imitate a language model…</td>
<td>combustion, power generation, miscellaneous, incineration, industrial processes, volatile organic compounds (carbon-based chemicals that vapourize easily at relatively low temperatures [e.g., pesticides and herbicides])</td>
</tr>
</tbody>
</table>
### Student Learning Tasks

With a partner, analyze **Handout 2-27: “Projections and Analysis Chart,”** using the following questions as a guide:

- What is the major source of each pollutant?
- Make three statements based on the chart.
- What is the biggest single source of air pollution in Canada? (*P*)

Share your answers with the class. (*C*)

### Teacher Notes and References

**Handout 2-27: “Projections and Analysis Chart”**
**Outcomes**

- **SLO 1.1** Engage with increasingly difficult oral and/or visual texts...
- **SLO 1.4** Show an awareness of organizational patterns...
- **SLO 1.5** Examine and interpret various visual media...
- **SLO 1.7** Evaluate a given text...
- **SLO 2.1.1** Analyze and edit texts...
- **SLO 2.1.4** Refine pronunciation to increase intelligibility...
- **SLO 2.2** Use several visual techniques...
- **SLO 4.1** Use language to encourage...
- **SLO 6.1.1** Use advanced organization...
- **SLO 6.1.3** Use directed attention...
- **SLO 6.1.5** Use selective attention...
- **SLO 6.2.3** Use grouping of items to classify...
- **SLO 6.2.4** Use note taking...
- **SLO 6.2.5** Use deduction and induction...
- **SLO 6.2.8** Use imagery in the form of mental or actual pictures...
- **SLO 6.2.12** Use inferencing to guess the meanings...
- **SLO 6.3.2** Use co-operation...

**Instructional and Learning Sequence**

**Sequence 2**

**Reading Extended Text**

Introduce **Handout 2-28:** “Environmental Implications of the Automobile: (SOE Fact Sheet No. 93-1)”

- Source (government department—Environment Canada)
- Intended audience (general public)
- Purpose (to discuss the facts about this issue)
- Genre or form (fact sheet, one of many)
- Date (not given, but may be indicated by “No 93-1,” or guessed by the dates of references and statistics. Why is the general date important?)

**Student Instructions:** See Student Learning Tasks column.

After students have read Handout 2-28, ask:

- How do the visuals (photos, charts, diagrams, et cetera) help the reader? If you are using the whole text, where in the text is each visual referred to?
- Have students, working with a partner, select three vocabulary words essential for understanding the reading, and prepare to explain them to the class.

If no one has chosen it, discuss the term “dilemma.” What does a dilemma require? (difficult decision) Why is the car (paragraph 4) called an “environmental dilemma?”

**Language Features**

**Vocabulary**

- student-selected
- **From AWL:** affects, challenge, complex, considerable, consume, economy, elements, eliminate, energy, environmental, image, impact, impacts, implications, infrastructure, interactions, liberated, radically, range, ratios, resources, respond, significantly, source, stresses, sustainable, technology

- **Prefix:** infra-

- **Metaphor:** “tightly woven into the fabric of Canadian life”

**Structures**

- use of present perfect in paragraph 1

**Discourse Features**

- organization of a fact sheet
- relationship of text and graphics

**Academic Language Functions**

- skim for main idea
Refer to Handout 2-28: “Environmental Implications of the Automobile: (SOE Fact Sheet No. 93-1)” and:

a) Look at the source, the intended audience, purpose, genre or form, and date. Answer the question: Why is the general date important? (C)

b) Preview by reading the title, heading, and subheadings. Read the first and last paragraphs and the first and last sentences of each paragraph. Examine the visuals briefly. Formulate several questions that may be answered by the reading. (I)

c) Skim the first five paragraphs to answer the question: Does the article support or oppose the use of automobiles? Explain. (I)

d) With a partner, select three vocabulary words essential for understanding the reading and prepare to explain them to the class. (P) (C)
Outcomes

| SLO 1.7 | Evaluate a given text… |
| SLO 2.1.3 | Use developing control of grammatical features… |
| SLO 4.6 | Respond to and critique a variety of individual perspectives… |
| SLO 5.1 | Identify common themes and symbols… |
| SLO 6.1.5 | Use selective attention… |

Instructional and Learning Sequence

Optional Speaking Activity

**Instant Debate:** Have half the students read for information in defence of the car in Canadian life, while the other half finds the effects on the environment. Write the points on the board in two columns. Discuss which of the points reflect the situation in the students’ countries of origin.

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Discourse Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>expression of opinion; agreement and disagreement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Academic Language Functions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>scan for specific information</td>
<td></td>
</tr>
</tbody>
</table>
Student Learning Tasks

a) Debate: Group 1 reads for information in defence of the car in Canadian life, while the other group finds the effects on the environment. (G) (C)

b) Discuss the points that reflect the situation in your country of origin. (G) (C)
Reading Extended Text (continued)

After examining the introduction to the article, students should be able to find the thesis statement, likely the second sentence of paragraph 5.

Present students with Handout 2-29: “Overhead—Environmental Implications of the Automobile.” How does each section appear to support the main idea?

Choose one section of the text for close reading, focusing on whatever discourse markers are present. Show how they signal meaning and organization.

Paraphrase the main idea of the paragraph in 10 words or less. Demonstrate how to use a thesaurus (print or online) to find synonyms, if desired. Have students volunteer to put their paraphrases on the board for teacher and peer editing.

### Language Features

<table>
<thead>
<tr>
<th>Discourse Features</th>
<th>Academic Language Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>thesis statement (versus “topic”)</td>
<td>paraphrasing</td>
</tr>
<tr>
<td>outline structure</td>
<td>using a thesaurus to find synonyms</td>
</tr>
<tr>
<td>discourse markers in the chosen section</td>
<td></td>
</tr>
</tbody>
</table>
### Student Learning Tasks

Examine the introduction to the article, and find the thesis statement.

Listen to the lesson.

Paraphrase the main idea of the paragraph in 10 words or less. Volunteer to put your paraphrases on the board for teacher and peer editing.

### Teacher Notes and References

**Handout 2-29:**

“Overhead—Environmental Implications of the Automobile”

Thesaurus, if desired

In a longer piece of writing, the central idea or thesis may not be stated in the first paragraph, but should appear somewhere in the first section. The first several paragraphs may set the background for the topic.

Paraphrasing is very difficult, so a coaching approach works well here.

Use a mini-lesson, if necessary. Be sure that the paraphrase does not retain the original structure or wording. It must be different. Point out that paraphrasing is one of the components of effective use of outside sources.
Brainstorm ways of reducing the impact of the automobile on the environment.

**Reading/Speaking:** Present the chart to the class. With a partner or a group, students predict the short-term and long-term implications for the environment and society for each of the solutions. Discuss as a group which solutions are the most feasible. Are there other solutions that have not been mentioned?

**Writing Task**

Have students write a short description of the role of the automobile in their countries, predicting the possible short-term and long-term effects of the automobile on their cultures and the environment. They should include several new words from this lesson (underline new words).

<table>
<thead>
<tr>
<th>Language Features</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vocabulary</strong></td>
<td>short term, long term, implications, feasible</td>
</tr>
<tr>
<td><strong>Structures</strong></td>
<td><strong>Modals:</strong> conditional and hypothetical conditional future time structures</td>
</tr>
<tr>
<td><strong>Discourse Features</strong></td>
<td>classification comparison cause and effect markers transition markers</td>
</tr>
<tr>
<td><strong>Academic Language Functions</strong></td>
<td>hypothesizing evaluation</td>
</tr>
</tbody>
</table>
Brainstorm ways of reducing the impact of the automobile on the environment. (C)

With a partner or a group, predict the short-term and long-term implications for the environment and society for each of the solutions. Discuss as a group which solutions are the most feasible. Are there other solutions that have not been mentioned? (P) (G)

**Assignment**

Write a short description of the role of the automobile in your country of origin, predicting the possible short-term and long-term effects of the automobile on your culture and the environment. Include several new words from this lesson (underline new words). (P) or (G)

**Teacher Notes and References**

**Handout:** A chart from a science textbook or magazine describing ways of reducing the pollution caused by automobiles (teacher-provided)

**Assessment:** Paragraphs should contain a topic sentence, short- and long-term consequences, effective transition markers, and a conclusion. They should use new vocabulary and grammatical structures appropriately.
Mathematics: Distribute a chart of automobile fuel economy ratings (current ones will be available online). Have students work in small groups to discuss the meaning and importance of fuel economy ratings, followed by working aloud through questions chosen from Handout 2-30: “Fuel Economy Questions” and Handout 2-31: “Air Pollution Questions.”

Model the math problem-solving strategy and then work in groups to solve. Choose one person at random from each group (AFTER the question is solved) to demonstrate solutions to the class.

OR

Focus the discussion on the removal of contaminants from the exhaust of automobiles and factories, followed by a sample of questions related to reducing exhaust emissions.

Optional: Have students write a word problem on the topic of air pollution, using the information available in the readings. Students evaluate by solving each other’s problems.
## Student Learning Tasks

Work in small groups to discuss the meaning and importance of fuel economy ratings. Then work through the questions chosen from **Handout 2-30**: “Fuel Economy Questions” and **Handout 2-31**: “Air Pollution Questions,” and discuss among your group. (E)

One person from each group demonstrates solutions to the class. (I) (C)

OR

Write a word problem on the topic of air pollution, using the information available in the readings. Evaluate by solving each other’s problems. (I) (C)

## Teacher Notes and References

- **Handout 2-30**: “Fuel Economy Questions”
- **Handout 2-31**: “Air Pollution Questions”

Some of the solutions are technological answers and some are lifestyle changes.

These questions do not present difficult math concepts, but give language practice for working with numbers, ratios and proportion, fractions, graphing, problem solving, and critical thinking.
### Outcomes

<table>
<thead>
<tr>
<th>SLO 2.1</th>
<th>Show sufficient control over linguistic structures…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 2.3.1</td>
<td>Use the structures and language features…</td>
</tr>
<tr>
<td>SLO 2.3.3</td>
<td>Produce effective oral presentations.</td>
</tr>
<tr>
<td>SLO 2.4</td>
<td>Use the steps of the writing process…</td>
</tr>
<tr>
<td>SLO 3.1</td>
<td>Seek, organize, and synthesize information…</td>
</tr>
<tr>
<td>SLO 3.2</td>
<td>Develop and implement a plan for researching…</td>
</tr>
<tr>
<td>SLO 3.3</td>
<td>Quote from or refer to sources…</td>
</tr>
<tr>
<td>GLO 6</td>
<td>Students will know and use effectively metacognitive strategies… (SLOs 6.1.1, 6.1.2, 6.1.5, 6.1.6, 6.1.7, 6.2.1, 6.2.4, 6.2.7, 6.2.8, 6.2.9, 6.2.13, 6.3.1, 6.3.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SLO 1.3</th>
<th>Develop and express a personal position in a variety of ways…</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLO 6.1.6</td>
<td>Use self-monitoring to check…</td>
</tr>
</tbody>
</table>

### Instructional and Learning Sequence

#### Writing Activity

Have students pick a research topic related to air pollution. Students will arrange essential information about the causes and effects of air pollution in a chart for a presentation to follow. The chart should include:

- the cause and effects of air pollution
- chemical compounds involved in the cause or effects of air pollution
- reactions and processes involved in air pollution
- effects of air pollution on plants, animals, humans, and infrastructure
- possible solutions or remedies

Require students to prepare computer slides (PowerPoint, et cetera) of the material to accompany a short presentation to the class.

Emphasize the need to cite references, and model correct format for various sources.

#### Roundup

Have students add to their personal dictionary words that they encounter in more than two or three settings, or words that they think are important for understanding and talking about this topic.

**Vocabulary Review Game:** Twenty Questions, using environmental problems

**Journal:** Ask students to respond to the questions: How have cars changed our lives? Could you go back and live in a time before modern transportation?

**Learning Log:** Have students write about one activity in the lesson they felt helped them learn. What strategies did they use to complete the task?
## Student Learning Tasks

### Assignment

Pick a research topic related to air pollution. Arrange essential information about the causes and effects of air pollution in a chart that you will use in a presentation. The chart should include:

- the cause and effects of air pollution
- chemical compounds involved in the cause or effects of air pollution
- reactions and processes involved in air pollution
- effects of air pollution on plants, animals, humans, and infrastructure
- possible solutions or remedies

Prepare computer slides (*PowerPoint*, et cetera) of the material to accompany a short presentation to the class. (1)

### Assignment

a) Add to your personal dictionary words that you encounter in more than two or three settings, or words that you think are important for understanding and talking about this topic.

b) **Journal Response to the Questions:** How have cars changed our lives? Could you go back and live in a time before modern transportation?

c) **Learning Log:** Write about one activity in the lesson that you felt helped you learn. What strategies did you use to complete the task?

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## Teacher Notes and References

By this time, students should have a topic for their research project.

Note the use of point form.

Citation Machine at: <http://citationmachine.net>

Students can use this site to automatically format citations in MLA or APA style.

**Handout 2-30:** “Fuel Economy Questions”

**Handout 2-31:** “Air Pollution Questions”
## Major Air Pollutants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Physical Characteristics</th>
<th>Effect on humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>colourless gas with a pungent odour</td>
<td>Irritation of the respiratory tract; may aggravate asthma</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>colourless, odourless, tasteless gas</td>
<td>When inhaled, reduces the body’s ability to use oxygen; in high quantities, may cause drowsiness or asphyxiation</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>reddish-brown gas</td>
<td>Irritating; can impair lung function; at high concentrations, makes breathing difficult for people with respiratory problems</td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>pungent smelling, colourless gas, formed when sunlight heats other air pollutants</td>
<td>Significantly reduces lung function, even in healthy people</td>
</tr>
<tr>
<td>Particulates</td>
<td>microscopic solids or liquids; vary widely in size and chemical composition</td>
<td>Can irritate the eyes and respiratory system; cause coughing and breathing difficulties; associated with cardiac problems; finer particles can cause deep lung damage</td>
</tr>
</tbody>
</table>

**Air Pollutants in Canada**

- **Particulates**: 53% (22%), 16% (6%), 30% (1%)<br>
- **Carbon monoxide**: 70% (4%), 12% (11%)
- **Sulphur dioxide**: 25% (3%), 28% (11%)
- **Hydrocarbons**: 42% (10%), 22% (2%), 5% (0.6%)

**Sources**
- Fuel combustion (including industries, utilities, and wood burning)
- Transportation
- Miscellaneous (mainly slash burning)
- Incineration (mainly wood waste)
- Industrial processes
Urban air pollution, also known as smog, has five main components, each of which is harmful to the human respiratory system. Sulphur dioxide (SO₂) is a colourless gas with a pungent odour. It causes irritation of the upper respiratory tract and eyes and may lead to an increase in respiratory diseases. Carbon monoxide (CO) is also a colourless gas, but odourless and tasteless. Low concentrations of CO slow reflexes, while higher concentrations may cause drowsiness and asphyxiation. Nitrous dioxide (NO₂), a reddish-brown gas, also causes an increased risk of respiratory infection and produces constricted air passages in people suffering from asthma. Ozone (O₃), a pungent-smelling, colourless gas, causes coughing and irritation to the lungs and eyes. In addition to the gases, microscopic particles of solids and liquids suspended in the air contain a variety of irritating chemical compounds. These particulates reduce visibility and can damage the lungs and heart.
### Projections and Analysis Chart

#### NAICCC Consensus Forecast - Canada

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<td>Incineration/Misc Ot</td>
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<td>100%</td>
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The automobile has probably done more to shape the character of 20th-century Canada than any other piece of technology. It has given us mobility and independence. It has given us the convenience of going where we want to, when we want to, and of doing so in comfort. It has liberated the average person from the limitations of time and place, opening up new opportunities and offering new experiences. More significantly, it is one of the pivotal elements of our economy. No wonder, then, that Canadians have made the car such a central fixture of their lives.

But the automobile also affects the environment in many ways. Cars and their associated infrastructure use resources, consume energy, and emit pollutants on a substantial scale. They are a source of noise and congestion and a leading cause of accidental deaths. They have also radically reshaped the landscape—directly through the building of expressways, roads, and other infrastructure, and indirectly through effects on settlement patterns.

The automobile’s impact has been all the greater because of its success. More than 12 million cars now traverse Canada’s roads—one for nearly every two Canadians, one of the highest ratios of car ownership in the world. Each of these cars travels, on average, more than 16,000 km per year, a total of some 200 billion kilometres, or more than 1,000 times the distance between the Earth and the sun.

Because it is so tightly woven into the fabric of Canadian life, the car presents a special kind of environmental dilemma. On the one hand, there is the need to eliminate or reduce the environmental stresses associated with it. On the other, there is the desire to preserve the advantages it has given us. Reconciling these objectives presents a considerable challenge.

As Figure 1 shows, the automobile is part of a complex web of interactions. To determine its place in a sustainable environment, we must examine its impacts and devise solutions that effectively respond to this entire range of interactions.
Environmental Implications of the Automobile (continued)

The Car and the Economy

In Canada, the demand for automobiles and associated products and services has stimulated activity in virtually every sector of the economy, contributing to a standard of living that is one of the highest in the world.

With the economic boom that followed the Second World War, car ownership rose dramatically. More people could afford to live and work in widely separated areas, and low-density suburbs began to spring up at the edges of large cities and nearby towns. For the suburbanites, car ownership was not only a convenience but often a necessity. More cars and expansive development increased the demand for motor vehicle infrastructure, such as roads, bridges, and parking lots. More service outlets, dealerships, gas stations, auto parts stores, and other car-related services became necessary. Motels, restaurants, and retail businesses along well-travelled routes also began to benefit. Both directly and indirectly, the automobile had become an important influence on Canada’s economic activity, employment opportunities, and development patterns.

In general, the fortunes of the motor vehicle industry have been a good indicator of those of the economy as a whole. In good economic times, car production increases; in bad times, it declines (Fig. 2). And as the automobile industry goes, so go the many other industries, such as mining, manufacturing, and retail sales, that depend on it. In 1988, for example, the motor vehicle manufacturing industry used more than $30 billion worth of materials, indirectly stimulating demand in sectors such as energy and mineral resources (Statistics Canada, 1988a).

Between 1986 and 1990, about 1.9 million motor vehicles and $35 billion worth of motor vehicles and parts were produced each year (ISTC, 1991). The value of these goods was equal to over 6% of Canada’s Gross Domestic Product and accounted for more than a quarter of the nation’s exports (Statistics Canada, 1990b, 1990f). In 1990, 572,000 people—roughly one out of every 20 working Canadians—were employed in jobs directly linked to motor vehicles. They earned approximately $16 billion in gross wages (Statistics Canada, 1990c).

Retail sales of motor vehicles, parts, and associated services make up the largest proportion of Canadian retail activity—35% in 1988 (Statistics Canada, 1988b). Hotel, restaurant, and other retail businesses associated with domestic automobile travel amounted to $9.1 billion, or 64% of domestic travel spending, in 1990 (Statistics Canada, 1990c).

Figure 2: The relationship between number of automobiles and Gross Domestic Product.
The Car and the Environment

Most Canadians are aware of the high-profile environmental concerns associated with automobiles, such as the consumption of fossil fuels and the subsequent air pollution that accompanies their use. While these are legitimate concerns, a number of less obvious but equally significant environmental stresses occur during the car’s life cycle. These impacts are related not only to its use but also to its manufacture, demand for infrastructure, and disposal. Understanding the full spectrum of these impacts is an important first step towards minimizing the negative environmental effects of the car.

Motor Vehicle Manufacture

The transformation of raw resources and energy into motor vehicles gives rise to a variety of environmental consequences. The most important of these are the depletion of nonrenewable resources (including metals and energy) and the environmental stresses associated with the production and use of these resources.

Use of nonrenewable materials. In 1989, the average motor vehicle weighed 1,428 kg, 77% of which was metal (Table 1). It can therefore be estimated that more than 2 billion kilograms of metal could be used in the manufacture of the 1.9 million motor vehicles produced each year in Canada. While much of this metal is recovered or recycled when the vehicle is taken out of service, it is neither cost-effective nor technologically possible to recover all of the metal used in motor vehicle manufacture. Furthermore, because the number of vehicles being produced is growing, more metal is needed for the manufacture of new vehicles than can be obtained from old ones. Consequently, some depletion of nonrenewable resources is inevitable.

In addition, the extraction, smelting, and refining of these metals can give rise to a number of other concerns, such as land disturbances, leaching of metals from mine tailings, acid mine and saline drainage, runoff of milling effluent containing toxic reagents used to extract minerals from the ore, and release of nitrogen oxides (NOx), volatile organic compounds (VOCs), sulphur dioxide (SO2), carbon dioxide (CO2), carbon monoxide (CO), particulates, and other pollutants (Government of Canada, 1991).

Table 1: Weights and types of materials utilized in the construction of an average motor vehicle, 1989

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain carbon steel</td>
<td>643.8</td>
</tr>
<tr>
<td>High-strength steel</td>
<td>106.4</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>14.1</td>
</tr>
<tr>
<td>Other steel</td>
<td>21.4</td>
</tr>
<tr>
<td>Iron</td>
<td>206.6</td>
</tr>
<tr>
<td>Plastics/composites</td>
<td>102.0</td>
</tr>
<tr>
<td>Fluids/lubricants</td>
<td>81.6</td>
</tr>
<tr>
<td>Rubber</td>
<td>61.1</td>
</tr>
<tr>
<td>Aluminum</td>
<td>70.7</td>
</tr>
<tr>
<td>Glass</td>
<td>36.6</td>
</tr>
<tr>
<td>Copper</td>
<td>22.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>9.1</td>
</tr>
<tr>
<td>Other materials</td>
<td>47.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1427.7</strong></td>
</tr>
</tbody>
</table>

Includes cars, vans, and station wagons.


Consumption of energy. As much as 20% of all the energy consumed throughout the life of a vehicle goes into its manufacture (Matsumoto, 1984). It has been estimated that between 66 and 105 gigajoules of energy are needed to produce a motor vehicle, depending on the proportion of recycled materials used. This is equivalent to the energy contained in between 2000 and 3100 L of gasoline, or the amount of fuel consumed by 16,000 to 26,000 km of driving. Production of the 1.9 million motor vehicles made in Canada in 1989 would thus have consumed between 1.8% and 2.9% of Canada’s end-use energy demand, or the energy used by the final consumer (Tien et al., 1975; Government of Canada, 1991).

The environmental stresses that may result from using this energy depend on its source. Fossil fuels, for example, emit SO2, CO2, NOx, CO, and particulates, while nuclear power plants generate toxic radioactive wastes, which are often difficult to dispose of. Hydroelectric energy may cause ecological disruption through flooding. Regardless of origin, electric power requires the construction and maintenance of transmission lines and associated rights-of-way.

Infrastructure and Land Use

The infrastructure required by the increasing numbers of vehicles on Canada’s roads today can be linked to a variety of environmental effects, including the occupation of productive land and the alteration of ecosystems. (continued)
Overall, there are about 879,000 km of highways in Canada (Statistics Canada, 1991). In urban areas, up to 42% of the land in downtown cores and 18% of the land in greater metropolitan areas may be occupied by motor vehicle infrastructure, including roads, rights-of-way, bridges, garages, retail outlets, and parking lots (Simpson-Lewis et al., 1979). In Toronto, 2% of the city’s area is devoted specifically to parking (Macpherson, 1988).

Much of this land was once prime agricultural land. Urban development patterns, while beginning to change, are still often characterized by the demand for low population density suburbs and are based on the assumption that cars will be the primary mode of transportation. As most of Canada’s largest urban centres—the Windsor–Quebec City corridor, for example, or British Columbia’s Lower Fraser Valley—have typically developed in productive agricultural areas, motor vehicle infrastructure usually consumes some of the country’s best farmland. The most recent data available show that, between 1981 and 1986, 55,200 ha of rural land near 70 Canadian cities was urbanized. Of this, 59% was prime agricultural land (Government of Canada, 1991).

Roads and supporting services for vehicles affect the environment in numerous other ways as well. Road salt, leaked motor oil, and particulate emissions, for example, wash off road surfaces and concentrate in ditches and storm sewers. The extent of the contamination of water and land by these routes has not yet been determined. In addition, highway construction may alter traditional drainage patterns, and soil erosion and landslides may occur more frequently around roads and bridges. Roads may also divide otherwise undisturbed lands, interfering with the movements of wildlife and altering habitats.

The Demand for Fossil Fuels

In 1990, transportation accounted for 29% of Canada’s end-use energy demand. Retail sales of gasoline for motor vehicles accounted for 54% of this, or 16% of end-use energy demand (Statistics Canada, 1990d). Although fuel consumption per vehicle has declined in recent years, a number of concerns remain. These include dependence on a nonrenewable energy source, the environmental damage that accompanies the exploration, extraction, refining, storage, delivery, and disposal of fossil fuels, and the pollution produced by combustion.

Consumption of energy resources. In 1988, the average personal-use passenger car was driven 6% farther but consumed 22% less fuel than its 1980 counterpart. The average fuel consumption of all in-use automobiles decreased from 16.5 to 12.0 L/100 km between 1980 and 1988 (Statistics Canada, 1991). For new cars, the average consumption decreased from 10.2 to 8.1 L/100 km over the same period (Transport Canada, 1991). Reduced engine size and vehicle weight have both contributed to improved fuel efficiency.

Energy production and delivery. About 35% of the crude oil that enters Canadian refineries is turned into motor gasoline. The processing and handling of these substances can result in such environmentally damaging events as oil and gas spills. Between 1985 and 1990, an average of 7.9 million litres of motor gasoline and 16.2 million litres of crude oil per year were reported to have been spilled in Canada during extraction, transportation, refining, storage, and delivery (NATES, 1992). It is suspected that unreported events, such as the dumping of contaminated ballast from tankers and runoff from roads and sewers, may release even greater amounts (OECD, 1991). Furthermore, leaking gasoline from underground storage tanks has recently begun to emerge as a significant contributor to the contamination of soil and water. A single litre of gasoline can make up to 1 million litres of water unfit for human consumption (Krusse et al., 1991).

In 1987, crude oil refineries collectively discharged, on a daily basis, 1,080 kg of oil and grease, 4,039 kg of suspended solids, 77 kg of phenols, 21 kg of sulphide, and 726 kg of ammonia nitrogen. However, a general downward trend in refinery discharges has been apparent. Between 1972 and 1987, discharges of oil and grease were reduced by 87%, suspended solids by 81%, phenols by 96%, sulphides by 99.5%, and ammonia nitrogen by 93%. In 1987, refineries were, on average, in compliance with monthly emission standards 94% of the time and with daily standards more than 99% of the time (Losier, 1990).

VOCs, which contribute to the formation of ground-level ozone, are commonly released into the air when gasoline is transferred between facilities and vehicles are refuelled. In 1985, these processes contributed an estimated 6% of the human-released VOCs in Canada (Government of Canada, 1991).
Fossil fuel combustion. Emissions from fossil fuel combustion can lead to a number of environmental and human health problems (Table 2). In the past 20 years, factors such as improved fuel efficiency, the increased use of emission control devices, and stricter new car emission control standards have contributed to a decline in per-vehicle emissions of some common pollutants. A new car today emits only 24% of the NOx, 4% of the VOCs, and 4% of the CO of a new car in the early 1970s (Motor Vehicle Manufacturers’ Association 1991). Between 1985 and 1990, total emissions of NOx from automobiles decreased from 352,000 to 248,283 t, VOC emissions decreased from 412,700 to 340,838 t, and CO emissions decreased from 4.0 to 2.7 million tonnes (Kosteltz and Deslauriers, 1990; Environment Canada, Pollution Data Analysis Division, unpublished data).

Reduced automobile emissions may be contributing to improved urban air quality in some Canadian cities. For example, in Vancouver, Calgary, Toronto, Ottawa, Montreal, and Quebec City, where cars are a major influence on air quality, indicators such as ambient NO2 and CO decreased by an average of 8.6% and 33%, respectively, between 1980 and 1990 (T. Furmanczyk, personal communication).

<table>
<thead>
<tr>
<th>Emission</th>
<th>Health impacts</th>
<th>Environmental impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxides (NOx)</td>
<td>• NO2 is a lung irritant at high concentrations.</td>
<td>• NO2 reacts with water to form nitrate (NO3-) a source of acid rain.</td>
</tr>
<tr>
<td></td>
<td>• NO2 may lead to depression of the immune system, with children and the elderly being at risk.</td>
<td>• NO2 contributes to the formation of ground-level ozone.</td>
</tr>
<tr>
<td></td>
<td>• NO2 reacts with water to form nitrate (NO3-) a source of acid rain.</td>
<td>• NO2 is associated with suppressed vegetation growth.</td>
</tr>
<tr>
<td></td>
<td>• NO2 may lead to depression of the immune system, with children and the elderly being at risk.</td>
<td>• NO2 contributes to the corrosion of metals and degradation of textiles, rubber, and polyurethane.</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>• CO reduces the ability of the blood to carry oxygen, with smokers, persons with heart disease, and those with anemia being especially sensitive.</td>
<td>• CO may contribute to the formation of ground-level ozone by depleting the atmosphere's supply of hydroxyl radical (OH).</td>
</tr>
<tr>
<td>Carbon dioxide (CO2)</td>
<td>• Many individual VOCs (e.g., benzene) are known to have or are suspected of having human health effects ranging from carcinogenicity to neurotoxicity.</td>
<td>• CO2 is an important greenhouse gas, contributing to global warming.</td>
</tr>
<tr>
<td>Volatile organic compounds (VOCs)</td>
<td>• Exposure to O3 is associated with changes in lung function, decreased immune function, and possibly the development of chronic lung disease.</td>
<td>• VOCs contribute to the formation of ground-level ozone.</td>
</tr>
<tr>
<td>Ozone (O3)</td>
<td>• O3 reduces agricultural productivity and the growth rate of trees.</td>
<td>• Ground-level ozone is a global warming agent.</td>
</tr>
</tbody>
</table>

Source: Modified from Healthy City Office (1991)

Table 2: Major impacts of common pollutants associated with automobile use on human health and the environment (continued)
Environmental Implications of the Automobile (continued)

In spite of these improvements, the automobile remains a major source of some pollutants. A 1985 survey of national air emissions showed that gasoline-powered cars contributed 18.7% of total NOx emissions, 22.9% of total VOC emissions, and 37.1% of total CO emissions (Kosteltz and Deslauriers, 1990). Although emissions of these pollutants from the average personal-use passenger car decreased between 1980 and 1988, the total number of kilometres driven increased. As a result, the reduction in overall emissions was less dramatic than might have been expected (Fig. 3).

The occurrence of ground-level ozone, a product of the interaction of NOx, VOCs, and sunlight, should also be decreasing. However, because of the increased number of vehicles on the road, emissions of NOx and VOCs still lead to concerns about ground-level ozone, especially in urban centres where automobile use is concentrated. The Lower Fraser Valley, the Windsor–Quebec City corridor, and the Southern Atlantic Region have been identified as problem areas, as they exceed Canada’s maximum acceptable ground-level ozone objectives most frequently (Hilborn and Still, 1990).

Canadian emissions of CO2, which contribute to increasing CO2 levels internationally and concerns of global warming, have decreased on a per-vehicle basis in recent years as average fuel efficiencies have improved. Nevertheless, between 1987 and 1990, total CO2 emissions from automobiles rose slightly, from 48.4 to 49.0 million tonnes, as a result of the increase in vehicle numbers and use. In 1990, automobiles continued to be among the most important sources of CO2 in Canada, accounting for almost 11% of our total emissions (Jaques, 1992).

Disposal. Large amounts of waste motor oil, containing a diversity of contaminants ranging from PCBs to metals, enter the environment because of improper disposal. Of the estimated 230 million litres of waste motor oil generated by motor vehicles in 1990, approximately 50% was rerefined and 34% was used as fuel to power incinerators and furnaces. The remaining 16%—over 36 million litres—is believed to have been disposed of in ways that allow environmental contamination, including dumping in landfills and sewers and use as a dust suppressant (Environment Canada, Office of Waste Management, unpublished data).

(continued)
Driving and Maintenance Habits

Technical improvements in fuel efficiency and emission controls can be offset by the driving and maintenance habits of automobile owners. A Vancouver study, for example, showed that passenger cars made up 98.4% of downtown rush-hour traffic but carried only 62.6% of the commuters (B.C. Transit, 1990)—an inefficient use of transportation energy when compared with the use of public transit vehicles (Table 3). In addition, traffic congestion reduces fuel efficiency and increases pollution, as engines not running at maximum efficiency tend to consume more fuel and release proportionately more emissions. It has been estimated that a 16-km trip taken in light traffic and requiring 11 minutes would produce 2 g of VOCs; the same trip in heavy traffic and requiring 30 minutes would generate 7 g—a 250% increase (Go Green, 1990).

<table>
<thead>
<tr>
<th>Transportation mode</th>
<th>Fuel or electricity use (L/100 km)</th>
<th>Number of commuters</th>
<th>Energy use (MJ/person-km)</th>
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<tbody>
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<td>Automobile</td>
<td>15</td>
<td>1</td>
<td>4.74</td>
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<tr>
<td></td>
<td>10</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Diesel bus</td>
<td>56</td>
<td>0.52</td>
</tr>
<tr>
<td>Subway</td>
<td>2.61 kwh/km</td>
<td>75 (per car)</td>
<td>0.13</td>
</tr>
<tr>
<td>GO Rail</td>
<td>761</td>
<td>810</td>
<td>0.35</td>
</tr>
</tbody>
</table>

MJ = megajoule
Source: Modified from Healthy City Office (1991)

Table 3: A comparison of energy use by transportation mode

Car maintenance also influences fuel efficiency and emissions. New vehicle emission standards for NOx, VOCs, and CO assume a properly maintained vehicle. Unfortunately, many vehicles do not receive regular maintenance or may no longer have functioning emission control devices. Inadequate maintenance may result in emission levels 2–10 times higher, per car, than might be expected (B.C. Ministry of Solicitor General, 1991). As a result, a relatively small number of vehicles may account for an unusually large proportion of emissions. One recent study suggested that nearly 50% of total emissions may be produced by only about 10% of all vehicles—mostly those that are older and poorly maintained (Ontario Round Table on Environment and Economy, 1991). Vehicle emissions may often be lowered by simple repairs, such as replacing the air filter or spark plugs, resetting the engine timing, or adjusting the carburetor, measures that may also increase fuel efficiency and improve driving performance.

Automobile Air Conditioners

Approximately 60% of the cars and light-duty trucks sold in Canada are equipped with air conditioners that contain chlorofluorocarbons, or CFCs, which contribute to stratospheric ozone depletion and global warming. Even well-maintained motor vehicle air conditioners leak CFCs during their normal functioning, and additional CFCs are usually released when air conditioners are serviced. Furthermore, old air conditioners release whatever CFCs they still contain when crushed at auto wreckers. In 1991, motor vehicles accounted for 23% of Canada’s CFC consumption (Environment Canada, Commercial Chemicals Branch, unpublished data).

Disposal

Once automobiles, or any of their components, wear out, the issue of their disposal must be contended with. A great deal of material goes into the manufacture of a car, making discarded vehicles and components a significant source of metals, plastics, and rubber. Although some materials in scrapped cars are recycled, the disposal of others presents problems. The disposal of tires illustrates the challenge. An estimated 19.5 million vehicle tires are discarded every year in Canada, about 13 million of which come from passenger vehicles (CCME, 1990). However, no process exists for converting old tires into materials suitable for manufacturing new tires, in the way that new metal products, for example, can be made from old.

At present, 62% of discarded tires are landfilled, 18% are recycled or retreaded, 6% are burned in an environmentally acceptable manner as a fuel source, and the remaining 14% are stockpiled (CCME, 1990). Although landfilling may not be a desirable method of disposal, stockpiling presents risks such as fires, the emissions from which contaminate adjacent air, land, and water. Such an event occurred in 1990, when 11.5 million discarded tires caught fire at a stockpile site near Hagersville, Ontario.
New technologies may lead to uses for discarded tires and change their status from waste to resource. Researchers are now exploring the incorporation of rubber from waste tires into plastics and asphalt. However, considerably more research will be needed before such uses will be accepted as operationally, economically, and environmentally feasible.

Recycling

About 75% of the materials in scrap vehicles can be recycled (Siuru, 1991). In fact, automobile recycling already contributes significantly to national production levels of some materials. The salvage of platinum from old catalytic converters, for instance, accounts for one-third of domestic platinum production. In addition to extending the life span of nonrenewable resources, metal recycling requires 50–74% less energy for production and releases 86% less air pollutants, 76% less water contaminants, and 97% less solid waste than metal production from ores (Government of Canada, 1991).

Most metallic components, such as engine blocks, starting motors, and generators, can be and are reused or recycled, but nonmetallic items, such as plastics, fluids, and rubber, are more difficult to contend with. Car manufacturers are now intensifying their research on recycling, and especially on ways of dealing with nonmetallic components. In North America, one of the most recent initiatives has been the formation of the Vehicle Recycling Partnership to coordinate the research activities of the major automobile manufacturers and to establish recycling guidelines.

An important concept that has been receiving increasing attention is “design for recycling.” The idea is that recyclability should be designed into the car from the beginning by selecting materials that can be recycled and by making the car easier to dismantle. Many manufacturers, for example, now label plastic components with standard codes to make it easier to sort them by chemical composition when they are recycled.

To encourage the recycling of certain other components, some provinces place a fee on their purchase. A few, for example, charge tire fees, with the objective of funding research into environmentally acceptable methods of disposal. In British Columbia, a similar system has been set up to facilitate the collection and recycling of lead-acid batteries, thus preventing them from being landfilled or burned. Such fees can help to reduce the landfilling of waste, particularly toxic items such as batteries.

(continued)
Inspection and Maintenance Programs

Inspection and maintenance programs are aimed at reducing in-use vehicle emissions and are designed to detect vehicles with excessive emission levels. The Greater Vancouver Regional District’s program, possibly the most comprehensive in North America, consists of an annual visual inspection of emission control devices and the measurement of tailpipe emissions. Owners are charged a fee for the inspection, and those whose vehicles do not meet the standards are required to restore them to proper operating condition before being issued registration or re-registration documents. Inspection and maintenance programs are in place or being planned for other regions of Canada.

Employer-Sponsored Initiatives

Some employers have taken steps to reduce the dependence of their employees on automobiles. These include flexible schedules that allow employees to commute during off-peak times or to work longer hours per day but fewer days per week; telecommuting, or communicating with work by phone, fax, or computer, which allows some employees to work out of their homes on a full- or a part-time basis; subsidized parking for employees who carpool, to encourage groups of employees to coordinate their commuting; and satellite offices that enable some employees to work closer to home and reduce commuting distances.

Alternative Transportation Modes

<table>
<thead>
<tr>
<th>Transportation mode</th>
<th>NOx</th>
<th>VOCs</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light rail</td>
<td>43.0</td>
<td>0.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Transit bus</td>
<td>95.0</td>
<td>12.0</td>
<td>189.0</td>
</tr>
<tr>
<td>Van pool</td>
<td>24.0</td>
<td>22.0</td>
<td>150.0</td>
</tr>
<tr>
<td>Car pool</td>
<td>43.0</td>
<td>43.0</td>
<td>311.0</td>
</tr>
<tr>
<td>Single-occupant car</td>
<td>129.0</td>
<td>130.0</td>
<td>934.0</td>
</tr>
</tbody>
</table>

Table 4: A comparison of emissions by transportation mode (g/person-100 km)

In areas of high population density, a shift to alternative transit modes can be encouraged by controlling access by cars, improving public transit systems, improving interfaces between cars and public transit (for example, park and ride), and creating and improving facilities for walking and cycling. In low-density suburban developments, where public transit is less practical, car- or van-commuting schemes may be more efficient (Reid, 1986). As well as using less energy, alternative modes of transit produce lower emission levels per passenger (Table 4).

Reduction to Accidentally Released VOCs

The Canadian petroleum industry has installed equipment in the Vancouver and Toronto areas to recover releases of VOCs that occur during the transfer of gasoline between facilities (CPPI, 1991a). In addition, refineries decreased the amount of butane added to summer gasolines in Canada in 1991 to reduce their volatility and thus minimize VOC releases during refuelling and transfer (CPPI, 1991b).

CFC Replacement in Air Conditioners

As part of Canada’s commitment to phase out CFCs, automobile manufacturers will replace CFC-12 in air conditioners with hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) by the year 2000. HCFCs have considerably less stratospheric ozone-depleting potential than CFCs, while HFCs have virtually no capacity to deplete stratospheric ozone. Both groups of compounds appear to have significantly less impact on global warming than CFC-12. Some automobile manufacturers will voluntarily begin to use HFCs and HCFCs as soon as 1993 but will continue to service vehicles containing CFC-12 until the end of the century. Some also plan to install recycling equipment in authorized service centres to reduce CFC-12 losses during servicing.

New Emission Standards

Automobile manufacturers have voluntarily agreed to introduce, in Canada, vehicles that meet the stringent exhaust emission standards being progressively introduced in the United States beginning in 1994. These vehicles will emit 60% less NOx and 29% less VOCs than are currently allowed. The government is developing comprehensive emission control regulations to be effective in the 1996 time frame.

Alternative Fuels

Currently available alternatives to gasoline include propane, natural gas, methanol, ethanol, and oxygenated gasolines (varying mixtures of gasoline and alcohol) such as M85, which is 85% methanol and 15% gasoline. These fuels burn more efficiently than gasoline and thus emit fewer pollutants.
Furthermore, ethanol and methanol can be produced from biomass and are therefore renewable. Domestic automobile manufacturers have recently begun to introduce flexible-fuel vehicles that can run on conventional fuel as well as M85 or ethanol. Electric vehicles or those powered by hydrogen cells may provide a renewable and even cleaner generation of alternatives to gasoline. In fact, with the development of more efficient batteries, some car makers are now preparing to introduce electric cars to the market. Hydrogen fuels are still in the experimental stages and will require additional research before becoming available to consumers.

The Car and a Sustainable Environment

How can we ensure that the automobile is compatible with a sustainable environment? Certainly there is no simple answer. Cars are likely to be a permanent fixture of industrialized and semi-industrialized societies for some time to come.

Nor can we rely exclusively on technology to put the issue to rest. Technological improvements over the last 20 years have already done much to reduce the environmental impact of the individual car, and further improvements can be expected in coming years. But much of the ground gained through technological improvements is being lost as more and more cars crowd the roads. To offset the effect of growing numbers, we shall have to look to other solutions—urban planning initiatives, economic strategies, and education—to lessen our dependence on the automobile. Eventually, these solutions could give us a more varied choice of transportation options in which the car plays a more efficient role.

Whatever the solutions we choose, they must work within an international as well as a national context. Nothing is accomplished if some of the problems, such as those associated with manufacture or disposal, are simply transferred from one country to another, thus solving problems at home but passing on challenges to global neighbours.

With continuing population growth and rising standards of living, the demand for car ownership will continue to increase. Because of that, we are unlikely to find an ultimate solution to the environmental problems associated with the automobile. Instead, we shall always have to confront the task of balancing the demand for cars with our need for a sustainable environment. That means that the issue must constantly be readdressed, with new solutions devised and old solutions reworked as conditions change.

Above all, we have to recognize the complexity of the many issues surrounding the car and look for solutions on a multitude of fronts—technological, social, economic, political, and ecological. Such a holistic approach is our best chance for preserving the benefits of the car while keeping its environmental effects within the limits of sustainability.

1. In this fact sheet, the term “automobiles” is used synonymously with “passenger cars,” a group that includes both personal-use passenger cars and fleet vehicles. In contrast, “motor vehicles” is defined to include both passenger cars and light-duty trucks and vans.
Environmental Implications of the Automobile (SOE Fact Sheet No. 93-1)

Outline

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The Car and the Economy

The Car and the Environment

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  Use of non-renewable materials
  Consumption of energy

Infrastructure and Land Use

The Demand for Fossil Fuels
  Consumption of energy resources
  Energy production and delivery
  Fossil fuel combustion
  Disposal

Driving and Maintenance Habits

Automobile Air Conditioners

Disposal

Meeting the Challenge

Manufacturing

Recycling

Inspection and Maintenance Programs

Employee-Sponsored Initiatives

Alternative Transportation Modes

Reduction of Accidentally Released VOCs

CCF Replacement in Air Conditioners

New Emission Standards

Alternative Fuels

The Car and a Sustainable Environment

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Graphic: Workers on an assembly line
Figure 2: The relationship between number of automobiles and Gross Domestic Product
Table 1: Weights and types of materials utilized in the construction of an average motor vehicle, 1989
Table 2: Major impacts of common pollutants associated with automobile use on human health and the environment
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Graphic: Burning tires at Hagersville (a town)
Table 4: A comparison of emissions by transportation mode (q/person-100 km)

In Canada, a car or truck’s fuel economy is measured in litres per 100 kilometres (L/100 km). For example, a car’s fuel economy rating may be 8.7 L/100 km. This means that, on average, the car burns 8.7 litres of fuel to travel 100 kilometres. By doing the following problems you will gain a better understanding of fuel economy.

1. Rank the following fuel economy ratings from best (most fuel efficient) to worst (least fuel efficient). Use the numbers from 1 to 5 to rank them—1 is the best, 5 is the worst.

   Your ranking (best to worst):
   12.6 L/100 km  ______
   6.2 L/100 km  ______
   9.5 L/100 km  ______
   7.3 L/100 km  ______
   10.7 L/100 km  ______

2. A car has a fuel economy rating of 9.3 L/100 km.
   (a) How many litres of gasoline will be needed to travel:
      (i) 325 km?
      (ii) 750 km?
   (b) How many kilometres can this car travel on:
      (i) 45.7 L of fuel?
      (ii) 65.2 L of fuel?
   (c) The capacity of the fuel tank is 58.5 L. What is the cruising range of the car?

3. Find, correct to one decimal place, the fuel economy of:
   (a) a car that travels 450 km on 52.5 L of fuel.
   (b) a van that travels 415 km on 65.0 L of fuel.
   (c) a transport truck that travels 6000 km on 1482 L of fuel.

4. Two families drive to Florida for the March break. One family drives a car whose fuel economy rating is 7.3 L/100 km, and the other drives a car that is rated at 10.5 L/100 km. Each family travelled 5,200 km and the average cost for fuel was 45.7¢ per litre. Calculate the amount of fuel that each family used for the trip and also the cost for fuel for each family.

5. Suppose that you or your family drives a car whose fuel economy is 10.6 L/100 km. By having the engine tuned up you can improve the fuel economy to 8.9 L/100 km but the tune-up will cost $125. You drive an average of 20,000 km per year and fuel costs 58.9¢ per litre. Calculate the savings or the costs that will result over the next year by having the engine tuned up now.

(continued)
Fuel Economy Questions (continued)

6. Repeated tests show that the fuel economy of a car is 7.5 L/100 km for highway driving and 12.7 L/100 km for city driving. This car is to be taken on a vacation trip of 8,000 km that is 70% highway driving and the rest is city driving.

   (a) Calculate, correct to one decimal place, the expected overall fuel economy on this trip.

   (b) Use your answer to part (a) to compute the expected cost for fuel on this trip if the average cost per litre of fuel is 60.3¢.

7. Let’s suppose that, on average, cars operate with a fuel efficiency of 9.3 L/100 km. Let’s also suppose that we could increase the fuel efficiency of every vehicle to 7.3 L/100 km.

   (a) How many litres of fuel would be saved each year by a person who drives 20,000 km per year?

   (b) If there were 250,000 vehicles in a city, and each of them could burn that much less fuel, how many litres of fuel would be saved?

   (c) If the cost of fuel is 59.5¢ per litre, how much money would be saved?

   (d) Think of some worthwhile community projects that could be financed with this saved money.

   (e) There are over 12,000,000 vehicles in Canada. Perform calculations for Canada similar to those you did for the city in parts (b) and (c). Then suggest several worthwhile national projects that could be financed with the saved money.

8. Clearly there are financial advantages for the consumer to increasing the fuel efficiency of his or her car. Now try to think more globally (for example, think about society or the physical environment).

   (a) What are some other advantages to increasing the fuel economy of vehicles?

   (b) Suggest some ways that we could improve the fuel economy of our vehicles.

   (c) Do you see any disadvantages to increasing the fuel economy of vehicles? If so, what are they?
Emissions from vehicles and from industrial plants get mixed with the air that we breathe. Two of the more common pollutants in the air are nitrogen dioxide and sulphur dioxide. The rain dissolves these and other substances and they come back to the earth in the form of “acid rain.” This rain falls everywhere and causes environmental damage.

To help prevent this, cars and factories have devices which “scrub” their exhaust. These scrubbers remove some of the pollutants from the exhaust before they can enter the atmosphere and produce acid rain.

The concentration of pollutants in exhaust is measured in parts per million (ppm).

Doing the questions that follow will help you to increase your understanding of the mathematics of cleaner air.

1. A scrubber unit installed in a factory removes half of the pollutants each time the exhaust gas passes through it. Untreated exhaust contains 2,000 ppm of contaminants.
   (a) Complete the table of values below which show values of
      
      n - number of times the exhaust gas passes through the scrubber
      c - the concentration in ppm of contaminants that remain in the exhaust gas

      | n | 1 | 2 | 3 | 4 | 5 | 6 |
      |---|---|---|---|---|---|---|
      | c |    |    |    |    |    |    |

   (b) Plot the ordered pairs from the table of values in part (a). Number of times breathed on an x axis and concentration in ppm on a y axis.

   (c) Could all of the contaminants in the exhaust gas be removed in this way? Explain.

2. A company installed a scrubber which removes one-third of the pollutants each time exhaust gas passes through it. Untreated exhaust contains 1,500 ppm of sulphur dioxide. In its annual report the company states that by passing exhaust gas through the scrubber three times, all of the sulphur dioxide will be removed. You believe this statement to be false. Write a short letter to the company which explains and corrects its error.

3. A scrubber removes two-thirds of the pollutants each time exhaust gas passes through it. Before treatment, the gas contains 1,200 ppm of contaminants.
   (a) What is the concentration of contaminants in the gas after it has passed through the scrubber 2 times?
   (b) After the gas has passed through the scrubber 2 times, what fraction of the contaminants has been removed and what fraction remains?

4. Before exhaust gas can be released into the air, it must contain less than 200 ppm of sulphur dioxide. If untreated exhaust contains 3,600 ppm of sulphur dioxide and if a scrubber can remove half of the pollutants each time the gas passes through it, how many times should the gas be treated before it is released?

5. A manufacturing plant passes its exhaust gas through three cleaning stations before it is released into the atmosphere. Station A removes three-quarters of the pollutants, station B removes one-third of the pollutants, and station C removes half of the pollutants.
   (a) What fraction of the pollutants will be removed after the gas passes through all three stations?
   (b) Does it matter in which order the gas passes through the three stations? Explain.
   (c) If untreated exhaust contains 4,500 ppm of pollutants, what will be the concentration of pollutants after the gas has been cleaned by all three stations?
   (d) A problem with station B is causing it to work at 50% efficiency. What percent of the pollutants will be emitted into the atmosphere after treatment by all three stations?