Environmental Quality: Outline for a National Index for Canada

Data on the overall environmental quality in Canada are put on an index basis, in analogy to economic indices.

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The term "quality of life" is, to rephrase an old aphorism, something that everyone talks about but nobody understands. At least, that is the impression one gets from scanning the literature where, in recent years, quality of life has been defined as comprising, in part, earth sciences (*1*), education (*2*), medical science (*3*), research (*4*), physics (*5*), electric power (*6*), and many other components. As the parts which make up the quality of life become greater in number, the term becomes less scientific and more moral and political. Indeed, a recent Canadian election was fought on the basis of which party could best improve the quality of life.

Diffuse as the term can become, most would agree that the state of the environment forms a significant part of it. If we can evaluate environmental factors properly, we are well on our way to formulating an approach to evaluating the quality of life. The Japanese, it has been reported (*7*), have already attempted to quantify the quality of life.

Accounts of man's environment have tended to be descriptive ("this is a smoggy day") or numerical ("there are *x* micrograms of sulfur dioxide per cubic meter of air today"). As our knowledge of the environment has become greater, more and more has been put on a numerical basis. The idea then comes to mind of presenting this information in the form of an index—that is, comparing one environmental state to another state, either an optimal state or one which is judged to pose hazards to human beings or other components of the environment. The states to which comparison is made are chosen on the basis of scientific judgment.

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The idea of an environmental quality index (EQI) has been discussed before, in terms of air quality (*8*), water quality (*9*), noise (*10*), wildlife (*11*), pesticides (*12*), radiation (*13*), and many other aspects of the environment. A great many of the aspects of individual environmental indices are discussed in Thomas (*14*).

As well as the individual investigators mentioned in Thomas (*14*), government agencies have taken an interest in formulating an EQI, or a number of EQI's, which would tell us (i) what we know or do not know about the environment on a broad scale and (ii) how its state was changing because of governmental and private actions.

As an example of this official work, I have mentioned the Japanese effort toward devising an overall index for the quality of life; this Japanese index is said to include an EQI (*7*). In the United States, the Council on Environmental Quality (part of the Executive Office of the President) commissioned a series of studies on aspects of EQI's in 1971 (*15*). Results of some were presented in its annual report for 1972 (*16*). However, the chapter which summarized them was significantly entitled "The quest for environmental indices." In other words, because of the developing nature of our understanding of the environment, any EQI will not be perfectly comprehensive, and in fact may never be.

For example, let us consider mercury in fish. Until the consequences on the food chain of dumping mercury into water were realized on a worldwide basis in the 1960's, and until adequate instrumentation was available for making measurements of the concentration of mercury in edible fish on a consistent and accurate basis, a subindex of this aspect of environmental quality was not possible. It is probable, even highly likely, that any EQI we devise now, in turn, leaves out areas which will later be incorporated.

However, this does not obviate the use of an EQI for telling us the approximate state of the environment now. In fact, the problem is endemic to all makers of indices describing human activities or their consequences. For example, when the consumer price index (CPI) became generally accepted in the 1930's, television and air conditioners were not in much use, and provision for expenditure on them had to be included in later editions of the CPI. Any EQI faces the same problem.

A Canadian Environmental Quality Index

In 1972, a small working group was set up in the Canadian Federal Department of the Environment to try to devise an overall EQI. To take account of as many viewpoints as possible, more than 50 scientists, engineers, and administrators dealing in environmental matters were consulted. It was decided to express all data in the form of an index, defined as a number, free from units, which ranged from 0, for the best possible environmental condition, to increasing numbers for progressively worse environmental quality. In this way, several indices could be combined to give an overall picture of environmental quality. With this index, a value of 1 generally means that an objective (or standard) is being met, or that the index is at its highest level according to a particular scale of values, or that a certain environmental condition is equal to a national average. It was not possible to be consistent with respect to the criteria throughout the entire EQI because of the wide variety of data and the general lack of official standards.

In effect, the EQI runs the same way as the CPI: lower numbers are "good" and higher numbers are "bad." However, we still do not have enough knowledge of the environment to remove the quotation marks from these adjectives. Furthermore, the CPI has the advantage, which economic indices possess, that all quantities which comprise it can be reduced to a monetary unit like the dollar. The unit-free indices mentioned above were devised to enable us to add the bad aspects of, say, sulfur dioxide in air to the good aspects of access to parkland.

Four basic requirements of data were that they had to be (i) numerical rather than descriptive; (ii) reasonably national and comprehensive; (iii) if at all possible, relating to the same time period; and (iv) comparable with a standard (or status level) so that the data could be made into a unit-free index.

The first of these requirements has already been discussed. The second requirement by no means implies that the measurement or estimate in question had to apply to everyone in the country; very few, if any, environmental measurements do. However, the data had to be of a general rather than of an isolated nature. The third was difficult to achieve in practice. Most of the data in the EQI related to 1971. However, some data were from prior to that date and others were from 1972 (*17*). Finally, to fulfill the fourth requirement, calculations were based, whenever possible, on government standards. Since such standards do not exist for most environmental conditions, standards for these conditions were chosen on the basis of expert judgment, and of course varied depending on the subindex being considered.

Because of the differing types of standards, the task of combining subindices was made more difficult. In general, the farther away we get, mathematically speaking, from the original data, the harder it is to assess the overall value of the index we obtain.

It is virtually impossible to reach a value of 0 (or "perfection") for some of the subindices, no matter what the degree of government or private action. In air, there is always a certain amount of dust and other matter due to winds or active volcanoes, for example. As a result, the subindex for suspended particulate matter in air can never become 0. In many other subindices, environmental deterioration is caused by a combination of man-made and natural causes, and the extent of our knowledge is such that we cannot generally separate the two.

Hierarchy of the Environmental Quality Index

To calculate an overall value of the EQI which could be compared from year to year, it was necessary to use a hierarchial structure, in which a broad index was built up of subindices, each of which in turn could be made up of sub-subindices, and so on. For purposes of convenience, the EQI was broken down into four sections, dealing with air, water, land, and those aspects which do not fit logically into the other three sections, and which were deemed "miscellaneous." While a mathematical construction of overall environmental quality can be done in many ways, this arrangement has the advantages of being simple and logical. It was sug-

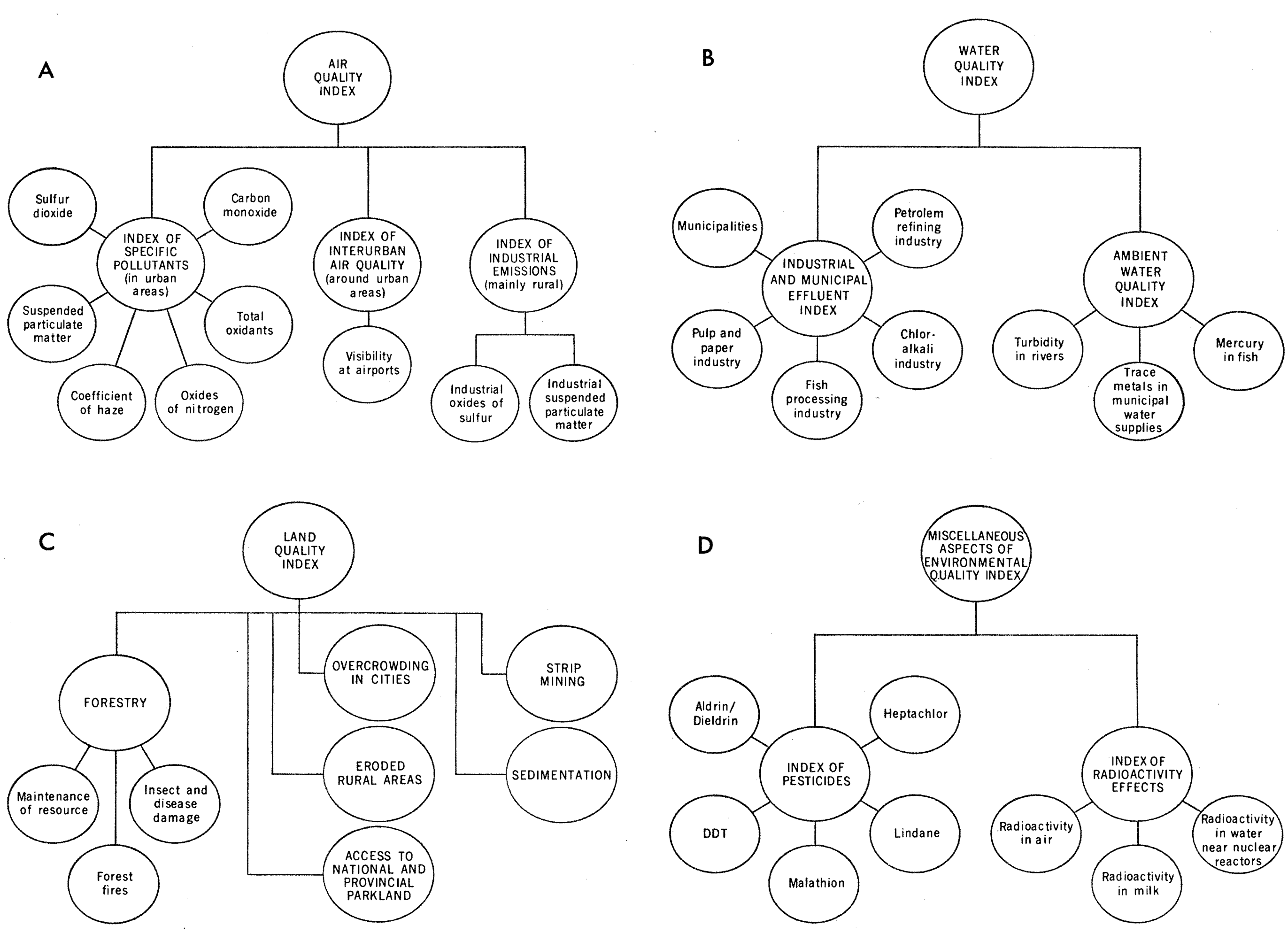


Fig. 1. Schematic diagrams of the indices for (A) air quality, (B) water quality, (C) land quality, and (D) miscellaneous aspects of environmental quality.

gested by the EQI prototypes developed by the National Wildlife Federation of the United States, as mentioned in Thomas (*14*). There is also a connection with ancient mythology. The Sumerians, creators of the world's first cuneiform system of writing, had thousands of gods, but four were particularly significant: Enlil (the god of air), Enki (the god of water), Ninhursaga (the earth goddess), and An (god of the sky) (*18*). If we regard the first three as representing the three major components of the environment, and the fourth as giving a bird's-eye view of the others, we have a succinct description of the parts of the EQI, 4500 years old.

The arrangement of the different indices and subindices is shown in Fig. 1. It should be noted that we were limited in our coverage by the available data and by the four criteria noted above. If and when more data become available, they can be incorporated into future EQI's.

The air quality index was broken down into three major sections, dealing with air quality in urban areas (specific pollutants such as sulfur dioxide, oxides of nitrogen, suspended particulate matter, and so on), air quality around these areas (visibility, a measure of air pollution, at airports, for example), and air quality outside major urban areas (industrial emissions in smaller urban areas).

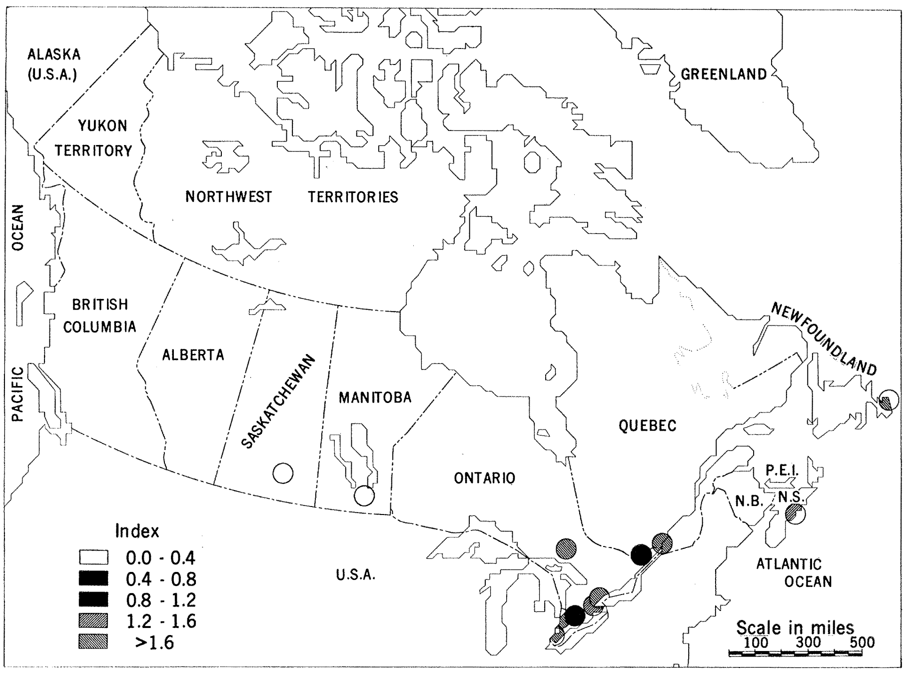
The water quality index was broken down into two major sectors. The first pertains to industrial and municipal discharges of wastes into water, and the second with the actual measured water quality and some secondary aspects of it. The index concerned with effluent discharges has five sections on four major Canadian industries—pulp and paper, chlor-alkali, fish processing, and petroleum refining—and municipalities. The other index deals with turbidity in rivers, mercury levels in fish, and trace metals in municipal water supplies.

In the land quality index, six subindices were combined. These included characteristics of forests, overcrowding in cities, erosion, access to parkland, strip mining, and sedimentation.

In the index for miscellaneous aspects of environmental quality, subindices on pesticides and radioactivity were combined.

It should be noted that some of the subindices in each of the four main sections were themselves made up of sub-subindices. For example, the subindex on forestry had three sub-subindices.

In order to produce a numerical index, a number of mathematical methods were employed on the data. Because of the stage of our knowledge, environmental data tend to be relatively crude, and we found it practical to use relatively straightforward mathematics. For example, to combine indices or subindices, the root-mean-square method was used. This method combines the advantages of simplicity with a greater sensitivity to extreme values of indices of environmental conditions than ordinary linear averaging. In other words,



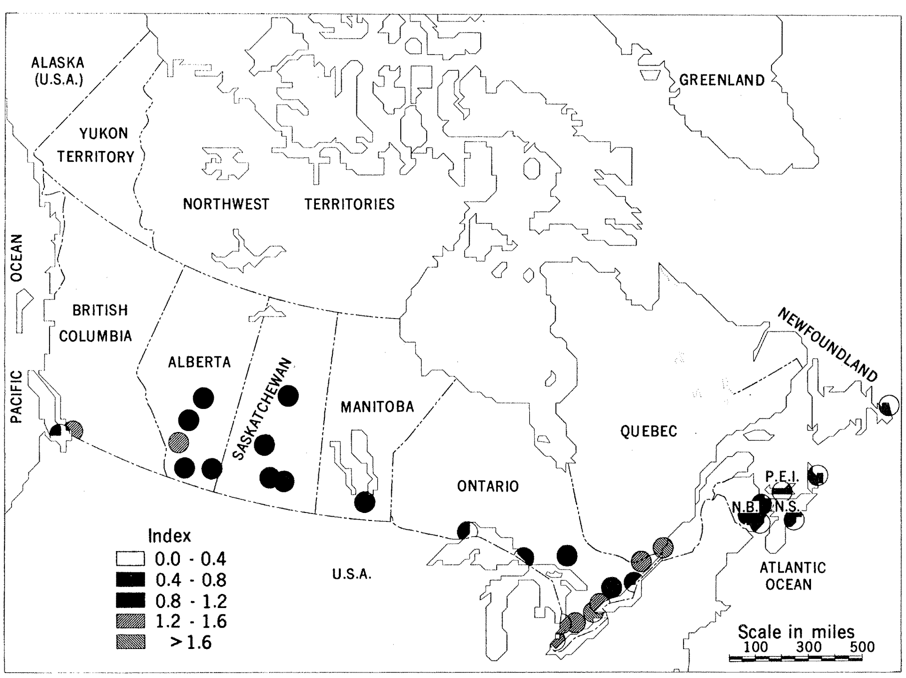


Fig. 2 (top). Sulfur dioxide index, I_{SO_2}. Most of eastern Canada has relatively high values of the index compared to those in western Canada. Shaded circles around a city indicate only the average range of values for that city, and do not necessarily mean that the entire area which is shaded has that range of values. Because of the different ways in which data were made available, and the varied value judgments placed on them, the indices shown in the other maps in this article generally have dissimilar scales. Fig. 3 (bottom). Suspended particulate matter index, I_{SPM}. Regions having the highest values for this index are in southern Ontario; there are also regions with high values in Quebec, Alberta, and British Columbia. Cities in the four East Coast provinces generally have low values. More data were available on this pollutant than on sulfur dioxide.

if indices were averaged linearly, a large value (indicating an undesirable condition) would tend to be "lost" when combined with other indices of low values. The root-mean-square method tends to emphasize these large values mathematically, and so produces somewhat larger values of a combined index than averaging does.

A system of weights, to note the fact that some parts of the environment are more important than others, was also used. These weights were assigned on the advice of experts, but by no means are certain. In fact, determining a more equitable method of preferential weighting, one which also takes into account the judgment of the public, could be an important task if future EQI's are constructed. To use the analogy of economic indices, the CPI now considers popular preferences of different types of food, housing, clothing, and the like. As yet, we do not have a comparable mechanism for the EQI. Fortunately, however, the majority of the indices are not extremely sensitive to the weights chosen. In other words, weights could be changed somewhat without altering general conclusions.

The second type of weighting used was that with respect to population. Since many parts of the EQI describe environmental conditions for people, indices were weighted, whenever possible, according to the population that was likely to be affected. For example, if a given city had twice the population of another, it had twice the mathematical emphasis put on it.

Air Quality Index

It is not possible to discuss all 36 maps and diagrams of the EQI in this article. Only the air quality index will be discussed here in detail, although examples will be given of other indices. Components of the air quality index are shown in Fig. 1A, and were chosen to take account of different aspects of air quality across the country.

The index of specific pollutants is a measure of air quality in urban areas. The index of interurban air quality describes it around urban areas. One way of obtaining this index is by noting the visibilities at airports, which are generally located some distance from the center of cities. The visibility is a rough measure of the effect on air quality of a number of air pollutants. Finally, we consider the air quality in

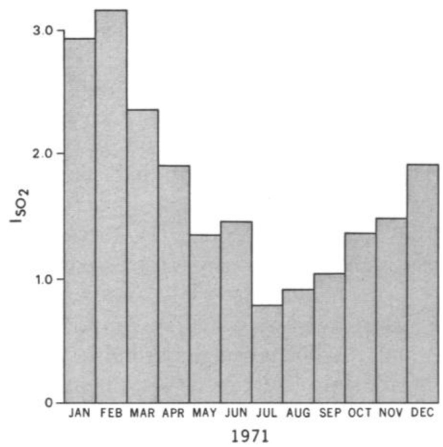


Fig. 4. National sulfur dioxide index. I_{SO_2}, on a month-to-month basis. There are large variations in this index, with the maximum occurring in the winter months, probably because of heating and the industrial use of fuels. At those times, the index is relatively high, with a value greater than 2.0. It decreases to about 0.8 by July. To compute this index, the city-wide averages were weighted according to the respective populations of each city concerned, and these weighted averages were combined by a root-mean-square method.

areas far from major urban centers, and especially where large industries exist. Some of the pollutants emitted by these industries have a much greater effect on surrounding vegetation, soil, water, and wildlife in the countryside than urban emissions. To produce an overall air quality index, these three indices were combined by the root-mean-square method.

If we return now to the first of the major subindices, an "ideal" index for specific pollutants might be

$$I_{SP} = \{[(I_{SO_2})^2 + (I_{SPM})^2 + (I_{CO})^2 + (I_{OX})^2 + (I_{NO_x})^2]/5\}^{1/2} \qquad (1)$$

where I_{SO_2} is the index for sulfur dioxide, I_{SPM} is the index for suspended particulate matter, I_{CO} is the index for carbon monoxide, I_{OX} is the index of of total oxidants, and I_{NO_x} is the index for oxides of nitrogen. Each pollutant in this equation is weighted equally in importance (weight of 1). The denominator is the sum of the weights.

Since a large amount of data on the coefficient of haze (COH) has been gathered in Canada, it was decided to allot half of the weight for I_{SPM} to the index of COH, I_{COH}. The reason for this is that the COH is also a measure of the amount of particulate matter in the air. To summarize these results, the index of specific pollutants is then

$$I_{SP} = \{[(I_{SO_2})^2 + \tfrac{1}{2}(I_{SPM})^2 + \tfrac{1}{2}(I_{COH})^2 + (I_{CO})^2 + (I_{OX})^2 + (I_{NO_x})^2]/5\}^{1/2} \qquad (2)$$

For each of these six specific pollutants, objectives (or standards) were chosen. They were generally set by governmental bodies. Although other aspects of urban air quality are measured from time to time, they were judged to be (i) a duplication of one or more of these six quantities, (ii) included in the index of interurban air quality, (iii) of inadequate reliability, or (iv) not pertinent in terms of overall air quality.

Because some of the objectives for specific pollutants were in terms of hourly and daily as well as annual concentrations, special methods were used to take account of these different objectives, but are not shown here for reasons of space.

Typical results for the sulfur dioxide index I_{SO_2}, found by comparing measured values to objectives, are shown in Fig. 2. Cities whose metropolitan areas contained about 40 percent of Canada's population were included in the measurements. If there was more than one measuring station in a city, an average concentration was taken. Most of the cities in eastern Canada had relatively high values of the index, compared to those in western Canada. The national average of this index, calculated by taking into account the populations of different cities, was 1.61.

Figure 3 shows the index for suspended particulate matter, I_{SPM}. A total of 33 cities, whose metropolitan areas contained about 50 percent of Canada's population, were included in the measurements. The highest values of the index are in southern Ontario, with high values also in Quebec, Alberta, and British Columbia. Levels of I_{SPM} in the eastern provinces (Maritimes) and most of the midwestern provinces (Prairies) tend to be low. The national average for I_{SPM} was 1.33 and so was relatively high along with I_{SO_2}.

In a similar way, the values for the other subindices for the index of specific pollutants were calculated. The national averages for I_{COH}, I_{CO}, I_{OX}, and I_{NO_x} were 1.11, 0.41, 1.69, and 0.63, respectively. Using Eq. 2, we find that I_{SP} equals 1.23.

The way the subindices of specific pollutants varied with time was also of interest. An example is shown in Fig. 4, where the national average of I_{SO_2} varies on a monthly basis. There are very large differences in this index with changes in season. The index is very high (around 3.0) in the first 2 months of the year, but decreases quickly to a minimum of around 1.0

in July and August. This change is of course due to the fact that the bulk of industrial and home-heating uses of sulfur-containing fuels occurs in the winter months.

Interurban Air Quality and Industrial Emissions

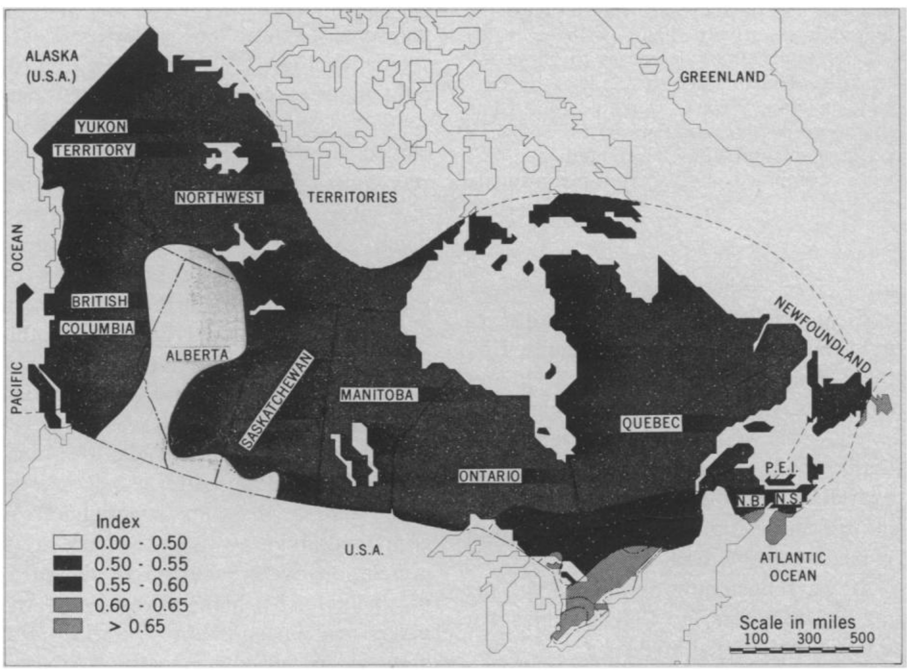
As mentioned above, the index of interurban air quality, I_{reg}, is based on visibility readings at airports. In general, as the amount of particles in the air increases, the visibility decreases. The visibility was defined as the average distance that a trained observer could see. To eliminate climatic conditions as much as possible, readings in which precipitation was noted were eliminated from the calculations.

In the previous discussion on specific pollutants, it was noted that standards or objectives were used for each of the specific pollutants. A "standard" for visibility was necessary to compare data from one airport to another on a consistent basis. Since no government standards for average visibilities have been or are likely to be set, the average visibilities at two far north stations (Yellowknife and Whitehorse in the Northwest Territories) were taken as a baseline measure. It was assumed that since these stations were so small and distant from major sources of urban pollution, they would be little affected by air pollution.

Results of the computation are shown in Fig. 5. Because of the large amount of data available, the indices are presented in the form of contours, similar to meteorological pressure maps. Regions of highest value are in southwestern Ontario. However, the entire "industrial corridor" of eastern Canada, extending from Windsor, Ontario, to about Quebec City, Quebec, tends to have higher indices than western Canada. In this latter region, there is a ridge of very low indices running along the southern extremes of British Columbia, Alberta, and Saskatchewan.

A national index of regional (or interurban) air quality was computed by weighting each local value of the index according to the metropolitan population of the city near which the airport lay. The average for 96 urban areas was 0.59.

As a third and final component of the air quality index, the index of industrial emissions, I_{ie}, was computed. Its purpose has already been discussed. Physical measurements of air quality, from which the index I_{SP} was constructed, are generally not available for small urban areas and nonurban industrial sites. Since the level of air pollution in these areas is important in evaluating air quality for the entire country, use was made of an inventory of air pollutant emissions, listing the estimated weight of emissions for major point and area sources. Emissions from major urban areas were subtracted from the



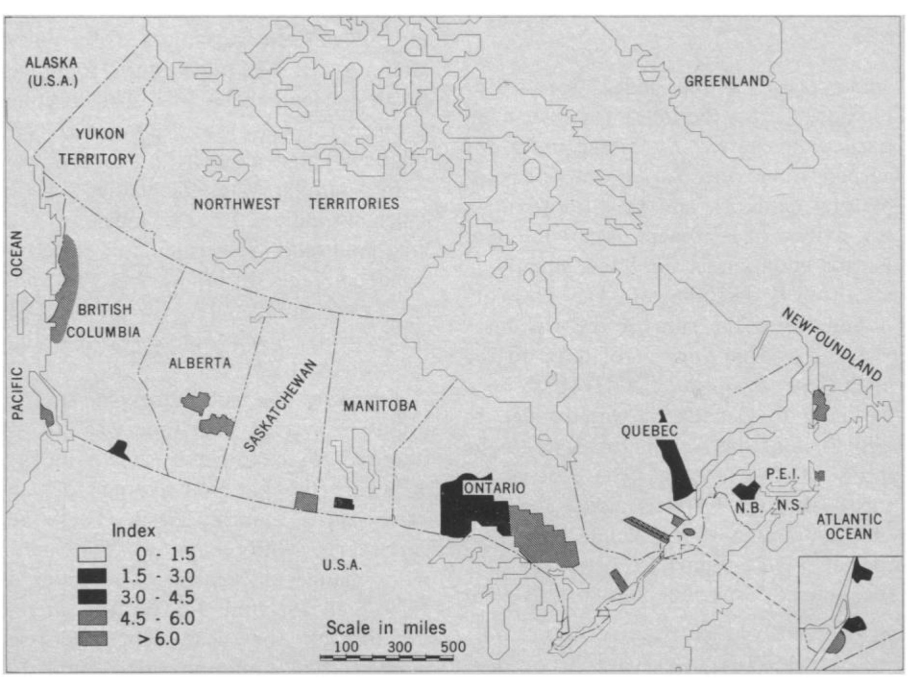


Fig. 5 (top). Index of interurban air quality, I_{reg} (based on visibility). Because of the relatively large number of measuring stations, the data were "contoured." Stations within a given shading lie within that range of values of the index. This arrangement does not imply, however, that all areas in a particular shading have the same range of values. Southeastern Ontario has the highest values of this index, indicating the lowest visibility. Values decrease toward the north. The southern parts of British Columbia, Alberta, and Saskatchewan have relatively low values, as does western Alberta. Fig. 6 (bottom). Index of industrial emissions of suspended particulate matter, I_{SPM}. The index was averaged over counties, and generally excluded industrial emissions in large cities. Quebec and Ontario have the largest number of areas with relatively high values of the index. For some counties, because of their geographical extent, only regions containing the main sources of emissions were shaded.

total, since they have been accounted for in the physical measurements of the index of specific pollutants.

As in the case of visibility, there is no national standard for this index. To solve this problem, a temporary standard was constructed in which the average weight of emission per person in a county was compared to the average weight of emission per person nationwide. It would obviously be more satisfactory to use airshed boundaries as geographical units rather than political subdivisions, but these boundaries are not generally known. The equation that takes these factors into account can be written

$$I_{ie} = (E_c/P_c)/(E_t/P_t) \quad (3)$$

where E_c is the weight of the industrial emissions in a given county, P_c is the population of that county, E_t is the total nationwide weight of the emission, and P_t is the national population. A typical example of this index is shown in Fig. 6, in which I_{ie} is calculated for suspended particulate matter. It is difficult to draw conclusions for the whole nation, since there are only 28 counties with more than 4500 metric tons of this pollutant (the lower limit of tabulation) being emitted annually. However, Fig. 6 shows that Ontario and Quebec, the most industrialized Canadian provinces, have the largest number of counties whose value of the index I_{ie} is in the highest category.

The three components of the overall air quality index, dealing with specific pollutants, regional or interurban air quality, and industrial emissions, were combined by the root-mean-square technique with weights assigned of 5, 3, and 2, respectively. These weights were chosen to reflect the approximate importance of each index to the overall Canadian air quality index. Thus the overall air quality index is

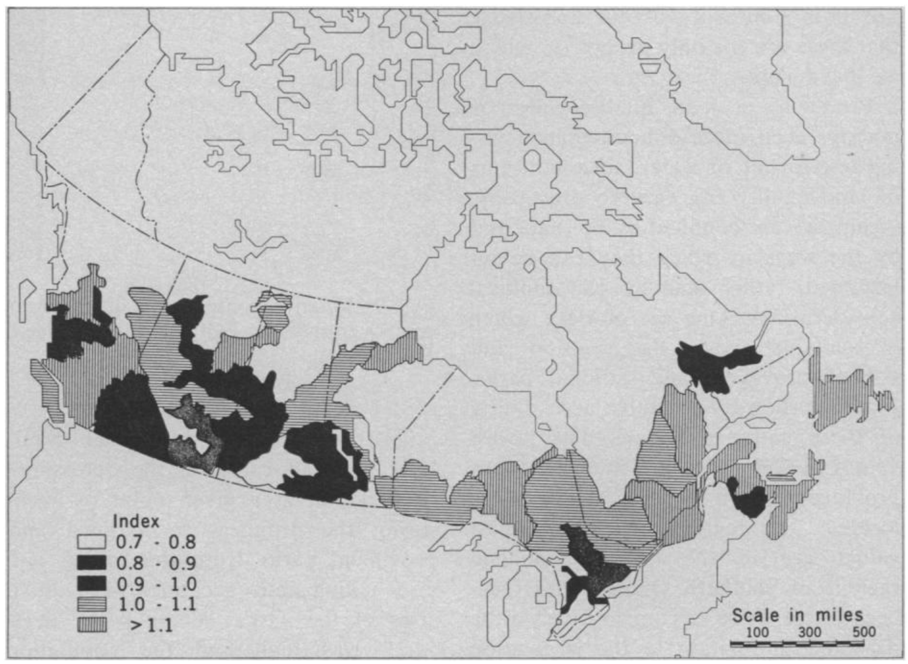
$$I_{air} = \{[5(I_{sp})^2 + 3(I_{reg})^2 + 2(I_{ie})^2]/10\}^{1/2} \quad (4)$$

where the denominator is the sum of the weights. Using values for each of these three major subindices, we find that I_{air} equals 0.99.

Water and Land Indices

As an example of indices dealing with environmental quantities other than air, let us consider one each from the water and land indices. Figure 7 shows a measure of the cleanup efforts of one contributor to water pollution, municipal waste treatment plants. The map is arranged on the basis of water basins rather than cities or counties, as is the case for air. Almost every province has at least one basin which falls into the highest category. These basins cover both very urbanized and rural areas.

The subindices depicted in Fig. 7 were calculated by estimating the efficiencies of different types of treatment plants on different wastes. For example, primary treatment might remove 60 percent of suspended solids from water, but primary plus secondary treatment might remove 95 percent. The differing types of wastes which passed through the plant after treatment were



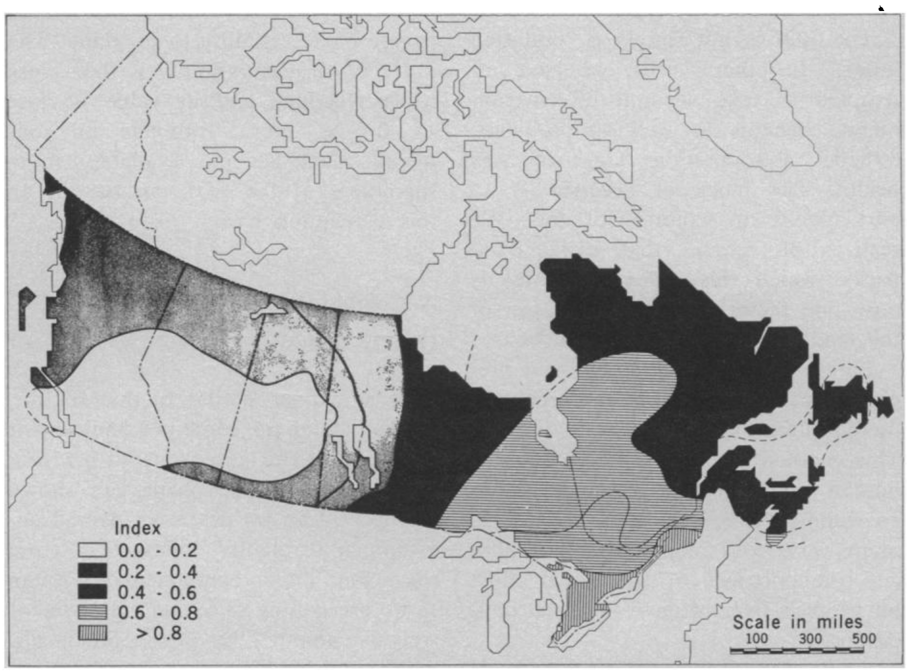


Fig. 7 (top). Index of unit loads for municipal waste treatment plants, averaged over water basins. This index is a measure of the cleanup efforts of municipalities, as opposed to industries. There is a wide range of values for this index within each province. However, the four East Coast provinces and Quebec tend to have relatively high values. Fig. 8 (bottom). Index of accessibility to national and provincial parks. This map looks different from the others because of the perception method used in its calculation (see text for details). The lowest values of this index are in the western regions near large national parks. Most of the rest of the country has moderate values, with the highest values occurring in highly populated southern Ontario and Quebec. This indicates relatively little access to parkland in those areas.

combined mathematically by assigning them weights based on government standards. Since there are no standards with respect to the total wastes from treatment plants, the average volume of waste per person in each basin was compared to the national average to derive the index shown in Fig. 7.

Roughly the same mathematical procedures were used to derive indices for the other four sectors shown in Fig. 1B. It is a measure of our knowledge that these are the only groups on which we have data.

Producing a land quality index is perhaps even more difficult than devising one for air or water, since concepts of land quality can vary so drastically. Again, we are confined by the data and by the ways in which they can be interpreted, rather than by philosophical considerations. One set of data which is available shows the location and size of provincial and national parks. Figure 8 shows the relative accessibility of these parks to people. The lowest values of this index are in the western provinces, where the largest parks are located. The regions with the highest values are in the highly populated regions of southern Ontario and Quebec, where there is comparatively little parkland in relation to the population density.

The EQI is not simply a "pollution index." In other words, we have attempted to take account of environmental benefits as well as problems, esthetic considerations as well as health. The index of accessibility to parkland is an example of this. We realize, of course, that distance to parks, which this index measures, is only one factor in recreational use of the land, but it is an important one.

Figure 8 appears different from preceding maps because of the perception method used in constructing its indices. This method tries to take account of human perception of distances from environmental benefits or problems. In many ways, this method gives a more accurate portrayal of the actual effect on people's lives of environmental conditions.

I will discuss the method briefly. It considers both population "pressure" and environmental "pressure." As an illustration of what is meant by the former, the "pressure" of people in a crowded room on an individual is much greater than the "pressure" on the individual standing in a wheat field. Mathematically, we calculate the "pressure" by measuring the distance of other people to the individual. Similarly, we can calculate the "pressure" of parkland at a given point by measuring the distances to national and provincial parks from that point, and also taking into account the relative sizes of the parks. Where park "pressure" was high and the population "pressure" was low, there was a high degree of accessibility to parkland. The index of this accessibility is then close to "perfection" and its value is close to 0. As more complete environmental data become available, more subindices of the EQI can be put on this perception basis.

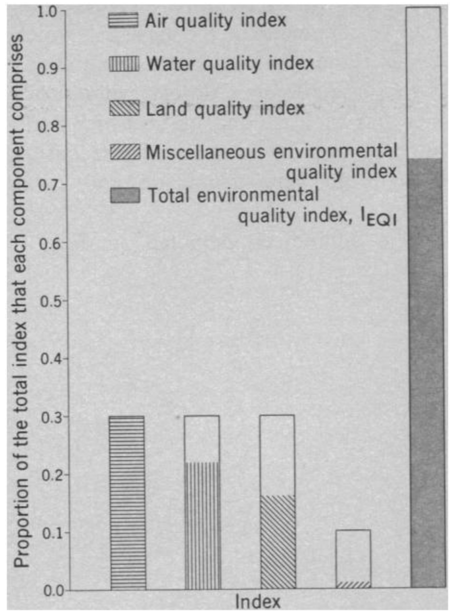


Fig. 9. Relative contribution of the four components of the EQI to the total index, I_{EQI}.

A Combined Environmental Quality Index

In a manner similar to that for air, we can build up combined indices for water, land, and miscellaneous environmental quality. The results are shown in Fig. 9. Can we devise an overall environmental quality index I_{EQI} from these four major components? We can if we are willing to assign a last set of weights among the four. Since air, water, and land are all important components of environmental quality, and since no data were available to assess the relative importance of each, it was decided to weight them equally. Since the index for miscellaneous aspects of environmental quality was much less comprehensive on average than the other three, we thought it should receive a lower weight.

Based on these assumptions, if total environmental quality is given an overall weight of 1, then the weights assigned to the air, water, land, and miscellaneous indices were 0.3, 0.3, 0.3, and 0.1, respectively. If we use the root-mean-square technique to combine these major indices as we have done to combine subindices, we have

$$I_{EQI} = \{[0.3(I_{air})^2 + 0.3(I_{water})^2 + 0.3(I_{land})^2 + 0.1(I_{misc})^2]/1\}^{1/2} \quad (5)$$

The values of I_{air}, I_{water}, I_{land}, and I_{misc} were 0.99, 0.73, 0.54, and 0.088, respectively, so that $I_{EQI} = 0.74$. In Fig. 9, the length of each of the four bars on the left-hand side is approximately proportional to the fraction of the combined index I_{EQI} that each of the four indices comprises. To calculate the length, the weight of the index is multiplied by the actual value of the index. For example, the air index extends to $0.3 \times 0.99 = 0.297$, and so on.

The question now arises: What does the value for I_{EQI} mean? As was pointed out previously, the farther we get mathematically from original data, the more nebulous the interpretation of the resultant index. It should be remembered that regardless of the methods used to combine indices, the information contained in each set of data can be used separately, if desired.

One way of describing the overall index is to define it as "the number resulting from all the physical, biological, and mathematical assumptions of the entire EQI." In other words, the value 0.74 for I_{EQI} does not represent *the* measure of the state of the Canadian environment, but rather *a* measure, based on the many assumptions we have made.

An analogy to this concept can be drawn from the intelligence quotient and the gross national product. The first is *a* measure of some forms of intelligence, not *the* measure of total intelligence. Similarly, the latter is *a* measure of many goods and services, not *the* measure of all goods and services. However, both quantities can be useful if applied carefully, and the same is the case with the index that I have outlined.

While an index value of 0.74 is difficult to grasp, a lower or higher value for any subsequent year in which an EQI is calculated would mean that, on the average, environmental conditions are getting better or worse, respectively. Change in the value of the EQI or its subindices may prove to be significant factors in measuring the "environmental health" of a country.

Measuring the quality of life is obviously a very difficult task. However, at least a few steps can be taken toward achieving this goal by devising an EQI. Periodic revisions and inclusion of more data will allow us to better understand our environment, and to determine which areas need our greatest efforts in improvement.

Summary

I have presented an approach to constructing an EQI for Canada. The index was divided into air, water, land, and miscellaneous sections. By noting individual subindices, it is possible to study how environmental conditions vary across the country. By combining the subindices, one can obtain a more crude gauge of the broad state of the environment. As indices and mathematical methods are improved, it may eventually be possible to measure this state in the same way as the economic state of the nation is measured now. The work described herein can be viewed as a simple guide to this measurement.

References and Notes

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17. For example, data on industrial air emissions are from a report prepared in 1972, but are based on data mostly from 1971 and before. In water, data on industrial effluents were mainly from 1972. Municipal effluent data were from a 1972 report based on 1971 data. On land, much forest data were from a report based on 1970 data. It is often difficult to determine the exact time that data were gathered from these and similar reports.
18. *Encyclopaedia Britannica* (Encyclopaedia Britannica, Inc., Chicago, 1966), vol. 2, pp. 973ff. This article differs somewhat in terminology and emphasis from that on p. 100 of the same volume.

19. Some of the many who helped with the EQI were R. Peters, J. Shah, G. V. Buxton, M. Kwizak, G. E. Munn, J. Ross, I. C. M. Place, and D. Eagles. Mrs. K. Przednowek and R. MacKay helped greatly with the many calculations, maps, and diagrams. Dr. F. K. Hare provided continued encouragement and wise advice. Most importantly, Dr. P. Meyboom was the inspiration for this work and steered it clear of many obstacles, both conceptual and scientific.

NEWS AND COMMENT

Soviet-American Copyright Deals: Better Where Barter Is Possible

The American Institute of Physics (AIP) and a Soviet government agency have recently reached an agreement which reconciles copyright issues in the publication of American physics literature in the Soviet Union and Soviet physics literature in this country. The agreement is probably the most noteworthy one concluded by a nonprofit, scientific publisher in the year and a half since the Soviet Union acceded to the Universal Copyright Convention (UCC).

For some other scientific publishers, agreement with the Soviets seems just as far away as ever. The American Chemical Society (ACS), for example, has been unable to arrive at terms with the Soviets. The two sides, however, have reached an interim understanding under which the Soviets have agreed to stop systematic, "cover-to-cover" copying of ACS publications and have also increased the number of regular paid subscriptions coming into the Soviet Union. The Soviets, in fact, seem to be buying more subscriptions to many of the estimated 270 American scientific and technical journals which they were formerly photocopying or translating. These were distributed in the U.S.S.R. and in countries belonging to the Council for Mutual Economic Assistance (CMEA)—which is made up of eastern European nations plus Cuba and Mongolia.

For many American and other Western publishers the main sore point is still the low royalties offered by the Soviets for publication rights. AIP is something of an exception because it translates Soviet physics journals into English and was able, in effect, to swing a barter deal. But publishers for whom no quid pro quo arrangement is possible tend to feel frustrated.

The general attitude toward the new Soviet copyright connection among American publishers is probably expressed by the comment of one person familiar with the views of commercial publishers who said, "Nobody's going to get rich, but it's better than nothing." A staff member of a professional scientific society which is a major nonprofit publisher commented with mixed idioms but unmistakable sentiment, "You can't beat 'em, you can't join 'em, you might as well take the crumbs from the table."

Until they signed the UCC, the Soviets had freely translated and reproduced American and other Western publications, including scientific and technical journals and books, without securing publication rights and, in most cases, without paying royalties.

After May 1973, when Soviet participation in UCC became effective, Soviet negotiations with foreign pub-