FORESTRY PESTICIDE SPRAYING AND CANCER INCIDENCE IN NEW BRUNSWICK: AN ECOLOGICAL STUDY

by

Patrick Seliske

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Department of Epidemiology and Biostatistics
McGill University
Montreal, Quebec

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Forestry pesticide spraying and cancer incidence in New Brunswick

This thesis is dedicated to Peggy, Michael, and Erica

For their unbounded love and support

ABSTRACT

The human health risk associated with exposure to pesticide formulations applied to New Brunswick forests was examined for 31 sites of cancer, using measures of exposure based on the proximity of non-city population centers to spray areas.

Two organochlorine and two organophosphate exposure indices were developed by using maps of areas sprayed each year during the period 1952 to 1976. These data were analyzed in relation to cancer incidence rates during the period 1977-1980 for 254 New Brunswick municipalities.

Follow-up case-control studies of the cancer sites considered does not seem to be a matter of high priority at present. However, continued surveillance and data analysis involving more recent data is needed, particularly in the case of organophosphate formulations, due to the relatively short interval between exposure and outcome ascertainment for this exposure.

RESUME

Le risque pour la santé humaine associe a l'exposition a des formules de pesticides repandus dans les forêts du Nouveau-Brunswick a eté examiné pour 31 cancers différents, ceci en utilisant des mesures d'exposition developpées selon la proximite des populations rurales aux zones aspergées.

Quatres indices d'exposition ont eté developpes en utilisant les cartes des regions aspergées de 1952 a 1976, deux indices ayant ete developpes pour les organochlores et deux autres pour les organophosphates. Les donnees recueillies ont ete analysees en fonction des taux d'incidence de cancer de 254 municipalites du Nouveau-Brunswick etablis pour la periode de 1977 a 1980.

Les etudes cas/temoins des cancers etudies ne semblent pas être une grande priorite presentement. Toutefois, une surveillance continue ainsi que l'analyse de donnees plus recentes sont necessaires, particulierement en ce qui concerne les formules organophosphates compte tenu de l'intervalle relativement court entre le moment de l'exposition et de la détermination objective de son resultat.

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CHAPTER I

INTRODUCTION

The long-term health effects of pesticides sprayed on forests in New Brunswick have never been studied adequately. To do so requires: a) the assembly, validation, and linkage of many disparate pieces of information from the fields of biology, physics, toxicology, and epidemiology, b) the development of measures of both exposure and outcome, and c) an appropriate statistical method of analysis.

This study contributes to the understanding of pesticide effects on human cancer risks through its development of appropriate exposure indices and their use to estimate cancer risk. The results should contribute constructively to the ongoing debate surrounding the hazard to health posed by the New Brunswick spruce budworm spray programme.

The spray programme is complex, in part due to the many changes over time in the substances used and the method of application. These changes have had a substantial impact on the degree of population exposure. The effects of these technological changes, compounded by increasing health concerns, have played an important role in shaping the history of the spray programme.

Chapter II begins with a brief history of spruce budworm spraying in New Brunswick. This is followed by summary information on the environmental impact of spraying,

some toxicological information about the nature of the substances sprayed, models used in the past for the estimation of exposure, and a review of the epidemiologic literature on pesticide exposure and cancer risk. Detailed information regarding cancer site-specific risk estimates are provided and form the basis for selecting additional sites for analysis that are incompatible with the global site classification in the main body of analysis. The results of these analyses also provide a basis for comparisons with other studies. More detailed information on all of these topics, excepting epidemiology, is located in Appendix I.

Chapter III contains information on the sources, quality, and means of linkage of exposure and cancer incidence data. This includes the definitions and relationships among the different geographical units used in this study. The choice and definition of potential confounders follows, and includes a brief review of the literature for each to determine the nature of their expected behaviour with respect to cancer risk. The methods employed in the development of separate near and medium-distance exposure indices for organochlorine and organophosphate pesticide spray formulations are then described and discussed. Outcome measure development is then presented to explain how the data received from the tumour registry were examined and prepared for analysis. This is followed, finally, by a description of the methods

of data analysis and the statistical techniques employed to generate risk estimates.

The data analysis section of Chapter III contains a discussion of the results of preliminary and exploratory work in which questions regarding the effectiveness of age standardization and the possibility of the interaction of exposure with age and other covariates are considered along with the appropriateness of the multiplicative model of causality in the assessment of cancer risks related to pesticide exposure.

Findings are presented in Chapter IV, which begins with some general descriptive information on the New Brunswick population and univariate descriptions of each of the exposure covariates examined in the study. Next, relationships among covariates are examined in the form of a series of bivariate distributions. A detailed description of population exposure to spray is provided and extended to the association of spray exposure with each of the study covariates. This is followed by the treatment of the tumour registry data and traces the construction of site groupings from the receipt of data tapes to the point of analysis. The distributions of standardized incidence ratios for each study variable are then examined as background prior to the Poisson regression used in the multivariate stage of the analysis. The main body of the analysis concludes with the fitting of multivariable regression models.

In the main analysis all tumours diagnosed as malignant were analysed using a global grouping of cancer sites. As the final stage of analysis, specific sites identified in the literature as being associated with pesticide exposure were examined separately along with a subset of other site groupings in which only microscopically confirmed cases were analysed. The site groupings involving only microscopically confirmed cases were chosen on the basis of the large proportion of non-microscopically confirmed cases within these groups and were analysed in this fashion to assure that the presence of potentially erroneously classified cases did not attenuate risk estimates.

The results of this study, their relationship to other studies, their interpretation, and conclusions are contained in Chapter V.

CHAPTER II

ENVIRONMENTAL, TOXICOLOGICAL, AND EPIDEMIOLOGICAL CONSIDERATIONS

I. ENVIRONMENTAL AND TOXICOLOGICAL CONSIDERATIONS

A. Introduction

Awareness of the potential health effects of pesticides began to materialize in New Brunswick in the middle 60's as Rachel Carson's Silent Spring focussed scientific and public attention on the hazards of pesticide use [Carson,1962]. Public concern over pesticide exposure in New Brunswick was further stimulated by an extensive annual forestry spray programme that had been initiated in 1952 as a joint venture of four large forestry companies. It had expanded enormously by the early 70's and spraying close to heavily populated areas in the south had intensified public anxiety.

In 1974, a team of medical investigators in Nova Scotia linked the use of certain insecticide formulations used in the spray programme with the occurrence of pathophysiological changes in mice that were similar to those of Reye's Syndrome in children [Crocker et al.,1974]. Reye's Syndrome is a rare but frequently fatal childhood condition. By 1978 these investigators had also linked the geographical distribution of cases of Reye's Syndrome to areas of forest sprayed with pesticides [Bagnell et al.,1978]. The epidemiological data were imprecise but seemed to indicate

an excess number of cases of Reye's Syndrome in New Brunswick compared to Nova Scotia; a province that did not spray its forests. Subsequent and more rigorous laboratory and epidemiological research failed to corroborate these findings [Spitzer et al.,1982;Spitzer et al.,1984].

In October of 1982 the New Brunswick Task Force on the Environment and Cancer convened, at the request of the New Brunswick Minister of Health, to evaluate the possible effects of forestry sprays on the occurrence of cancer in that province. The epidemiology sub-committee of the Task Force carried out preliminary cross-sectional analyses within New Brunswick (N=15 geographical units) and between New Brunswick and the adjacent non-forestry sprayed province of Nova Scotia. Cancers at 10 anatomical sites were identified as requiring further investigation.

Because of the complex nature of the environmental exposures involved (19 different chemicals over the period 1952-1983) and the relatively low precision in associating the pattern of spray activity with the population distribution within the province, the Task Force recommended provincial support for the development of a computerized exposure data base to be used in a more detailed analysis employing smaller and more homogeneous geographical units. Those sites that remained associated with exposure to spray after analysis using the new data base would be proposed for further examination by case-control studies.

The importance of developing and maintaining indices of population exposure to environmental substances is clearly expressed by U. Saffiotti, a former director of the NCI Carcinogenesis Programme:

> "If environmental chemicals continue to be used, because society deems them to be useful, it would at least be important to know the pattern and extent to which the population is exposed, in order to make selective preventive measures easier and to provide a basis for future monitoring and epidemiologic studies." [Saffiotti,1977]

B. Environmental Considerations

During the first 5 years of the programme, small slow-flying aircraft that were used for the aerial application of pesticides on agricultural crops were also used to spray New Brunswick forests. These planes used boom and nozzle spray equipment and flew close to the tree tops at speeds of about 150 kilometers per hour. Although no information is available on the technical aspects of the programme it is probably safe to assume that the droplet spectrum was very coarse by current standards. As a result of this coarseness the off-target drift was probably small.

Recent, intensive research into off-target spray drift has demonstrated that aircraft height above the canopy, speed, and droplet median diameters at point of release are important factors associated with off-target drift.

Two separate spray time periods are differentiated and used in this study. The DDT period extended from the

inception of the spray programme in 1952 until DDT use was discontinued in 1969. The organophosphate period began on a small scale in 1963, and fenitrothion, the most common pesticide in this period, was in large scale use by 1969.

There are two important differences between the spray periods. Firstly, DDT was applied at relatively high volumes in an oil solution while fenitrothion and other organophosphate pesticides were applied at low volumes in aqueous solutions. Secondly, the decrease in application rates per hectare was primarily attributable to the large-scale implementation of ultra-low-volume spray technology and applies predominantly to the organophosphate period.

The mobility, persistence, accumulation, and biological concentration of chemicals, their isomers and degradation products within the environment, are important features of all environmental impact assessments. Fairly extensive information is available for the organophosphate and carbamate pesticides used in the New Brunswick forestry spray programme, but little is generally known about the activity of their isomers or degradation products, and even less is known about the many substances used in their formulation (See Appendix I). Despite this the organophosphate and carbamate pesticides are generally viewed as non-persistent.

An important feature of the budworm spray programme is the large number of different substances and mixtures used over the years. These compounds are classified into general

groupings that reflect the formulations that were actually applied in time and space including the association of various classes of adjuvants with particular types of pesticides. The classification of formulations is:

a) organochlorine;
b) organophosphate;
c) carbamate.

C. Toxicological Considerations

Exposure to chemical compounds contained in aerially applied pesticide formulations can occur by absorption from the skin or respiratory system or through oral ingestion. Spray exposure is in the form of both aerosol droplets and vapor. Although estimates vary [NRCC 18979,1982,pg.74;WHO, 1979,pg.200], aerosol droplets less than 5 microns are known to penetrate deeply into the lung and are deposited in the bronchioles and alveoli. Droplets between 5 and 10 microns are deposited in the upper airways where, depending on their solubility, they are either absorbed or swept into the pharynx to be swallowed or expectorated. Aerosol droplets ranging in size from 10 to 50 microns are most likely to be deposited in the nasal passages and eventually add to oral exposure.

Two approaches to the estimation of aerosol pesticide exposure have been used within the context of the New Brunswick spray programme. The first is commonly referred to as the "worst-case scenario" approach in which it is

assumed that 100% of the mass released from the aircraft is available for exposure. The second approach to exposure estimation uses computer simulation techniques to model the behavior of aerosol droplets in the environment after their release from spray nozzles. Table 2.1 contains worst-case estimates of exposure at the spray line for DDT, fenitrothion, and aminocarb and computer model estimates of exposure at the spray line for aminocarb.

The computer model provides lower estimates for all routes, and in particular for inhalation and oral routes, despite the fact that the worst-case scenario estimates were modified to reflect that only 75% of the spray mass is contained within a droplet spectrum likely to adhere to the relevant body tissue. The computer model uses a series of algorithms to calculate the time-integrated changes as the droplets evaporate while the worst-case scenario does not take into consideration the effects of evaporation on the droplet spectrum. It has been shown that a 150 micron diameter droplet containing 70% #2 fuel oil and 20% aromatic co-solvent decreases to 50% of its size in approximately 6 minutes [NRCC 16073,1977,pg.176].

Dermal exposure differs between models to a much lesser degree because it is much more affected by larger droplets whose velocities are less dramatically altered by the process of evaporation. The worst-case scenario and the computer model also differ slightly with respect to the amount of exposed skin used in their calculations. This

Table 2.1 Franklin Worst-Case Scenario and Crabbe Computer Model Estimates of 1 Hour, Unsheltered, Spray Line Aerosol Exposure to DDT, Fenitrothion, Aminocarb (1)

	Spray Line Aerosol Exposure (micro gr./kg./bw.)			
Route of Exposure	DDT Worst-Case	Fenitrothion Worst-Case	Aminocarb Worst-Case	Aminocarb Computer
Dermal (2)	188.00	67.56	22.50	6.78
Inhalation (3)	NA	0.87	0.29	0.00091
Oral	NA	12.18	4.06	0.01330
Total	188.00	80.61	26.85	6.69221

(1) all calculations based on figures from NRCC 18979,1982,pg.78
(2) assumes 75% of spray mass available rather than the less realistic 100% used in the Franklin worst-case scenario
(3) aerosol exposure only (does not include vapour)

NA not available

difference may account for a small part of the disagreement. The worst-case scenario uses 3000 square centimeters [NRCC 18979,1982,pg.73] while the computer model uses 3400 square centimeters [NRCC 18979,1982,pg.207]. Absorption of substances deposited on the skin is through passive diffusion and is affected by mechanisms in the lipid and protein structure of the skin. The physical properties of chemical compounds in addition to factors such as age, sex, amount of body fat and region of the body exposed play important roles in determining the actual degree of absorption.

Absorption of aerosols entering the body through the oral route has been assumed to be 100% [NRCC 18979,1982, pg.80]. This assumption should be qualified in the case of DDT and perhaps other pesticides by considering the nature of the solvent in which the substance is dissolved. DDT is less toxic when dissolved in petroleum products than when dissolved in either animal or vegetable oils [WHO,1979, pg.117]. This may be due to a laxative effect of the petroleum oil and might therefore also apply to other pesticides dissolved in oil.

Data collected in the field confirm that the concentration of aerosol in the atmosphere follows a log normal distribution up to 7.5 kilometers as predicted by the computer model [Crabbe et al.,LTR-UA-52,1980,pg.ii]. These results are also consistent with what is already known about

the distribution of aerosol masses in general [Brain et al.,1974,pg.2].

Under calm spraying conditions it was found that approximately 16% of the pesticide mass of the spray formulation drifts beyond 7.5 kilometers while 6% drifts beyond this point under more turbulent conditions [Crabbe et al.,LTR-UA-56,1980,pg.28]. Turbulence acts to drive a larger percentage of the smaller droplets into the forest canopy thus preventing their off-target drift.

Droplets that drift beyond 7.5 kilometers were found to range below 30 microns and are therefore likely to drift for an indefinite period of time before being removed from the atmosphere. Additional sampling at 22 kilometers from the spray line suggests that droplets become mono-dispersed at around 5 microns in size [Crabbe et al.,LTR-UA-52,1980, pg.23]. In view of the fact that spraying has historically taken place during periods of relative calm, the 16% value is the most meaningful for the purposes of this study.

Neither the worst-case scenario nor the computer model estimates produced so far include vapor exposure. Data collected in the field could be found only for fenitrothion; these are contained in Table 2.2. This table is based on data collected following a morning spray. Spraying takes place both in the morning and in the evening to take advantage of the calm created by temperature inversions during these periods. Although not discussed in the literature, a similar pattern probably exists for evening

Table 2.2 Sub-Canopy Fenitrothion Vapor Inhalation Exposure (1)

Period After Spray (hours)	Vapor Exposure (micro gr./kg/bw.) Distance (meters) (2)				
	Spray Line - 200	300	500	700	1000 (3)
0 - 1	.448	.307	.245	.205	.150
1 - 3	5.368	3.081	2.444	2.195	1.788
3 - 6	21.476	12.713	10.701	9.129	8.946
6 - 10	53.690	30.826	24.452	21.932	17.904
Total for 10 Hour Work Day	80.982	46.927	37.802	33.501	28.788

(1) based on inhalation rate of 29 litres per minute [NRCC 18979,1982,pg.74] for a 70 Kg person using measured sub-canopy fenitrothion vapour [LTR-UA-56,1980,pg.25.]

(2) weights were applied to figures at each distance to adjust the data to reflect values expected from operational multi-swath spraying (20 swaths). Original test results are based on 1 swath only. [LTR-UA-56,1980,pg.27]

(3) extrapolated by Crabbe et al. based on test data [LTR-UA-56,1980,pg.25]

spray, except for an initial lag of several hours. Other important features of this table include the fact that exposure was standardized to a 70 kg. person breathing at a rate of 29 litres per minute. This figure appears high when compared with amounts reported elsewhere but may accurately reflect exercise rates in exposed persons, and was used to retain consistency with what has been reported for aerosol inhalation in both exposure model estimates for aminocarb. Clinical investigators associated with the Newfoundland Medical Association used 20 liters in their estimates [NMAC,1979,pg.31] and Crabbe et al. used 6 liters on one occasion [Crabbe et al.,LTR-UA-56,1980,pg.i] and 10 litres on another [Crabbe et al.,LTR-UA-65,1983,pg.i]. Finally the Task Group of the International Commission on Radiological Protection used 21.75 litres per minute in their report [Brain et al.,1974,pg.8]. The data in Table 2.2 show clear trends. Vapor exposure decreases with distance and increases over time as ambient temperatures in the environment rise.

Very little DDT vapor is expected following spraying based on calculations using a formula for estimating vapor exposure reported in a National Research Council of Canada publication on the effects of aminocarb in the environment [NRCC 18979,1982,pg.76].

A more detailed coverage of the environmental and toxicological aspects of the New Brunswick Forestry Spray Programme is contained in Appendix I.

II. EPIDEMIOLOGICAL CONSIDERATIONS

A. Introduction

This study examined the full spectrum of cancer in relation to spruce budworm spraying within New Brunswick. A classification of sites of cancer was therefore needed to ensure an exhaustive and uniform coverage. Given the limits to the investigation imposed by the finite number of cases available for analysis, it was not feasible to examine all sites separately. The use of two different versions of the International Classification of Diseases (versions 8 and 9) during the period of ascertainment also required the grouping of certain topographical sites to ensure consistency and comparability. Furthermore, some cancers, such as sarcomas, lymphomas, and leukemias, can arise in different topographical sites though they may have the same causes. A method of classification that used both topographic and morphologic information was therefore developed for use in the main body of the analysis.

Other studies investigating cancer/pesticide associations have used different site groupings. The epidemiologic literature dealing with cancer and pesticide exposure was reviewed to establish a context for this study and identify sites or site groupings with elevated risk estimates for which estimates would be unavailable within the site grouping used for this study.

B. The Epidemiological Literature

Table 2.3 lists the 40 articles chosen from the literature and used as the source of relative risk estimates for cancer/pesticide associations. The periods of observation range between 1935 and 1986, and while the majority are from the United States, populations from many other countries are also represented. Sixteen of the studies used incidence data and 60% used mortality data. This table also serves as the reference key for all subsequent tables and citations in this section.

Two hundred and eighty eight relative risk estimates were obtained from the 40 articles in Table 2.3 and characterized in terms of such information as the site, exposure, population studied (male, female, or both), number of cases for each site, and confidence intervals. All sites were classified using a standard format supplied by D. Wigle of the Laboratory Centre for Disease Control, Health and Welfare Canada (Appendix II).

Table 2.4 lists the results of the studies reviewed in terms of negative, null, or positive relative risk estimates cross-classified by site and population studied (male, female, or both). Studies with relative risk point estimates of 0.95 - 1.05 were classified as null; those less than 0.95 were classified as negative; those greater than 1.05 as positive. A few studies only reported the direction

Table 2.3 List of Cancer/Pesticide Articles Reviewed

Reference	Place	Period	Type of Data
1. [Alavanja et al.,1987]	Sweden	1961-1979	incidence
2. [Austin et al.,1987]	USA	NA	incidence
3 [Axelson et al.,1980]	Sweden	1957-1978	mortality
4 [Barthel,1981]	German Democratic Republic	1948-1972	mortality
5 [Blair et al.,1983]	Florida	1965-1966	mortality
6 [Blair et al.,1979]	Nebraska	1957-1974	mortality
7 [Blair et al.,1980]	USA	1968-1976	mortality
8 [Brinton et al.,1984]	North Carolina/Virginia	1970-1980	incidence
9. [Brownson et al.,1988]	Missouri	1984-1986	incidence
10 [Burmeister et al.,1983]	Iowa	1964-1978	mortality
11 [Burmeister et al ,1982]	California	1971-1978	mortality
12 [Cantor et al.,1980]	USA	1950-1975	mortality
13 [Cantor et al.,1982]	Wisconsin	1968-1976	mortality
14 [Delzell et al.,1985]	North Carolina	1976-1978	mortality
15 [Eriksson et al.,1981]	Sweden	1974-1978	incidence
16 [Fasal et al.,1968]	USA	1969-1970	mortality
17 [Gallagher et al.,1984]	Canada	1950-1978	mortality
18 [Gold et al ,1979]	Baltimore	1965-1975	incidence
19 [Goldsmith et al.,1977]	California	1971-1972	mortality
20 [Hardell,1981]	Sweden	1978-1979	incidence
21 [Hearn et al.,1984]	Michigan	1957-1979	mortality
22 [Linet et al.,1987]	Baltimore	1975-1982	Incidence
23 [Mclaughlin et al.,1988]	Sweden	1961-1979	incidence
24 [Milham,1971]	Oregon, Washington	1950-1967	mortality
25 [Morgan et al.,1980]	USA	1967-1978	mortality
26 [Musicco et al.1982]	Milan, Italy	1979-1980	incidence
27 [Notkola et al.,1987]	Finland	1979-1983	mortality
28 [Olson et al.,1987]	Denmark	1970-1979	incidence
29 [Pearce et al.,1986]	New Zealand	1979-1983	incidence
30 [Pearce et al.,1985]	New Zealand	1977-1981	incidence
31 [Priester et al.,1974]	USA	1950-1969	mortality
32 [Schumacher,1985]	Utah	1967-1982	mortality
33 [Steinhagen et al.,1983]	New Jersey	1975-1980	incidence
34 [Thomas et al.,1986]	New Jersey, Philadelphia	1978-1981	mortality
35 [Wang et al ,1979(b)]	USA	1946-1976	mortality
36 [Wang et al ,1979(a)]	USA	1967-1976	mortality
37 [Wicklund et al.,1988]	Washington	1968-1980	mortality
38 [Williams et al.,1977]	USA	NA	incidence
39 [Wong et al ,1984]	Michigan	1935-1976	mortality
40. [Zagraniski et al.,1986]	Connecticut	1975-1980	incidence

NA not available

Table 2.4 Relative Risk Estimates From the Literature by Site and Type of Association

Site	Negative	Null	Positive
All Cancer	11(m),16(f),16(m),25(m), 27(m),35(m),36(m)	1(m),27(m),31(f), 31(m),39(m)	3(m),5(m),21(b),25(m)
Bladder (urinary)	14(m),28(f),28(m),38(m)	7(m)	1(m),5(m),36(m),39(m)
Urinary Organs			28(f),28(m)
Brain	1(m),14(m),34(m)		18(b),26(b)
Brain and Other Nervous System			5(m),38(f),38(m)
Breast	38(f)	28(f)	28(m),38(m)
Trachea, Bronchus, Lung, and Other	38(m)		3(m),4(m),5(m),39(m)
Buccal Cavity and Pharynx	14(m)		5(m),28(f),28(m),39(m)
Esophagus	1(m),14(m),28(m)	17(m),38(m)	28(f)
Larynx	28(m),38(m)	17(m)	5(m),28(f),40(m)
Mouth			38(m)
Nose and Sinuses		28(m)	8(b),28(f)
Pleura	28(f),28(m)		
Respiratory	1(m),37(m)		5(m),21(b),39(m)
Tongue, Mouth, and Pharynx	17(m)		
Bronchus and Lung	14(m),17(m),28(f), 28(m),36(m)		35(m),36(m)
Cervix Uteri	38(f)		28(f),31(f)
Corpus Uteri			38(f)
Female Genital		28(f)	
Ovary, Fallopian Tube, Broad Ligament			31(f),38(f),
Colon (excluding rectum)	5(m),14(m),17(m),39(m)		1(m),20(m),38(f),38(m)
Large Intestine and Rectum		28(m)	28(f)
Rectum and Rectosigmoid Junction	1(m),38(m)	5(m)	39(m)
Digestive Organs	5(m),35(m),36(m),39(m)		
Stomach	38(m),39(m)	1(m),14(m)	3(m),5(m),10(m),17(m),28(f),28(m)
Gallbladder	28(m)		28(f),38(f)
Liver	5(m),28(m)	2(b)	1(m),2(b),28(f),33(m)
Liver and Gallbladder			1(m)
Hodgkin's Disease	1(m),14(m),16(f)	31(f)	16(m),24(m),28(f),28(m),(31(m),38(m)
Lymphoid	30(m)		20(m),30(m)
Lymphosarcoma	19(m)	19(m)	19(m)
Lymphosarcoma and Reticulum Cell Sarcoma	16(f),16(m)		
Lymphatic and Hematopoietic Neoplasms	25(m),35(m)		39(m)
Non-Hodgkin's Lymphomas	28(f)	14(m),31(f),31(m)	1(m),10(m),12(b),13(m),24(m) 28(m),32(m)
Reticulum Cell Sarcoma	24(m)		
Soft-Tissue Sarcoma			15(m),20(m)
Leukemias	1(m),14(m),29(m),38(m)		5(m),6(m),28(f),28(m),29(m) 38(f),39(m)
Lymphatic Leukemia	22(b)	17(m),22(b), 31(f),31(m)	16(f),16(m),24(m)
Multiple Myeloma	14(m)	16(f),16(m)	1(m),10(m),23(m),24(m)
Myeloid Leukemia			28(f),28(m)
Other and Unspecified Leukemia	28(f)		28(m),38(m)
Malignant Melanoma	28(m)	28(f)	14(m)
Other Skin	1(m),28(f),28(m)		5(m),14(m),25(m),36(m)
Kidney	5(m),28(m),38(m)	28(f)	1(m)
Pancreas	1(m),14(m),24(m)	5(m),28(m)	17(m),28(f),38(f),38(m)
Prostate	1(m),5(m)		9(m),10(m),14(m),17(m),28(m),38(m)
Testis			28(m),38(m),39(m)

(m) Males; (f) Females; (b) Males and Females

of the effect (negative, null, or positive). While the results from these studies, viewed in this manner, appear inconsistent, the following sites appear to merit closer attention:

a) Brain and other nervous system;
b) Trachea, bronchus, lung and other;
c) Buccal cavity and pharynx;
d) Mouth;
e) Multiple myeloma;
f) Non-Hodgkins lymphoma;
g) Prostate;
h) Testis.

Single studies that included multiple sites and multiple pesticide exposure estimates sometimes showed negative, null, and/or positive results.

Table 2.5 provides more detailed information. Six of the 47 sites listed in this table have maximum relative risk estimates of 1.0 or less. Many of the estimates, however, are based on small numbers. Of the 41 sites with maximum relative risks greater than 1.0, 10 have minimum risk estimates that exceed 1.0. Of these 10, the following 3 are present in the previous list:

i) Brain and other nervous system;
ii) Mouth;
iii) Testis.

Table 2.5 Comparison of Selected Risk Estimates From the Literature by Site of Cancer for all Pesticide Exposures

Site	Lowest Estimate				Highest Estimate			
	Citation	Confidence Limits	Cases	RR	RR	Cases	Confidence Limits	Citation
All Cancer	25.	NA	(13)	0.7	2.2	(15)	NA	5
Bladder (urinary)	38.	NA	(6)	0.7	3.0	(2)	NA	36.
Urinary Organs	28.	0.7 - 2.2	(11)	1.2	1.3	(4)	0.5 - 3.6	28
Brain	14.	0.4 - 1.2	(17)	0.7	5.0	(47)	NA	26
Brain and Other Nervous System	38.	NA	(1)	1.7	50.8	(1)	NA	38
Breast	38.	NA	(6)	0.5	1.7	(1)	NA	38
Trachea Bronchus Lung and Other	38.	NA	(15)	0 8	1.8	(50)	NA	4
Buccal Cavity and Pharynx	14.	0.6 - 1.1	(31)	0.8	1.8	(11)	1.0 - 3 2	28
Esophagus	14.	0.3 - 0.8	(15)	0.5	1.4	(3)	0.5 - 4 4	28
Larynx	38.	NA	(1)	0.4	2.9	(7)	0.8 11 2	40
Mouth	38.	NA	(8)	2.0	2.0	(8)	NA	38
Nose and Sinuses	28.	0.3 - 3 0	(3)	1.0	2.5	(2)	0.6 - 9 8	28
Pleura	28.	0.1 - 6.1	(1)	0.9	0.9	(4)	0.3 2 4	28
Respiratory	1.	0.7 - 1.4	(32)	0 8	1.9	(5)	NA	21
Tongue Mouth and Pharynx	17.	0.1 - 2.1	(2)	0.6	0.6	(2)	0.1 2 1	17.
Bronchus and Lung	28.	0.4 - 0.9	(23)	0 6	1.3	(12)	0.7 2 3	35
Cervix Uteri	38.	NA	(2)	0 3	1.2	(11509)	NA	51
Corpus Uteri	38.	NA	(4)	2 3	2.3	(4)	NA	38
Female Genital	28.	0.8 - 1.2	(85)	1 0	1.0	(85)	0.8 1 2	28
Ovary Fallopian Tube Broad Ligament	31.	NA	(8776)	1.1	1.4	(1)	NA	38
Colon (excluding rectum)	39.	0.1 - 3.3	(1)	0.6	1.8	(154)	0.6 - 5 3	20
Large Intestine and Rectum	28.	0.9 - 1.2	(141)	1.1	1.2	(72)	0.9 - 1.5	28.
Rectum and Rectosigmoid Junction	38.	NA	(6)	0.8	1.6	(1)	0.2 - 8 9	39.
Digestive	36.	NA	(1)	0 2	0.9	(7)	0.4 - 1.7	35
Stomach	38.	NA	(4)	0.5	4.2	(3)	NA	5.
Gallbladder	28.	0.3 - 1.4	(5)	0 6	7.4	(1)	NA	38
Liver	28.	0.4 - 1.5	(9)	0.8	2.4	(10)	1.1 4 4	1.
Liver and Gallbladder	1	1.0 - 3.0	(14)	1 8	1.8	(14)	1.0 3 0	1
Hodgkin's Disease	16.	NA	(316)	0 5	1.7	(6)	0.8 5 8	28
Lymphoid	30.	0.0 - 1.4	(1)	0.2	5 5	(4)	1.5 20 9	30
Lymphosarcoma	19.	NA	(7)	0.4	2.5	(36)	NA	19
Lymphosarcoma and Reticulum Cell Sarcoma	16.	NA	(981)	0.8	0.9	(715)	NA	16
Lymphatic and Hematopoietic Neoplasms	25.	NA	(4)	0.3	1.3	(3)	0.3 - 5.7	39.
Non-Hodgkin's Lymphomas	28.	0.3 - 1.5	(5)	0.6	2.6	(59)	0.8 - 8 3	13.
Reticulum Cell Sarcoma	24.	NA	(7)	0.8	0.8	(7)	NA	24
Soft-Tissue Sarcoma	15.	1.3 - 8.1	(11)	3.3	6.8	(14)	2.6 - 17.3	15
Leukemias	29.	0.1 - 2 6	(2)	0.4	3.0	(9)	1.2 - 7 3	29
Lymphatic Leukemia	22.	0.3 - 1.8	(8)	0.7	1.4	(237)	NA	24.
Multiple Myeloma	14.	0.7 - 1.2	(24)	0.9	1.8	(60)	NA	24
Myeloid Leukemia	28.	1.1 - 2.6	(20)	1.7	1.7	(8)	0.9 - 3 4	28
Other and Unspecified Leukemia	28.	0.7 - 1.0	(158)	0.9	2.2	(1)	NA	38
Malignant Melanoma	28.	0.4 - 1.1	(16)	0.7	1.2	(24)	0.6 - 2 6	14
Other Skin	28.	0.6 - 1.1	(37)	0.8	5.7	(4)	NA	25
Kidney	5.	NA	(1)	0.5	1.1	(15)	0.6 - 1.9	1.
Pancreas	1.	0.3 - 1.3	(9)	0.7	4.2	(1)	NA	38.
Prostate	5.	NA	(2)	0.5	1.7	(7)	0.6 - 4.6	9.
Testis	28.	0.8 - 1.4	(47)	1.1	3.9	(1)	0.5 - 21.8	39

NA not available

Of the articles reviewed, seven contained relative risk estimates for brain or brain and nervous system cancers (1,5,14,18,26,34,38). While none of these were statistically significant or had relative risks that excluded 1.0, four of the studies contained estimates that were greater than 1.7 (5,18,26,38).

The evidence pertaining to mouth cancer is much weaker insofar as only one estimate was available from the literature (38) and another grouping of sites that included mouth had a relative risk estimate of 0.58 (17).

1. Detailed Cancer Site Examination

A closer examination of c), f), and g) from the first list of sites that appeared to merit closer attention indicates that of the five estimates available for buccal cavity and pharynx listed in Table 2.4 (5,14,28(f),28(m),39) all except one (14) range from 1.25 to 1.77.

Two of the eleven non-hodgkin's lymphoma relative risks reviewed were positive and statistically significant (10,12). Seven of the remaining nine relative risks were between 1.23 and 2.6 (1,10,13,24,28(f),28(m),32) with the number of cases ranging between 10 and 1101.

Eleven relative risk estimates were available for prostate cancer, of which three were both positive and statistically significant with relative risks estimates of 1.2, 1.4, and 1.5 (10,9(m),9(m)).

Cancer of the testis was dropped from further consideration as the only estimate based on more than one observation had a relative risk of 1.06 (28); just above the criterion for a positive association. A closer examination of the literature for multiple myeloma revealed that three of the four positive relative risks reported were statistically significant (23(M),10(M),24(M)).

Based on the examination of Table 2.5 the following additional sites were examined in greater detail:

a) Urinary;
b) Corpus uteri;
c) Liver and gallbladder;
d) Soft-tissue sarcoma;
e) Myeloid leukemia.

The rubric "urinary" includes cancers of both kidney and urinary bladder. Three of the five kidney relative risk estimates listed in Table 2.4 were between 0.5 and 0.6 (5,28,38). The nine relative risk estimates available for bladder cancer ranged between 0.7 and 3.0 [1,5,7,14,28(m), 28(f),36,38,39]. In general, the risk estimates above 1.0 were based on small numbers (1,5,36,39). Only two estimates for urinary cancer are available from the literature reviewed and both come from the same study (28). The estimates reported were 1.21 (N=11) and 1.34 (N=4).

Cancer of the corpus uteri is contained within two rubrics (corpus uteri, female genital) in Table 2.4 and only one estimate is available for each. The estimate for corpus uteri is 2.28 (N=4) and 1.02 (N=85) for female genital.

Although based on larger numbers, less weight is placed on the estimate for female genital as it is a broad rubric containing the following sites of cancer: corpus uteri; cervix uteri; chorionepithelioma; ovary, fallopian tube, and broad ligament; other and unspecified female genital organs.

The combined rubric of liver and gallbladder is represented in the literature reviewed by seven relative risk estimates for liver (1,2(b),2(b),5,28(m),28(f),33), three for gallbladder (28(m),28(f),38) and one for liver and gallbladder combined (1). Of the eleven risk estimates two were significantly positive for liver: 1.9 (33) and 2.4 (1) with confidence intervals of 1.2 to 3.0 and 1.2 to 4.4 respectively. Of the remaining nine, six were greater than 1.0 and five were below 1.0.

Sarcomas are widely distributed across many sites, most notably bone, connective tissue, brain and other nervous system, genital in females, and testis in males. Soft-tissue sarcomas, in particular, are difficult to characterize using the site based International Classification of Diseases. The connective tissue rubric 171 (ICD-9), where many of the soft-tissue sarcomas appear, is incomplete in its coverage of these cell types. For this reason risk estimates for these tumours are rarely available from ecological studies. Four estimates were obtained from the literature and all four were positive and significant. Estimates range between 3.3 and 6.8 (15,20).

Of the 24 risk estimates available for rubrics containing myeloid leukemia, two are for myeloid leukemia specifically. Both estimates are positive (1.69,1.72) with one having a confidence interval of 1.2 - 2.6 (28). Eighteen of the remaining 22 are positive with relative risks of 1.1 - 3.0 and five (6,28(m),28(f),29(m),29(f)) have confidence intervals that exclude 1.0.

2. Pesticide Exposures in the Literature

Pesticide exposure can and has been defined and quantified in many different ways. Appendix III lists some of the terms used in the literature to describe exposures. While in the majority of cases it is not possible to isolate specific pesticide exposures, the terms were grouped into four broad categories in order to highlight important differences in exposure intensity and cancer risk. For example, farming occupation and other variables related to farming activity are frequently used as proxies for pesticide exposure. While the probability of pesticide exposure among farmers is probably much higher than among most other segments of the population, farmers are also exposed to many other chemical agents such as machine and fuel oils, fertilizers, and infectious agents in animal populations. Correlates of farming activity such as crop acreages have also been used as estimates of population exposure to pesticides.

Tables 2.6 through 2.9 present relative risk estimates from the literature classified within each of the following types:

a) Forestry and agricultural occupations;
b) Farming occupations;
c) Occupational exposure to pesticides other than farming forestry or agriculture;
d) Other miscellaneous pesticide exposures.

These tables contain the same information as in previous tables except that the risk estimates are examined by the type of exposure for which they were reported. As in previous tables, single studies often report many relative risk estimates for a variety of exposure/site/sex combinations. It is therefore possible for the same study to provide lowest and highest relative risk estimates for a given site.

The category forestry and agriculture is a broad industrial classification used by a few studies. Because potential risks in forestry and agriculture are so different, this category was not combined with farming. The farming category includes studies of both farming as an occupation and correlates of farming activity. The "occupations other than farming forestry or agriculture" category contains the results of studies of populations that wereexposed to pesticides through their work. Of all the categories, the results contained within the occupational group are most likely to be associated with pesticide

Table 2.6 Relative Risks From the Literature by Site of Cancer for Forestry and Agricultural Occupations

Site	Lowest Estimate				Highest Estimate			
	Citation	Confidence Limits	Cases	RR	RR	Cases	Confidence Limits	Citation
Brain	34.	0.4 - 1.8	(718)	0.8	0.8	(718)	0.4 - 1.8	34.
Buccal Cavity and Pharynx	28.	1.1 - 1.9	(51)	1.5	1.8	(11)	1.0 - 3.2	28.
Non-Hodgkin's Lymphomas	28.	0.3 - 1.5	(5)	0.6	1.2	(28)	0.9 - 1.8	28.
Prostate	28.	0.9 - 1.4	(97)	1.1	1.1	(97)	0.9 - 1.4	28.
Liver	28.	0.4 - 1.5	(9)	0.8	1.7	(6)	0.8 - 3.9	28.
Gallbladder	28.	0.3 - 1.4	(5)	0.6	2.2	(14)	1.3 - 3.7	28.
Leukemias	29.	0.1 - 2.6	(2)	0.4	1.6	(30)	1.1 - 2.3	28.
Multiple Myeloma	1.	0.6 - 2.9	(7)	1.4	1.4	(7)	0.6 - 2.9	1.
Myeloid Leukemia	28.	1.1 - 2.6	(20)	1.7	1.7	(8)	0.9 - 3.4	28.

Table 2.7 Relative Risks From the Literature by Site of Cancer for Farming Occupations

Site	Lowest Estimate				Highest Estimate			
	Citation	Confidence Limits	Cases	RR	RR	Cases	Confidence Limits	Citation
Brain	14.	0.4 - 1.2	(17)	0.7	5.0	(47)	NA	26.
Brain and Other Nervous System	38.	NA	(1)	1.7	50.8	(1)	NA	38.
Buccal Cavity and Pharynx	14.	0.6 - 1.1	(31)	0.8	0.8	(31)	0.6 - 1.1	14.
Non-Hodgkin's Lymphomas	NA	NA	NA	NA	2.6	(59)	0.8 - 8.3	13.
Prostate	17.	0.8 - 1.5	(40)	1.1	1.7	(7)	0.6 - 4.6	9.
Liver	33.	0.5 - 3.0	(8)	1.2	2.4	(10)	1.1 - 4.4	1.
Liver and Gallbladder	1.	1.0 - 3.0	(14)	1.8	1.8	(14)	1.0 - 3.0	1.
Gallbladder	38.	NA	(1)	7.4	7.4	(1)	NA	38.
Leukemias	38.	NA	(2)	0.6	3.0	(9)	1.2 - 7.3	29.
Multiple Myeloma	14.	0.7 - 1.2	(24)	0.9	1.8	(60)	NA	24.

NA not available

Table 2.8 Relative Risks From the Literature by Site of Cancer for Occupational Exposure to Pesticides Other Than Farming, Forestry, or Agriculture

Site	Lowest Estimate				Highest Estimate			
	Citation	Confidence Limits	Cases	RR	RR	Cases	Confidence Limits	Citation
Brain and Other Nervous System	5.	NA	(5)	2.0	2.0	(5)	NA	5
Buccal Cavity and Pharynx	5.	NA	(3)	1.3	1.5	(1)	0.2 - 8.2	59.
Prostate	5.	NA	(2)	0.5	0.5	(2)	NA	5
Liver	5.	NA	(1)	0.8	0.8	(1)	NA	5.
Leukemias	5.	NA	(4)	1.3	2.1	(2)	0.2 - 7.6	59
Multiple Myeloma	23.	NA	(23)	1.1	1.1	(23)	NA	23

NA not available

Table 2.9 Relative Risks From the Literature by Site of Cancer for Other Miscellaneous Pesticide Exposures

Site	Lowest Estimate				Highest Estimate			
	Citation	Confidence Limits	Cases	RR	RR	Cases	Confidence Limits	Citation
Brain and Other Nervous System	5.	NA	(5)	2.0	2.0	(5)	NA	5.
Buccal Cavity and Pharynx	5.	NA	(3)	1.3	1.5	(1)	0.2 - 8.2	39.
Prostate	5.	NA	(2)	0.5	0.5	(2)	NA	5.
Liver	5.	NA	(1)	0.8	0.8	(1)	NA	5.
Leukemias	5.	NA	(4)	1.3	2.1	(2)	0.2 - 7.6	39.

NA not available

exposure. The final category, other specific pesticide exposures, groups the remaining results that do not fit into any of the previous three categories.

Table 2.10 permits the comparison of results across categories. There is a noticeable degree of consistency in the results across categories; most notably for the leukemias.

C. Conclusions

The results available in the literature for cancer/pesticide associations are inconsistent. The following subset of "suspect" sites has been identified through a systematic examination of 288 relative risk estimates from 40 studies:

a) Brain and other nervous system;
b) Buccal cavity and pharynx;
c) Non-Hodgkins lymphoma;
d) Prostate;
e) Liver and gallbladder;
f) Soft-tissue sarcoma;
g) Myeloid leukemia;
h) Leukemia (excluding myeloid);
i) Multiple Myeloma.

Results for these sites have been found to be fairly consistent across a number of broad exposure categories. Given the generally low precision with which pesticide exposure has been estimated, the identified sites are those for which the prior evidence is strongest.

Table 2.10 Highest Relative Risks by Site of Cancer and Exposure Category

	All		Agriculture/Forestry		Farming		Occupational		Other (1)	
Brain	5.0	(47)	0.8	(718)	5.0	(47)	NA	NA	2.3	(19)
Brain and Other Nervous System	50.8	(1)	NA	NA	50.8	(1)	2.0	(5)	NA	NA
Buccal Cavity and Pharynx	1.8	(11)	1.8	(11)	0.8	(31)	1.5	(1)	NA	NA
Non-Hodgkin's Lymphomas	2.6	(59)	1.2	(28)	2.6	(59)	NA	NA	NA	NA
Prostate	1.7	(7)	1.1	(97)	1.7	(7)	0.5	(2)	NA	NA
Liver	2.4	(10)	1.7	(6)	2.4	(10)	0.8	(1)	2.1	(11)
Liver and Gallbladder	1.8	(14)	NA	NA	1.8	(14)	NA	NA	NA	NA
Gallbladder	7.4	(1)	2.2	(14)	7.4	(1)	NA	NA	NA	NA
Soft-Tissue Sarcoma	6.8	(14)	NA	NA	NA	NA	NA	NA	6.8	(14)
Leukemias	3.0	(9)	1.6	(30)	3.0	(9)	2.1	(2)	1.2	(433)
Multiple Myeloma	5.4	(1)	1.4	(7)	1.8	(60)	1.1	(23)	NA	NA
Myeloid Leukemia	1.7	(8)	1.7	(8)	NA	NA	NA	NA	NA	NA

(1) other miscellaneous pesticide exposures

NA not available

CHAPTER III

METHODS

I. BACKGROUND

Spruce budworm spray exposure and its possible effects on human health has been a source of concern to New Brunswickers for several decades, but attempts to address these concerns have been difficult for the following reasons:

a) spraying has been carried out over a long period of time;
b) the areas sprayed vary from year to year;
c) different spray compounds have been used within and across years;
d) the geographic distribution of the population vis-à-vis its proximity to spraying is difficult to establish;
e) data on geographic distribution of health events within the population are imprecise.

An important practical goal of this study was to obtain the highest quality data available on exposure and cancer incidence and to manipulate them in a such a way as to preserve their detail while also permitting the examination of their joint geographic distribution. Superficially, the geographical representation of incidence data is incompatible with that of budworm spraying within the province. Spray data were available only in the form of maps while the geographical reporting of cancer incidence was by municipality.

The preparation and linkage of these data required the acquisition and manipulation of many types of geographical data. A brief description of these follows.

The population of New Brunswick, approximately 695,000 persons, resides within an area of 696,403 square kilometers [Stats Canada E-562,1982]. There are thousands of settlements within New Brunswick in which people live and for which official names are recorded [CPCGN,1972]. In 1981, Statistics Canada identified 1,597 of these along with their populations [Stats Canada 94-902,1983]. These settlements are classified under the general rubrics of incorporated and unincorporated places and were used as the basis for developing spray exposure scores.

Most of the settlements (places) within New Brunswick are non-incorporated, and these contain approximately one third of the population [Allen et al.,1976]. Settlements vary greatly in both population size and the range of services provided. Incorporated settlements such as towns, villages, and cities have local governments that are legally responsible for the planning and provision of a broad range of services that affect the safety and quality of life within their boarders. In non-incorporated places these services are provided by the provincial government.

All incorporated places are uniquely identified in the Standard Geographic Classification (SGC) developed by Statistics Canada [Stats Canada 12-567,1982]. Indian Reservations are also identified in this manner. The

remaining, non-incorporated, settlements of New Brunswick are grouped together within large geographically defined areas referred to as parishes. All non-incorporated places within the same parish therefore share the same SGC. The 1981 Standard Geographic Classification recognized 285 towns, villages, cities, Indian reservations, and parishes within New Brunswick. These geographical units are frequently referred to generically as municipalities or census subdivisions.

These 285 municipalities, and aggregations of them, are the basic units of geography used here for the calculation of risk. Municipalities can be grouped into large geographic territories for mapping purposes. The Census Consolidated Subdivision (CCS) is used for this purpose. The Census of Agriculture frequently uses the CCS as the basis for its reporting of statistical data. CCS's are made up of geographically contiguous Census Subdivisions [Stats Canada 12-567,1982,pg.24]. The following rules are applied by Statistics Canada in defining a CCS:

a) "all census subdivisions smaller than 25 square kilometers are grouped with a larger subdivision"

b) "if a census subdivision greater than 25 square kilometers is surrounded on more than half its perimeter by another subdivision, it is included as part of the CCS formed by the other subdivision; if not the census subdivision forms a CCS on its own."

The geographic limits for most CCS's within New Brunswick correspond to those of parishes but contain those towns, villages and cities enclosed within their limits. In rare cases a single CCS represents the merger of 2 or more parishes and in the case of certain large cities such as Saint John, a city may itself be a CCS. In 1981 there were 153 CCS's within New Brunswick. Also in 1981, for the first time, the Census of Agriculture used the same definitions of CCS's as the Census of the Population.

Finally, Census Districts represent the largest geographic units within provinces. New Brunswick has 15 Census Districts.

In summary, New Brunswick is divided into 285 non-overlapping geographic units (some of which are the non-town residuals of parishes). These are collapsed by geographic contiguity into 153 Census Consolidated Subdivisions, which are further collapsed into 15 Census Districts. However, the data for the 285 smallest units are available individually and can be pooled on bases other than geographical contiguity.

II. DATA SOURCES

A. Spruce Budworm Spraying and Population Settlement Patterns Within New Brunswick

1. Spruce Budworm Spray Maps: 1952-1983; Data Sources, Content, and Quality

Maps indicating the location of areas sprayed for spruce budworm during the 32 year period 1952 through 1983 were obtained from two sources. Forest Protection Ltd. (FPL), which has administered New Brunswick's spray programme since the programme's inception in 1952, supplied 32 maps (scale 1:500,000) which covered all of its operational spray activities during that period. J.D. Irving Ltd., a privately owned corporation, has operated its own spray programme since 1971. These operations occurred over portions of freehold land that was not designated to be sprayed by FPL. The data from these combined sources is estimated to account for more than 98% of the total area of New Brunswick sprayed from 1952 through 1983, inclusive.

A second source of budworm spraying, not contained in these data, include spray trials conducted by the Forest Pest Management Institute (Canadian Forestry Service) in collaboration with FPL. These trials involve the use of new formulations and typically involve forest areas of 50 to 5,000 hectares, generally located in areas remote from human

settlement. These trials include operations against the budworm moth in 1973 and 1974.

The supplied maps were silk-screened summaries of the flight plan maps used during spray application. The maps contained legends that identify the pesticide formulation(s) used in a particular year. I developed a coding system to classify:

a) the active ingredient;
b) the carrier (oil, water, or other solvent);
c) the number of applications.

The coding system also indicates where the same pesticide formulation was applied repeatedly and where different formulations were applied to the same area in a given year. In all there are 27 unique codes within the exposure data base (See Appendix IV). All spray maps were coded twice by me and all detected errors were corrected.

2. Settlement Patterns Within New Brunswick; Data Sources, Content and Quality

Statistics Canada produces provincial listings of non-incorporated and incorporated places with their populations. In 1981 it published its Place Name Reference List [Stats Canada 94-902,1983] with population information on 1,587 settlements within New Brunswick. According to sources within Statistics Canada, for reasons of confidentiality, population data for places with 5 or fewer permanent dwellings are not published. This exclusion applies to

approximately 12% of the total New Brunswick population and is concentrated solely within the parishes. The effect of this exclusion on exposure estimation will be discussed in detail later.

Geographic coordinates (Lambert) to the nearest minute were obtained for each of the 1,581 New Brunswick settlements from the Gazetteer of Canada for New Brunswick [CPCGN,1972]. These coordinates identify the approximate physical center of each settlement except where a central point of human activity is identifiable, such as a town center or a community hall [Energy, Mines, and Resources; personal communication,1984]. Close examination of 1:50,000 scale maps showing the location of buildings indicates that the degree to which these coordinates approximate the center of human habitation varies a great deal from settlement to settlement.

While Statistics Canada also publishes a set of coordinates that are designed to reflect the centers of settlements, these are of low precision for unincorporated settlements. This is because enumeration areas, which are the smallest geographic units within the census, frequently encompass many small settlements. The coordinates reported for these settlements are those calculated for the enumeration area as a whole. This fact is incorrectly documented in some Statistics Canada publications and results in substantial distortion in the geographic situation of these small settlements.

3. Integration of Spray Data and Settlement Patterns; Methods and Quality

Detailed instructions on the coding of the spray maps were supplied to Maritime Resource Management Services (MRMS) for the purposes of computerizing the spray maps.

MRMS produced a data base which contains the following:

a) the spray year;
b) the distance in kilometers between the point defined by the coordinates of each of the settlements and the closest point on the margin of each spray area within a 100 kilometer radius;
c) the name and 1981 population of each settlement;
d) the geographic coordinates of each settlement;
e) the true compass bearing from each spray area within 100 kilometers of each settlement;
f) the area of each spray block in hectares.

In order to evaluate the quality of the work done by MRMS, the data for one year were verified. The 1965 spray year was chosen for this purpose because spraying that year was sufficiently extensive and complex to permit the identification of problems related to the process of digitization. The geographic location of a sample of settlements with the following characteristics were chosen as part of this process:

a) settlements within spray areas;
b) settlements situated outside of spray areas but within 10 kilometers of at least 1 spray area;
c) settlements beyond 100 kilometers from any spray block.

Distances and bearings were calculated and all comparisons were found to be in agreement and the precision with which distances were calculated did not vary as a function of the distance between settlements and the margins of surrounding spray areas. All formulation codes for the areas examined were also in agreement.

B. Cancer Data 1977-1980

The Province of New Brunswick collects data on human cancers from pathology reports, X-ray reports, consultations submitted to radiation oncologists at Saint John Regional Hospital, death certificates from the Provincial Department of Vital Statistics, and blood and cytology reports from Saint John Regional Hospital. Reporting to the registry is voluntary. No reports from hematology laboratories are received, and data pertaining to neoplasms of the blood and bone marrow are incomplete.

The Registry is housed in the Saint John Regional Hospital, which is the largest oncology referral centre in New Brunswick and has been in operation since 1952. This makes it one of the oldest cancer registries in Canada.

The New Brunswick Tumour Registry provided a computer tape containing case by case data for all reported cancers among New Brunswick residents for the period 1970 through 1980. Because the registry did not use Statistics Canada standard geographic codes prior to 1977, only 4 years of data could be used for this study (1977-1980). The 1971 and 1976 versions of the Standard Geographical Classification [Stats Canada,March 1972;Stats Canada,12556,1977] were used by the Tumour Registry during this period. The following data pertaining to the 12,288 cases recorded for the period 1977-1980 were obtained:

a) year of initial diagnosis;
b) age at time of diagnosis;
c) gender;
d) residential code (1971, 1976 Standard Geographical Classification);
e) site of cancer, coded to the International Classification of Diseases version 8 (1977-78) or version 9 (1979-80));
f) morphological classification of the tumour (Systematized Nomenclature of Pathology (SNOP) for 1977-78 or the International Classification of Diseases for Oncology (ICD-O) for 1979-80) including behaviour code;
g) basis for diagnosis (i.e., histological, cytological, X-ray, or clinical).

The 8th revision of the International Classification of Diseases [WHO,1968] was used by the Tumour Registry to code tumour topography for the years 1977-1978 while the 9th [WHO,1975] revision was used to code topography for 1979-1980. In order to insure compatibility of coding across

revisions for the cancer sites under investigation, a list of ICD codes cross-classified by site and revision was obtained from the Laboratory Centers for Disease Control (See Appendix II).

In 1977 and 1978 the Systematized Nomenclature of Pathology (SNOP) was used [CAP,1965] to classify tumours morphologically. In 1979 and 1980 the International Classification of Diseases for Oncology (ICD-O) [WHO,1976] was used. These classifications are compatible at the 3 digit level.

C. Data From the 1981 Census of the Population and Census of Agriculture

1. 1981 Census of the Population

Statistics Canada publishes many types of data for different levels of geographical aggregation. The levels of geographical aggregation chosen in this study were determined by the availability, at a given level, of population data cross-tabulated by sex and age and for which tumour registry cases could be similarly cross-tabulated. The municipality level was chosen as the smallest level for which all sources of data within the study could be rendered compatible.

Of the 285 municipalities, 260 were retained for analysis (See Appendix V) after the following modifications.

One municipality, Alma parish, (SGC81:607) was dropped as census data for 1981 indicated zero population and Tumour Registry data indicated no cases from this area. Another municipality, Clarendon parish (SGC81:214), was dropped as no places were reported for this parish and therefore no exposure data could be calculated. As in the case of Alma, no cases for this parish were reported by the Tumour Registry for the period 1977-1980. The 19 Indian reservations were merged into their surrounding municipalities due to the small size of their populations and the high frequency of data suppression by Statistics Canada for these units. This merger was carried out according to specifications supplied by the Federal Department of Vital Statistics (See Appendix VI) which has been routinely carrying out this procedure on mortality data since 1976. Finally, four towns were incorporated in 1981. According to the 1976 Standard Geographical Classification, residents of these municipalities were coded to the parishes within which these places were situated. Thus, resident cases could not be uniquely identified, and the municipalities were merged back into the parishes from which they arose:

a) Verret (SGC81:1330) merged into Madawaska (SGC81:1328);
b) Darlington (SGC81:1402) merged into Dalhousie (SGC81:1408);
c) Sheila (SGC81:1502) merged into Saumarez (SGC81:1501);

d) St. Leolin (SGC81:1517) merged into New Bandon (SGC81:1516).

Following initial data analysis all cities (N=6) were dropped. The justification for this decision can be found under the heading "Spray Exposure" in Chapter IV.

Population data, cross-tabulated by sex and 11 age group categories and their corresponding SGC codes, were obtained from Statistics Canada tabulations [Stats Canada E-562,1982] for each of the 254 retained non-city municipalities in order to calculate age standardized, sex specific cancer incidence rates (SIR) for each municipality within New Brunswick.

Data on potential confounders were also obtained in the following categories:

a. Language/Culture;
b. Education;
c. Income;
d. Urban/Rural Residence;
e. Migration.

Each of these categories was chosen to capture a specific dimension of human activity that may be related to health in general or to cancer in particular. In this sense each has the potential, independently of the others and of spray exposure, to influence the occurrence of cancer. These variables may also covary with spray exposure. As a group they fall within the general category of lifestyle variables. Occupation is not included in the analysis as a covariable. Adelstein [1980] found that control for social class, regional, and urbanization effects removed 94% of the

variation in cancer mortality between occupations. Others have also noted the importance and influence of "lifestyle factors" in occupational studies [Higginson,1980].

a. Language/Culture

Cultural or ethnic origin may affect health insofar as it encompasses a complex array of biological, behavioral and social factors that may influence susceptibility and other risk factors for disease. These factors are difficult to measure in the present context, but they are included in view of their possible importance.

Large cultural differences exist between English and French communities within New Brunswick. Language was chosen as the basis for estimating cultural differences. The number of persons reporting French as "the first language learned and still understood" (mother tongue) was obtained from Statistics Canada tabulations [Stats Canada E-562,1982] for each of the 254 non-city municipalities. Mother tongue was chosen over alternative measures such as the cultural group to which the respondent's ancestors belonged on first coming to this continent (ethnic origin) or the specific language spoken at home by the respondent at the time of the census (home language) as I felt it was more likely to reflect early and potentially more durable effects of culture. In addition, mother tongue, ethnic origin and home language are highly correlated.

The proportion of residents reporting French as their mother tongue was calculated for each of the 254 non-city municipalities. The distribution of these proportions was found to be U-shaped, with many communities having either low proportions of French or high proportions of French. Because few municipalities in the province had similar proportions of French and English, a dichotomous variable was created by cutting the distribution in half at the 50% point.

A further consideration was that when one culture dominates a community, any culture-related risk factors that operate on a community-wide basis will affect the non-dominant group as well. Thus cultural effects may be greater than linear in mixed communities.

b. Education

Education is correlated with income and occupation, but may act as an independent marker for additional factors associated with health behavior. For example persons who terminate their education before university or who receive technical training may not be as likely to be exposed to influences of those outside their class and or culture as those who attend university.

For each municipality, the proportion of persons who attended university (with or without degree) in the total population 15 years or older was calculated.

c. Income

An ecological study of socio-economic conditions and cancer mortality in men indicated that, among other variables, cancer mortality rates were higher than expected in areas where unemployment was high and where a high proportion of families lived in poverty [Jenkins,1983].

Of all the items available from the alternatives, the census includes several items related to poverty, such as the rate of unemployment, mean or median income, and percent of incomes below various standards. Given the seasonal nature of a large proportion of jobs within New Brunswick, labor force activity is unlikely to provide an accurate picture of income; mean income may be unduly affected by a few high values; and even medium income may have low correlation with severe economic distress. Percent low-income probably comes closest to capturing the concept of poverty.

Low-income cutoffs are based on estimates of the proportion of the total income of a family or unattached individual that is spent on food, clothing, and shelter. Data for the calculation of these cutoffs comes from the 1978 Family Expenditure Survey, updated according to changes in the Consumer Price Index (CPI). The CPI uses regression techniques to define income levels at which expenditures exceeded the average level by at least 20%. The effects of factors such as family size, region, and degree of

urbanization were considered in establishing average levels of expenditure [Stats Canada 8-3302-519,1983].

The following data were obtained from Statistics Canada tabulations for each of the 254 non-city municipalities retained for analysis:

a) the number of economic families [Stats Canada E-574,1983];
b) the number of low-income economic families [Stats Canada E-574,1983];
c) average number of persons per family of 2 or more persons [Stats Canada E-562,1982];
d) the number of unattached individuals [Stats Canada E-574,1983];
e) the number of low-income unattached individuals [Stats Canada E-574,1983].

The census reports low-income data separately for family units and for unattached individuals. The values for both types of units were combined into a single value in the following way. The number of low-income families within each municipality was multiplied by the average family size for that municipality. This value was added to the number of unattached persons to obtain an estimate of the total number of low-income persons. The number of families within each municipality was then multiplied by the average family size for that municipality and added to the total number of unattached persons to obtain the total number of persons. The estimated number of low-income persons within each municipality was then divided by the total number of persons in each municipality to obtain a single rate for each municipality. This procedure may introduce an error if low-

income families are, on average, larger or smaller than other families in that municipality. This error will affect the analysis here, however, only if the size of the error is seriously non-linear in percent below the chosen cutoff.

d. Urban/Rural Residence

The concept of urbanization has many facets, including population density and industrial development, that could confound associations between pesticide exposure and cancer.

Industrial contamination of the environment within New Brunswick is not necessarily concentrated in urban areas because forestry, the most important industry in the province, is fairly decentralized. Urbanization, however it is defined or measured, is likely to be a poor proxy for chemical pollution in New Brunswick.

Statistics Canada defines an urban area as an area with a population of at least 1000 persons and a population density of at least 384 persons per square kilometer. This simple definition based on density leads to some unusual situations in New Brunswick, where some relatively small populations inhabit small areas that do not conform to the usual concept of an urbanized center. Alternatively, the United States uses the criterion of 2500 or more inhabitants in an incorporated place to distinguish between urban and rural areas.

Approximately 53% of the 1981 population of New Brunswick live in settlements with populations of less than 2500 persons, while approximately 31% live in 6 cities ranging in size from 9818 to 80521. Therefore, unlike many other regions, there appears to be a fairly clear distinction between urban and rural settlements within New Brunswick. Municipalities with populations greater than 2500 were classified as urban in this study.

e. Migration

The numbers of persons "who on census day were residing in a different municipality within Canada than 5 years earlier" were obtained from Statistics Canada tabulations [Stats Canada E-574,1983] for each of the 254 municipalities retained for analysis. The potential influence of migration on cancer incidence involves both duration of exposure to agents in various environments, the association of repeated change of residence with certain lifestyle or socio-economic characteristics, and the effect of moving on case ascertainment and exposure estimation.

Historically, large migrations have been associated with environmental, social, or economic upheaval. To a smaller extent, these factors continue to influence migration patterns. For example Mancuso commented on the potential adverse health effects of the tendency for migrants to take undesirable jobs [1974]. Given the

relatively depressed economic conditions within New Brunswick, a high proportion of migrants may be young and jobless, and hence subject to a wide range of social, psychological, and economic stressors with direct or indirect effects on health.

Under ideal circumstances, cohorts of exposed and unexposed persons would be identified and followed forward in time, and cases of cancer would be identified within each cohort. Migration therefore would not affect membership in the cohort, and all cohort members would contribute to events used for the calculation of rates. No cohorts of this kind are identifiable within New Brunswick to evaluate the potential effects of budworm spray exposure on the occurrence of cancer. To the extent that out-migrants are replaced by in-migrants with similar cancer rates, the results of this study will approximate those of a cohort study, while net in or out-migration of high or low risk persons (whether or not these are associated with pesticide exposure) would bias the risk estimates.

The calculation of exposure scores uses weights that are proportional to the population size of each settlement. Given that this weight is intended to approximate average settlement size over the period of exposure, recent large in or out migration would also tend to distort exposure through its influence on settlement sizes.

Data on the proportion of the population of each municipality who were living in a municipality in 1981

different from the one they occupied in 1976 were obtained from Statistics Canada tabulations [Stats Canada E-574, 1983] and was used in fitted regression models.

f. Provincial Land Mass Data

The area of each of the 254 municipalities used in the analysis, in square kilometers, was obtained from Statistics Canada Tabulations [Stats Canada E-562,1982]. The areal measurements of the 19 Indian reservations were merged into the municipalities in which they were situated according to specifications supplied by the Federal Department of Vital Statistics (See Appendix VI).

2. 1981 Census of Agriculture

Statistics Canada provided special tabulations of the area of land under cultivation for crops in 1981 for each of 153 Census Consolidated Subdivisions (CCS), as reported within the 1981 Census of Agriculture [Stats Canada Special Tabulation,1983].

All municipalities were coded according to the CCS in which they were situated using the 1981 Standard Geographic Classification [Stats Canada 12-567,1982]. Total land area within each CCS and the proportion of land under crop cultivation were then calculated and assigned to all those municipalities within that CCS.

III. DEVELOPMENT OF SPRAY EXPOSURE MEASURES

A. Spruce Budworm Spray Pesticides

1. Introduction

While this study examines only the operational use of forestry insecticides, the use of herbicides within New Brunswick may also be of some concern in view of their reported association with soft-tissue sarcomas and malignant lymphomas [Hardell et al.,1979;Eriksson et al.,1981;Hardell et al.,1981;Hoar et al.,1986]. The exposure data base does not contain information on the use of forestry herbicides, but these are unlikely to seriously modify or confound the estimated effects of the exposures under study because of their method of application and their limited use. For example, herbicide spraying in forestry is usually carried out on the ground. The aerial application of herbicides began in the early to mid-seventies and is generally specific to privately owned coniferous plantations. Small areas sprayed with herbicides tend to be closer to areas of human settlement than other forms of forestry spraying. Other sources of operational exposure to herbicides include the ground-level spraying of highways, railways, and electrical rights of way.

2. Issues Pertaining to Quality of Data Used in the Calculation of Exposure Scores

All data pertaining to the geographical location of spray blocks within New Brunswick were taken from the 1:500,000 scale maps (i.e. 1 inch = 7.89 miles) supplied by Forest Protection Ltd. (FPL) and J.D. Irving Forest Products (JDI). The FPL maps were silk screened summaries of navigational maps used by the spray pilots, while those from JDI were in the form of xeroxed sheets from the same scale of maps and with the spray data more crudely represented. These are of less concern because of the small percentage and relatively remote location of the areas sprayed by JDI. Furthermore, JDI began spraying only in the early 1970's and one would expect the impact of this activity on cancer incidence during 1977-80 to be minimal.

The person who prepared the FPL summary maps estimated that the margins of FPL spray blocks are probably accurate within 1.6 kilometers. This estimate was subjective and based on his work in map preparation. An additional 0.2 kilometers of measurement error is associated with the process of computerizing (digitizing) the margins of the spray maps.

The geographic location of each settlement in New Brunswick, needed for distance calculations, was taken from the 1972 edition of the Gazetteer of Canada for New Brunswick [CPCGN,1972]. Even under ideal circumstances,

these coordinates are somewhat imprecise. For the process employed in determining these coordinates, the geographic limits of settlements were delineated and a point roughly approximating each area's physical center was assigned. The population of New Brunswick, which is highly rural, is not uniformly dispersed within most settlement areas. Even the larger settlements are often not nuclear, but extend along the sides of roads and highways. The coordinates available are only to the nearest minute and contribute further imprecision on the order of 1 kilometer. These data are, however, the most detailed that are available.

Approximately 12% of New Brunswick residents live in places that, for reasons of confidentiality, are not included in tabulations of New Brunswick settlement populations [Stats Canada 94-902,1983]. This is a serious loss of information because residences in small places are likely to be remote, close to the forests, and subject to above-average spray exposure. Because only small places are involved, only those municipalities that are parishes are affected. Exposure scores within these units are distorted in proportion to the size of this unknown segment and its average exposure. In order to reduce the impact of this problem, the sum of the place populations within a given parish was used as the denominator for the calculation of population weights, rather than the total population of that parish as published separately by Statistics Canada. The effect of this adjustment on the calculation of weights is

equivalent, mathematically, to assigning the average exposure of the "known" population within a parish to the unknown segment in that parish. To have used the complete population as the denominator of the rates would have been equivalent to assigning zero exposure to the unascertainable segment of each municipality, while they may in fact have had considerably above-average exposures.

3. Criteria for the Development of Exposure Indices

The basic data for the construction of exposure indices are the distances between each settlement centroid and the nearest margin of each spray block within a defined radius for each of the years 1952-1976. The number of spray blocks per settlement varies from year to year, and the total over the 25-year period ranges from 0 to 75 spray blocks per settlement. Furthermore, cancer incidence is geographically coded at the level of municipalities rather than settlements. In order to make maximum use of the available data, exposure indices have been defined so that they are:

a) additive over spray block data within settlement;
b) additive over settlements within municipalities for parishes;
c) additive over spray years within the period 1952-1976 for each municipality;

d) reflective of what is understood about the physical behavior of spray within the environment.

Spraying was usually carried out in the morning or evening to take advantage of the calmer conditions created by temperature inversions. Under these conditions, exposure was not uniform across areas contiguous to spray blocks, but varied with wind direction following temperature inversion breakups. This source of variability could not be integrated into the exposure indices.

4. DDT and Organophosphate Near-Distance Indices

Due to the nature of the dispersal of spray aerosols in the environment, the majority of settlement spray exposure in New Brunswick is dominated by the spray block which is nearest to each settlement. For this reason and the simplicity of calculating and interpreting a score based on the nearest block, a near-distance index was developed.

All settlements whose centroids were within one kilometer of a DDT or organophosphate spray block were scored as 1 for exposed while all others were scored as 0 for unexposed. This index therefore uses data for only one spray block per settlement.

Parishes are made up of many small settlements, only some of which may fall within the one kilometer limit. In these cases the exposure index is calculated as the sum of

populations in settlements within one kilometer, divided by the total of all the "known" settlement populations in that parish (see earlier discussion of population weights). Therefore, cumulative scores for parishes are rarely integers.

5. DDT and Organophosphate Medium-Distance Indices

In order to make use of all of the available spray data and to represent as closely as possible differences between DDT and organophosphate spray with respect to probable deposition rates as a function of distance, additional indices were developed. These include multiple spray block data up to a specified distance beyond which exposure is defined to be zero.

a. DDT Medium-Distance Index

The majority of DDT sprayed during the period 1952-1968 was sprayed by slow, low-flying aircraft using a boom and nozzle spray apparatus that generated relatively large spray droplets. For this reason the amount of off-target drift is expected to be much less than from the large, fast flying aircraft with ultra-low-volume spray apparatus used during the later organophosphate spray period. Therefore a simple linear deposition model was used. In the case of towns,

villages, and cities, the score for each place was calculated as 1-x/5, where x is the distance from the centroid for that place to the nearest margin of each DDT spray block within 5 kilometers. Scores are added over spray blocks and over years.

For parishes, a separate score was calculated for each settlement in the same fashion as for towns, villages, and cities, and then multiplied by the settlement size divided by the "known" parish population. These settlement scores were then summed to provide a total parish score. The calculation for each settlement is as follows: (settlement population/"known" parish population)(1-x/5).

b. Organophosphate Medium-Distance Index

The organophosphate medium-distance index differs from the DDT medium-distance index in two ways. Firstly, the scores for towns, villages, and cities were calculated as 1 divided by the exponent of distance (1/exp(x)) to provide an exponential decay of exposure with distance instead of the linear decay provided for DDT. Secondly, organophosphate scores were added over all spray blocks within 10 kilometers instead of the 5 kilometer limit used for DDT. All other calculations were carried out in the same fashion for both DDT and organophosphates.

B. Agricultural Activity Index

Exposure to agricultural pesticides may be the most important potential confounder of exposure in this study. Many of the pesticides used in forestry spraying have also been used in agriculture, and agricultural spraying tends to take place in areas not normally subjected to forestry spraying. Information from the Pesticide Division of the Department of Agriculture and Rural Development (New Brunswick) indicates that 52,632 hectares were sprayed with approximately 527,765 kilograms of pesticide in 1976. Forty-four percent of the total crop hectares treated were under cultivation for potatoes and these were sprayed with an average of 20 kilograms of pesticide per crop hectare. On average, potato crops receive more than 20 times the amount of pesticides sprayed on any other crop type. The Task Force on Chemicals in the Environment and Human Reproductive Problems in New Brunswick found, however, that only about 14% (2.8 kg./ha) of this amount is insecticides; the majority (72%) is fungicides with the remainder consisting of herbicides [Hatcher et al.,1985,pg.124].

Aside from a few general descriptions such as those mentioned above, the geographic distribution of agricultural pesticide usage within New Brunswick is poorly documented and had to be approximated by indirect methods.

In 1981, for the first time, the geographic boundaries of the Census of Agriculture agreed with those of the Census

of the Population at the level of the 153 Consolidated Census Subdivisions (CCS).

The Census of Agriculture collects data pertaining to land under cultivation in each province. The total agricultural acreage for each of the 153 CCS within New Brunswick as reported in the 1981 Census of Agriculture were obtained from Statistics Canada and used to develop proxies for agricultural pesticide exposure.

The degree to which confounding of forestry pesticide exposures by agricultural exposures can be controlled depends on the degree of association between present agricultural practices and activity in the past. Large changes in farming have occurred during the past 2 to 3 decades, including changes in crops grown, their location within the province, and the types and amounts of pesticides used. In the absence of comprehensive data it is not possible to estimate these changes in a manner that would be useful for this study. However, the Task Force on Chemicals in the Environment and Human Reproductive Problems in New Brunswick has examined the use of agricultural pesticides within New Brunswick and published several reports on pesticide exposure [Hatcher et al.;1983,1984,1985].

During their deliberations, the Task Force on Chemicals in the Environment and Human Reproductive Problems in New Brunswick considered using several data sources to derive indices of agricultural pesticide exposure for their period of interest (1970-81) and concluded that crop production

figures provide the best available basis for this [Hatcher et al.,1985,pg.14]. The Task Force combined these data with crop specific quantities of pesticides potentially applied, as estimated from the amount of pesticides sold within the province and application rates recommended by the Canadian Crop Guide. They discovered that crop specific acreage within New Brunswick fluctuated rather dramatically from year to year [Hatcher et al.,1984,pg.221]. Because crop specific acreage varied so much, it was decided that only total area under cultivation would be used in this study as the basis for estimation and that the additional uncertainty regarding the actual application rates of agricultural pesticides was too great for data to be incorporated into the indices developed.

The agricultural activity index was therefore calculated as: CCS area under cultivation/CCS land area.

IV. DEVELOPMENT OF OUTCOME MEASURES

A. Geography

Not all records within the New Brunswick Tumour Registry pertain to New Brunswick residents. Part of the standard geographic code used by the Tumour Registry identifies the province of residence. One hundred and seventy-three records of cases with residences outside of New Brunswick were excluded from the analysis. Ninety-nine

records with missing standard geographic codes and 21 records of New Brunswick residents with localities coded unknown were also excluded. Therefore, assuming all records with missing standard geographic codes as New Brunswick residents, 120 or 0.99% of the total New Brunswick cases received were lost to analysis as a result of missing geographical data.

Only non-city cases were retained for analysis.

B. Topography and Morphology

Not all of the analysable non-city cases pertained to malignant tumours. Seven hundred and seventy-two records in which the topographic code indicated a benign tumour or the morphology behaviour sub-code indicated carcinoma-in-situ or benign were excluded. Ninety percent of these were for neoplasms of the skin and cervix. All of the remaining cases were retained for analysis including 79 cases with uncertain behaviour and 622 cases for which no morphological data was recorded. All New Brunswick cases had topograph codes.

Four outcome categories based primarily on morphological data were created. They are as follows:

a) sarcomas (M880-M899, M902-M934);
b) brain (M935-M957);
c) lymphomas (M958-M975);
d) leukemias (M980-M998).

Values in brackets are the ICD-O morphology codes [WHO,1976] used for each category. All records with the above morphology codes were classified accordingly. The topography codes of the remaining cases for which morphology data were missing and 19 cases with topography codes indicating brain and other nervous system were added to the brain category; 62 cases with topography codes indicating leukemia were added to the leukemia category; 11 cases with topography codes indicating lymphoma were added to the lymphoma category and 1 "bone and articular cartilage" and 2 "connective and other soft-tissue" neoplasms were added to the sarcoma category.

All remaining records that had been coded for topography using the 8th revision of the International Classification of Diseases [WHO,1968] were examined for compatibility with the 9th revision of the International Classification of Diseases [WHO,1975] using a conversion list supplied by D. Wigle of the Laboratory Centers for Disease Control of Health and Welfare Canada (See Appendix II) and when necessary, sites were grouped to ensure compatibility.

The result of the process described above was to create an exhaustive and mutually exclusive set of outcome categories that combined both topography and morphology.

V. DATA ANALYSIS

A. Preliminary Analysis

The appropriateness of a multiplicative model of causality versus an additive one was evaluated by fitting each model to the study data. This was done to determine which causal model best fit the data. The multiplicative model was found to have the smallest deviances for all the sites examined and therefore was chosen as the basis for data analysis.

The effectiveness of the indirect method of age standardization used in this study was evaluated by using binomial regression on the age group, sex specific data. Models were fitted using age group, treated as a factor, and spray exposure, treated as a continuous variable. The sex specific age-adjusted relative risks from the binomial regressions were compared to those from the Poisson regressions. The relative risks from each type of regression were found to be in close agreement, thus supporting the conclusion that age standardization was effective.

The 11 age groups available for analysis were regrouped into the following 3 broad age categories: 1) 0-19 yrs., 2) 20-54 yrs., 3) 55 and up. The new 3-category variable was included as a factor with exposure measures, in binomial models with age group/exposure interaction terms, and

binomial models without the interaction terms. This was done to determine whether the effect of exposure differed across age groups. The inclusion of these interaction terms did not significantly improve the fit. It was therefore concluded that exposure effects, if any, were not modified by age.

B. Initial Data Analysis

Initial data analyses involved the characterization of the New Brunswick population in terms of: a) those factors that could potentially confound cancer/spray associations, b) forestry spray exposure, c) cancer incidence; and examined the degree to which these variables were associated. This step was intended to investigate whether or not these factors behaved as expected and was to facilitate the interpretation of results from the multivariate analysis.

C. Poisson Regression Analysis of Indirectly Standardized Incidence Ratios

Methods for the analysis of observed and expected values within the context of multiplicative models in epidemiology are well developed [Breslow et al.,1983]. Unlike regular regression, Poisson regression does not assume equality of variances for each independent variable

in the model. Variance is defined to be a function of the population mean, estimated from the sample means, and can therefore vary along the x axis.

Poisson regression represents a weighted analyses of observational units in which the weight is proportional to the size of the unit. This is a particularly desirable feature insofar as the population units for the current analysis are highly variable with respect to size.

The coefficients generated by the Poisson model are interpretable as estimates of standardized risk ratios when the model provides a good fit to the data [Frome,1984,pg.14].

Age/sex specific rates were calculated for each of the 254 non-city municipalities in New Brunswick. While the structure of these data permitted standardization using the direct method, the numbers in many of the age/sex/ municipality strata were small and would have led to the calculation of rates with large variances. The indirect method [Fleiss,1973] was therefore used. These two methods are known to be in agreement under most conditions. Preliminary analyses were carried out and indicated a high degree of concordance between the estimates generated by each of these methods.

Poisson regression was used to obtain risk ratio estimates of the effect of spray exposure on cancer incidence, controlling for potential confounders. This technique is an extension of that used for the analysis of standardized mortality ratios and is described in detail by

Breslow et al. [1983]. Parameter estimates were obtained using the Generalized Linear Interactive Modelling programme (GLIM) for the PC; Release 3.77 [Payne,1985].

Data analysis was carried out on the observed and expected values of the 254 observational units (non-city municipalities) in New Brunswick.

Colinearity among explanatory variables has been demonstrated to result in a destabilization of estimated coefficients and their standard errors [Chatterjee and Price,1977,pg.143]. This instability is expressed through dramatic changes in these parameters with the introduction of new terms into multivariate statistical models. The effect of the introduction of new terms on coefficients and their standard errors was carefully monitored during analysis in order to detect colinearity problems if present.

D. Estimation of Statistical Power

One important question regarding power that needs to be addressed in this type of study pertains to the likelihood of detecting an exposure effect if one exists. In view of the limitations of the available data it seems unlikely that small risks would be detected.

The data of this study are limited in 2 important ways: sample size and bias. Power deals only with the former whereas the latter is probably the more important of the two as far as its impact on this study.

The usual power estimates deal only with random error. This study, however, is subject to substantial non-random error so that the real uncertainty is greater than calculated. In short, the calculated p-values in this study are too small, and the confidence intervals too narrow, by unknown amounts. They are, however, still useful as lower bounds, and indicate how much bias would be needed to produce results if no effects are present (by some subjective process).

Statistical power is influenced by 4 factors: 1) the value of alpha, which was set to .05; 2) the size of the relative risk to be detected, which was set to 1.5, 2.5 and 5.0; 3) the total number of observed events; and 4) the ratio of the denominator of the exposed group to that of the unexposed. The total number of observed events in this situation is determined by cancer incidence rates in New Brunswick during the period 1977-1980 while the ratio of exposed to unexposed denominators will vary according to the choice of cut points on the developed exposure axes. Power estimates were calculated according to a method described by Brown and Green [1982] for 2 independently distributed Poisson variates.

The main tests of hypotheses in Chapter IV were conducted using a continuous exposure score. The power estimates, however, are based on a dichotomous variable, created by treating units with spray exposure scores of zero as unexposed and all others as exposed.

CHAPTER IV

RESULTS

I. INTRODUCTION

The population of New Brunswick can be partitioned geographically in many ways. The two most important partitions (geographic units) used in this study are settlements and municipalities. Settlements were used for the calculation of exposure scores. Settlements are the smallest units for which population data are available and permit the most precise estimation of distance based exposure indices, but the only data published for these units are their total populations. Municipalities, however, can be characterized demographically. Figure 4.1 is a map of New Brunswick with its 15 census divisions and the distribution of settlements used for spray exposure calculations.

An important feature of settlements and municipalities is the one-to-one correspondence to towns, villages, and cities, which are both settlements and municipalities. All other settlements are grouped into municipalities that are referred to as parishes. Therefore, there is 100% coverage of towns, villages, and cities in either partition, whereas only 88.4% of the total New Brunswick population was classified to settlements in 1981.

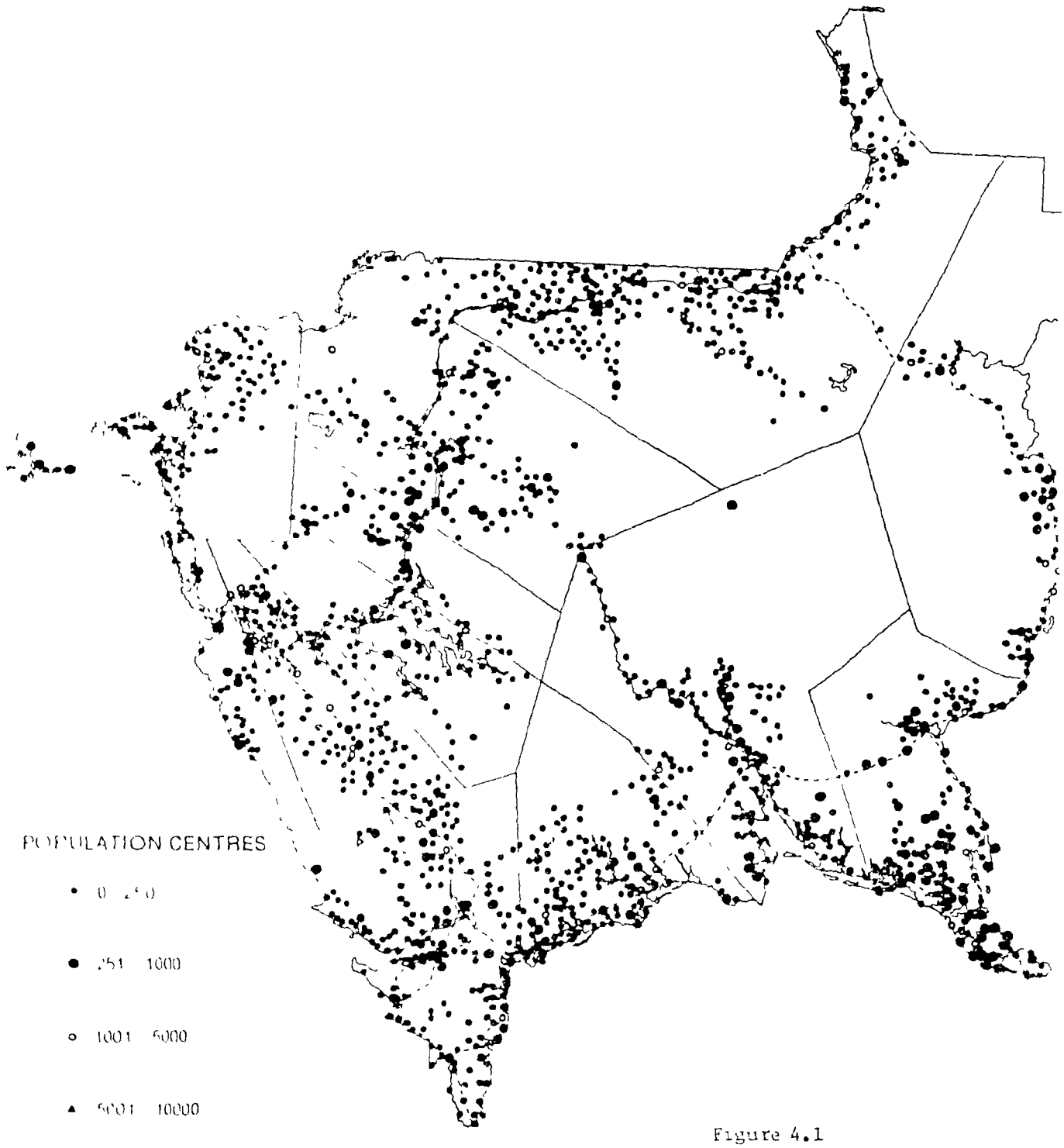

Figure 4.1

New Brunswick Census Divisions and Settlements

New Brunswick is a highly rural province with 52.5% (365,540) of its population living in settlements with populations of less than 2,500 persons. This figure is obtained by summing the populations of parishes, for which total populations are available, and whose settlement populations never exceed 2,500 persons, with the populations of towns and villages with populations less than 2500.

Of the 365,540 persons living in rural areas, 94,290 (25.8%) live in towns or villages while 271,250 live in small settlements within parishes. The remainder of the New Brunswick population (330,685) live in large towns, villages, and cities.

The New Brunswick population includes two major cultural groups; for convenience, these are designated by their predominant language as English and French. Thirty-three percent of New Brunswickers reported their mother tongue as French and only 1.3% reported their mother tongue to be other than French or English [Stats Canada E-562, 1982].

The French population within New Brunswick is concentrated along the east coast and within the northern regions of the province. Among the predominantly French municipalities, 78.6% of the population lives in rural areas compared to 42.2% of the population of predominantly English municipalities.

A higher proportion of persons having attended university are situated within cities than in more rural

areas. Municipalities in which there are large numbers of French also tend to have smaller numbers of persons who have attended university.

Predominantly French areas within the province also have higher proportions of persons with low-income than predominantly English areas.

Finally, larger proportions of the populations of urban areas migrate than do populations in rural areas. Migration is lower within predominantly French municipalities relative to English municipalities, is positively associated with educational attainment, and is highest where the incidence of low-income is lowest.

In summary, there appear to be two fairly distinct populations within New Brunswick. The French live in more rural areas, are less well educated, have lower incomes, and migrate less than their English counterparts. These two populations may vary with respect to lifestyle, and do vary in terms of their geographic distribution within the province. Undefined and unmeasured lifestyle factors may increase or decrease cancer risk within the French population relative to the English. The coastal location of French settlements is probably correlated with low spray exposure and their rural nature implies a decreased cancer risk.

Appendix VII contains the data upon which the preceding statements are based.

II. SPRAY EXPOSURE

As discussed earlier in the Methods section, different exposure indices were developed for DDT and organophosphates. The near-distance indices for DDT and organophosphates were calculated in the same way and are the simplest and most easily interpreted. A more complex set of indices was designed to reflect deposition differences between DDT and organophosphates. While this second set includes information on more than the nearest spray block, their measurement units are difficult to interpret. Therefore, the more complex indices were used only in the final stages of analysis.

Measures of agricultural activity were examined as a possible confounding factor, as many of the pesticide compounds used in forestry were also used in agriculture.

Near-distance scores for both DDT and organophosphates were calculated by assigning a score of 1 for each year a town, village, or city was within 1 kilometer of one or more spray blocks. For other settlements, the settlement population was divided by the "known" population for the parish within which it is situated. Therefore, fractional scores indicate that part of the parish population was exposed and a score of 1 indicates that all settlements within that parish were exposed. Cumulative scores were calculated by summing scores within municipalities over all years.

The total "known" population was based on information from a settlement file [Stats Canada 94-902,1983] which contained population data on 88.4% of the total New Brunswick population. The use of the "known" (615,350) instead of the "actual" population (696,225) allocated the average parish exposure to the portion of the population not allocated to a settlement or larger unit. Table 4.1 describes settlements within New Brunswick.

Different spray score cutoff values were used to examine the effect of the choice of cutoff on calculated exposure scores. This was intended to insure that the a priori choice of a 1 kilometer cutoff did not generate an idiosyncratic exposure profile and to insure that sufficient exposure variability was present. The same approach was used during the initial stages of model fitting to evaluate the effect of changing cutoffs on spray-related cancer risk.

Table 4.2 gives the distribution of person-years of exposure by formulation, type of municipality, period, and different cutoffs. One notable feature of these "one kilometer" data is the absence of exposure for cities, with the exception of organophosphates for the period 1973-76. With few exceptions the populations of parishes are more highly exposed than those of towns, villages, or cities. In general, the increases in person-years exposed tends to be low (on this numeric scale) up to 2.5 kilometers. On the

Table 4.1 1981 New Brunswick Population by Settlement Size

Settlement Sizes	Number of Settlements	Total Population	Average Size
All Settlements	1581	615350 (100.0%)	389.2
1. 0 Up to 100	867	44881 (7.3%)	51.7
2. 100 Up to 250	421	66358 (10.8%)	157.6
3. 250 Up to 500	143	48290 (7.8%)	337.7
4. 500 Up to 1000	75	51018 (8.3%)	680.2
5. 1000 Up to 2500	48	73560 (12.0%)	1532.5
6. 2500 Up to 5000	12	45794 (7.4%)	3816.2
7. 5000 Up to 10000	9	63455 (10.3%)	7050.6
8. 10000 & Up	6	221994 (36.1%)	36999.0

Source: Place Name Reference List [Stats Canada 94-902,1983]

Table 4.2 Person-Years of Potential Spray Exposure (1) by Formulation, Type of Municipality, Period, and Different Exposure Definitions (2)

Formulation, Type of Municipality, Period	Total P-Yrs	Person-Years of Exposure by Exposure Within			
		0 to 0.5 Km.	0 to 1.0 Km	0 to 2.5 Km.	0 to 5.0 Km.
DDT, Municipalities <2500; 1952-62	2841070	108727 (3.8%)	123026 (4.3%)	164848 (5.8%)	239052 (8.4%)
DDT, Towns, Villages 2500 up; 1952-62	1143380	3399 (0.3%)	12463 (1.1%)	21527 (1.9%)	46792 (4.1%)
DDT, Cities; 1952-62	2169050	0 (0.0%)	0 (0.0%)	174892 (8.1%)	174892 (8.1%)
DDT; Municipalities <2500; 1963-68	1704642	39256 (2.3%)	43514 (2.6%)	60940 (3.6%)	99426 (5.8%)
DDT, Towns, Villages 2500 up; 1963-68	686028	6284 (0.9%)	6284 (0.9%)	9457 (1.4%)	27727 (4.0%)
DDT, Cities, 1963-68	1301430	0 (0.0%)	0 (0.0%)	0 (0.0%)	87446 (6.7%)
Organophosphates, Municipalities <2500; 1963-68	1704642	6858 (0.4%)	7198 (0.4%)	8562 (0.5%)	13689 (0.8%)
Organophosphates; Towns, Villages 2500 up; 1963-68	686028	3173 (0.5%)	6346 (0.9%)	6346 (0.9%)	6346 (0.9%)
Organophosphates; Cities, 1963-68	1301430	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Organophosphates, Municipalities <2500; 1969-72	1136428	162054 (14.3%)	173981 (15.3%)	202000 (17.8%)	265148 (23.3%)
Organophosphates; Towns, Villages 2500 up; 1969-72	457352	75850 (16.6%)	80135 (17.5%)	114755 (25.1%)	144532 (31.6%)
Organophosphates, Cities, 1969-72	867620	0 (0.0%)	0 (0.0%)	55767 (6.4%)	55767 (6.4%)
Organophosphates, Municipalities <2500; 1973-76	1136428	161725 (14.2%)	199645 (17.6%)	302787 (26.6%)	454322 (40.0%)
Organophosphates; Towns, Villages 2500 up; 1973-76	457352	70770 (15.5%)	73984 (16.2%)	97508 (21.3%)	195511 (42.7%)
Organophosphates, Cities; 1973-76	867620	121530 (14.0%)	121530 (14.0%)	121530 (14.0%)	273523 (31.5%)

(1) person-years for 1977-80 population living in areas exposed during the time periods indicated

(2) exposure was deemed to have occurred for settlement populations that were within these distances from at least 1 spray block

Source Based on spray data supplied by Forest Protection Ltd. and J.D. Irving Forestry Products Inc

basis of these distributions of person-years exposed, there appears to be little reason for modifying the 1 kilometer cutoff criterion.

In the context of this study, person-years can be deceiving insofar as a few analytical units can generate a disproportionately large number of person-years. Consequently, the potential for substantial confounding is enhanced. Then, it is best to have risk estimates on reasonably large numbers of units. Table 4.3 presents the cumulative exposure scores by formulation, type of municipality, period and cutoff. The overall conclusions drawn from Table 4.2 are not changed by these data. However, the dangers of interpreting person-years under these conditions are highlighted by the 1.1% of total person-years in column 2, row 2 for towns and villages that is due to the exposure of only 2 towns or villages. It is also clear from Table 4.2 that exposure is highly concentrated among settlements with less than 2500 persons.

Approximately one third of the New Brunswick population (31.1%) lives in cities. The concentration of population within these 6 analytical units attributes large weights to these points within a regression model and for reasons largely unknown, city populations, in general, have higher rates of cancer than rural areas [Fasal et al.,1968;Levin et al.,1960;Teppo et al.,1984]. This indicates the operation of undefined risk factors within these populations.

Table 4.3 Spray Exposure Scores (1) by Formulation, Type of Municipality, Period, and Different Exposure Definitions (2)

Formulation; Type of Municipality; Period	Cumulative Scores for Exposures Within			
	0 to 0.5 Km.	0 to 1.0 Km.	0 to 2.5 Km.	0 to 5.0 Km
DDT; Municipalities <2500; 1952-62	85.2	95.5	131 3	191.9
DDT; Towns, Villages 2500 up; 1952-62	1.0	2.0	3.0	8 0
D T; Cities; 1952-62	0.0	0.0	4 0	4 0
DDT; Municipalities <2500; 1963-68	37 6	41.8	59 4	93 2
DDT; Towns, Villages 2500 up; 1963-68	1.0	1.0	2 0	6 0
DDT; Cities; 1963-68	0.0	0.0	0 0	2.0
Organophosphates; Municipalities <2500; 1963-68	6.7	6.9	8 0	13.9
Organophosphates; Towns, Villages 2500 up; 1963-68	1.0	2.0	2 0	2.0
Organophosphates; Cities; 1963-68	0.0	0.0	0 0	0.0
Organophosphates; Municipalities <2500; 1969-72	145.6	156.0	179 8	237.5
Organophosphates; Towns, Villages 2500 up; 1969-72	13.0	14.0	19.0	25 0
Organophosphates; Cities; 1969-72	0.0	0.0	2.0	2.0
Organophosphates; Municipalities <2500; 1973-76	153.4	184.0	269 4	404.9
Organophosphates; Towns, Villages 2500 up; 1973-76	12 0	13.0	18.0	35 0
Organophosphates; Cities; 1973-76	3 0	3.0	3 0	7 0

(1) towns, villages, and cities received a score of 1 for each year that conformed to an exposure definition; unincorporated places received a score equal to its population divided by the "known" population of the parish in which it was situated; these scores were accumulated over years within each formulation, type of municipality and period category

(2) exposure was deemed to have occurred for settlement populations that were within these distances from at least 1 spray block

Source: Based on spray data supplied by Forest Protection Ltd. and J D Irving Forestry Products Inc

Several possible risk factors used in this study have already been demonstrated to co-vary with urban/rural location. Previous tables indicate a definite association between urban/rural residence and spray exposure. With their low exposure variability, cities are not useful units for the estimation of exposure related cancer risk in New Brunswick, aside from their possible contribution to the precision with which zero and near-zero relative risks are estimated. The size of cities, however, and the particular nature of their populations provides a basis for substantial confounding. A large percentage of the non-city population falls in the zero exposure category (Table 4.4) so that the city populations are not needed to estimate risk at zero or low exposures. Overall, the benefits to precision of including cities seem to be outweighed by the danger of bias. Therefore and henceforth, analysis is limited to the non-city population of New Brunswick. This limitation also extends to the calculation of expected numbers of cancers.

Table 4.4 contains information on the 1981 non-city New Brunswick population by near-distance exposure scores and settlement sizes. The average near-distance exposure score for the population living within settlements smaller than 2500 is 0.59 for DDT and 1.49 for organophosphate pesticides. In other words this population, on average, was within 1 km. of at least one organophosphate spray block 2.53 times as often as it was to a DDT spray block. The exclusion o.

Table 4.4 1981 New Brunswick Non-City Population by DDT, Organophosphate Forestry Spray Exposure (1) and Urban/Rural Residence

Spray Exposure Score	Total	Population: Less than 2500	Population: 2500 or more
DDT			
Total	100.0% (479705)	100.0% (365440)	100.0% (114265)
Zero (0)	44.7% (214255)	32.5% (118695)	83.6% (95560)
Low (1 down to 0)	42.7% (204855)	50.9% (186150)	16.4% (18705)
Moderate (2 down to 1)	4.3% (20470)	5.6% (20470)	0.0% (0)
High (3 down to 2)	3.7% (17580)	4.8% (17580)	0.0% (0)
Very High (6 down to 3)	4.7% (22545)	6.2% (22545)	0.0% (0)
Mean Municipality Score	0.55 (254)	0.59 (233)	0.14 (21)
Organophosphates			
Total	100.0% (479705)	100.0% (365440)	100.0% (114265)
Zero (0)	14.2% (68285)	11.6% (42530)	22.5% (25755)
Low (1 down to 0)	31.9% (153095)	31.6% (115455)	32.9% (37640)
Moderate (2 down to 1)	34.0% (162915)	34.6% (126620)	31.8% (36295)
High (3 down to 2)	12.6% (60340)	13.4% (48930)	10.0% (11410)
Very High (6 down to 3)	7.3% (35070)	8.7% (31905)	2.8% (3165)
Mean Municipality Score	1.48 (254)	1.49 (233)	1.38 (21)

(1) based on 0-1 km. exposure definition with all exposure years combined

Source: 1981 New Brunswick population [Stats Canada E-562,1982]
Spray data supplied by Forest Protection Ltd. and J.D. Irving Products Ltd

cities does not affect the association between spray and urban/rural residence. The urban/rural differences are most striking for DDT where only 32.48% of the population of small settlements has never been exposed compared to 83.63% for large settlements.

A second set of exposure scores, medium-distance indices, was developed separately for DDT and organophosphates because there are possibly important aspects of exposure that are not captured by near-distance indices, including exposure from more than just the nearest spray block and exposure beyond one kilometer. Also, the method used for the calculation of medium-distance DDT scores was different from that for organophosphates.

All DDT spray blocks within a radius of 5 kilometers were used in the calculation of medium-distance spray scores. A score was assigned to each settlement whose value was calculated to lie on a straight line between 0 and 5 kilometers and whose range was 1 to 0. Thus, settlements situated 5 kilometers (or more) from a spray block, received a score of 0 whereas a settlement within a spray block received a score of 1. The values were then accumulated over spray blocks and years within municipalities.

The method of calculation of medium-distance scores for organophosphate differed from that for DDT in that spray blocks within a 10 kilometer, rather than 5 kilometer, radius were used and scores calculated to vary with the inverse exponent of distance. The scores were accumulated

in the same fashion as DDT. The larger radius was used because differences in spray methods caused organophosphate sprays to drift further than DDT sprays.

DDT was used extensively in agriculture as well as in forestry, and although fenitrothion, the most commonly used organophosphate pesticide in forestry, has not been used in commercial agriculture, many other similar compounds have been used. Agriculture is carried out in cleared areas within New Brunswick, so one might expect population exposure to agricultural pesticides to vary inversely with exposure to forestry sprays. Table 4.5 supports this premise. Agricultural activity is defined as the percentage of land within consolidated municipalities that is under cultivation. Consolidated municipality scores were applied to all municipalities within their boundaries. This table indicates that the percentage of population with exposure to DDT from forestry uses, defined by the 1 kilometer rule, declines as the percentage of land in agricultural increases. The tendency is most notable in terms of mean municipality scores. The association for organophosphates is not so strong.

Table 4.6 indicates that predominantly English communities are more highly exposed than predominantly French communities.

Table 4.5 1981 New Brunswick Non-City Population by DDT, Organophosphate Forestry Spray Exposure (1) and Agricultural Activity (2) Quartiles (3)

Spray Exposure Score	Total	Population by Agricultural Activity			
		Quartile 1	Quartile 2	Quartile 3	Quartile 4
DDT					
Total	100.0% (479705)	100.0% (107590)	100.0% (115120)	100.0% (117125)	100.0% (139870)
Zero (0)	44.7% (214255)	38.1% (40995)	34.0% (39125)	46 5% (54430)	57.0% (79705)
Low (1 down to 0)	42.7% (204855)	38.6% (41495)	53.7% (61860)	39.7% (46545)	39.3% (54955)
Moderate (2 down to 1)	4.3% (20470)	5.6% (6055)	4.1% (4730)	6 3% (7370)	1.7% (2315)
High (3 down to 2)	3.7% (17580)	10.3% (11050)	0.0% (0)	4.2% (4885)	1.2% (1645)
Very High (6 down to 3)	4.7% (22545)	7.4% (7995)	8.2% (9405)	3 3% (3895	0.9% (125[illegible])
Mean Municipality Score	0.55 (254)	0.84 (64)	0.60 (63)	0.54 (63)	0.23 (64)
Organophosphates					
Total	100.0% (479705)	100.0% (107590)	100.0% (115120)	100.0% (117125)	100.0% (139870)
Zero (0)	14 2% (68285)	9.2% (9895)	17.7% (20375)	22.5% (26295)	8.4% (11720)
Low (1 down to 0)	31.9% (153095)	33.3% (35845)	34.0% (39095)	31.1% (36420)	29.8% (41735)
Moderate (2 down to 1)	34.0% (162915)	26.9% (28990)	31.3% (36025)	31.9% (37410)	43.2% (60490)
High (3 down to 2)	12.6% (60340)	15.4% (16615)	7.1% (8130)	11.8% (13810)	15.6% (21785)
Very High (6 down to 3)	7.3% (35070)	15.1% (16245)	10.0% (11495)	2.7% (3190)	3.0% (4140)
Mean Municipality Score	1.48 (254)	1.72 (64)	1.42 (63)	1 32 (63)	1.46 (64)

(1) based on 0-1 km. exposure definition with all exposure years combined

(2) percentage of land under cultivation by consolidated census subdivision applied to all municipalities within their limits

(3) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source: 1981 New Brunswick non-city population [Stats Canada E-574,1983].
Spray data supplied by Forest Protection Ltd. and J.D. Irving Inc.
Agricultural Activity data obtained from 1981 Census of Agriculture.

Table 4.6 1981 New Brunswick Non-City Population by DDT, Organophosphate Forestry Spray Exposure (1) and Language/Culture (2)

Spray Exposure Score	Total	Population Predominantly French	Population Predominantly English
DDT			
Total	100.0% (479705)	100.0% (184880)	100.0% (294825)
Zero (0)	44.7% (214255)	50.1% (92645)	41.2% (121610)
Low (1 down to 0)	42.7% (204855)	47.7% (88150)	39.6% (116705)
Moderate (2 down to 1)	4.3% (20470)	2.2% (4085)	5.6% (16385)
High (3 down to 2)	3.7% (17580)	0.0% (0)	6.0% (17580)
Very High (6 down to 3)	4.7% (22545)	0.0% (0)	7.6% (22545)
Mean Municipality Score	0.55 (254)	0.17 (83)	0.74 (171)
Organophosphates			
Total	100.0% (479705)	100.0% (184880)	100.0% (294825)
Zero (0)	14.2% (68285)	17.0% (31380)	12.5% (36905)
Low (1 down to 0)	31.9% (153095)	46.2% (85350)	23.0% (67745)
Moderate (2 down to 1)	34.0% (162915)	32.9% (60905)	34.6% (102010)
High (3 down to 2)	12.6% (60340)	3.9% (7245)	18.0% (53095)
Very High (6 down to 3)	7.3% (35070)	0.0% (0)	11.9% (35070)
Mean Municipality Score	1.48 (254)	0.97 (83)	1.73 (171)

(1) based on 0-1 km exposure definition with all exposure years combined
(2) greater than 50% of municipal population

Source: 1981 New Brunswick non-city population [Stats Canada E-574, 1983]
Spray data supplied by Forest Protection Ltd and J.D. Irving Inc

Table 4.7 shows that as educational attainment increases, forestry exposure to either DDT or organophosphate exposure decreases. Table 4.8 shows that the incidence of low-income increases with organophosphate exposure, and slightly less consistently for DDT exposure, and is therefore consistent with the findings for urban/rural residence and educational attainment.

There appears to be a negative association between migration and DDT exposure, and a positive association between migration and organophosphate exposure (Table 4.9).

III. CANCER INCIDENCE; NEW BRUNSWICK TUMOUR REGISTRY DATA

Data on new cases of cancer for the period 1977-1980 was supplied by the New Brunswick Tumour Registry. Table 4.10 shows the distribution of the 12,288 cases received by their 3 digit topographical label. Cases for the 1977-1978 period were classified according to the eighth revision of the International Classification of Diseases (ICD-8); the 9th revision was used during 1979-1980. Sites were regrouped in all cases where topographic codes for the same site differed between versions. These differences were identified using a conversion table supplied by D. Wigle (See Appendix II). The site labels used in Table 4.10 are predominantly but not exclusively those of version 9 of the ICD. The unmodified term "bladder" refers uniformly to the urinary bladder; gallbladder is always so specified.

Table 4.7 1981 New Brunswick Non-City Population 15 Years and Over by DDT, Organophosphate Forestry Spray Exposure (1) and Educational Attainment (2) Quartiles (3)

Spray Exposure Score	Total	Population 15 Years and Over Within Educational Attainment			
		Quartile 1	Quartile 2	Quartile 3	Quartile 4
DDT					
Total	100.0% (351685)	100.0% (73400)	100.0% (81400)	100.0% (80295)	100.0% (116590)
Zero (0)	45.3% (159380)	22.3% (16390)	30.5% (24830)	42.3% (33995)	72.2% (84165)
Low (1 down to 0)	42.2% (148445)	55.0% (40340)	59.7% (48610)	45.0% (36095)	20.1% (23400)
Moderate (2 down to 1)	4.2% (14865)	7.7% (5640)	6.8% (5575)	4.5% (3650)	0.0% (0)
High (3 down 2)	3.5% (12395)	6.8% (4975)	1.5% (1240)	1.1% (885)	0.6% (695)
Very High (6 down to 3)	4.7% (16600)	8.2% (6055)	1.4% (1145)	7.1% (5680)	3.1% (3530)
Mean Municipality Score	0.55 (254)	0.76 (64)	0.54 (63)	0.50 (65)	0.41 (64)
Organophosphates					
Total	100.0% (351685)	100.0% (73400)	100.0% (81400)	100.0% (80295)	100.0% (116590)
Zero (0)	14.4% (50780)	6.1% (4470)	5.9% (4830)	23.6% (18960)	19.3% (22520)
Low (1 down to 0)	32.1% (112720)	30.1% (22125)	38.9% (31665)	25.3% (20330)	33.1% (38640)
Moderate (2 down to 1)	33.7% (118440)	41.6% (30540)	37.9% (30870)	26.8% (21510)	30.5% (35520)
High (3 down to 2)	12.5% (43915)	9.7% (7150)	10.4% (8500)	15.8% (12715)	13.5% (15550)
Very High (6 down to 3)	7.3% (25830)	12.4% (9115)	6.8% (5575)	8.4% (6780)	3.7% (4360)
Mean Municipality Score	1.48 (254)	1.57 (64)	1.68 (63)	1.38 (65)	1.30 (64)

(1) based on 0-1 km. exposure definition with all exposure years combined

(2) proportion of persons who attended university in the total population 15 or older

(3) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes, quartile 1 is low

Source: 1981 New Brunswick non city population [Stats Canada E-574,1983]
Spray data supplied by Forest Protection Ltd and J.D Irving Inc

Table 4.8 1981 New Brunswick Non-City Population by DDT, Organophosphate Forestry Spray Exposure (1) and Incidence of Low-Income (2) Quartiles (3)

Spray Exposure Score	Total	Population Within Incidence of Low-Income: Quartile 1	Quartile 2	Quartile 3	Quartile 4
DDT					
Total	100.0% (479705)	100.0% (131395)	100.0% (135070)	100.0% (125695)	100.0% (87545)
Zero (0)	44.7% (214255)	47.1% (61830)	60.9% (82325)	33.7% (42350)	31.7% (27750)
Low (1 down to 0)	42.7% (204855)	40.7% (53475)	33.2% (44825)	51.2% (64410)	48.1% (42145)
Moderate (2 down to 1)	4.3% (20470)	4.0% (5300)	0.0% (0)	4.0% (4970)	11.7% (10200)
High (3 down to 2)	3.7% (17580)	7.9% (10355)	1.3% (1750)	3.0% (3830)	1.9% (1645)
Very High (6 down to 3)	4.7% (22545)	0.3% (435)	4.6% (6170)	8.1% (10135)	6.6% (5805)
Mean Municipality Score	0.55 (254)	0.50 (64)	0.35 (63)	0.65 (63)	0.70 (64)
Organophosphates					
Total	100.0% (479705)	100.0% (131395)	100.0% (135070)	100.0% (125695)	100.0% (87545)
Zero (0)	14.2% (68285)	17.6% (23095)	15.9% (21475)	9.3% (11640)	13.8% (12075)
Low (1 down to 0)	31.9% (153095)	32.9% (43245)	37.9% (51245)	29.2% (36735)	25.0% (21870)
Moderate (2 down to 1)	34.0% (162915)	32.5% (42715)	30.5% (41230)	33.3% (41820)	42.4% (37150)
High (3 down to 2)	12.6% (60340)	12.3% (16130)	6.8% (9165)	20.9% (26225)	10.1% (8820)
Very High (6 down to 3)	7.3% (35070)	4.7% (6210)	8.9% (11955)	7.4% (9275)	8.7% (7630)
Mean Municipality Score	1.48 (254)	1.36 (64)	1.41 (63)	1.54 (63)	1.61 (64)

(1) based on 0-1 km. exposure definition with all exposure years combined

(2) expenditures for food, clothing, and shelter exceed the average level for the region of residence by at least 20%

(3) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source 1981 New Brunswick non-city population [Stats Canada E-574,1983]
Spray data supplied by Forest Protection Ltd. and J.D. Irving Inc.

Table 4.9 1981 New Brunswick Non-City Population by DDT, Organophosphate Forestry Spray Exposure (1) and Migration (2) Quartiles (3)

Spray Exposure Score	Total	Population Within Migration Quartile 1	Quartile 2	Quartile 3	Quartile 4
DDT					
Total	100.0% (479705)	100.0% (111355)	100.0% (115685)	100.0% (122090)	100.0% (130575)
Zero (0)	44.7% (214255)	35.3% (39325)	34.0% (39365)	47.1% (57470)	59.8% (78095)
Low (1 down to 0)	42.7% (204855)	45.6% (50765)	52.1% (60275)	47.4% (57865)	27.5% (35950)
Moderate (2 down to 1)	4.3% (20470)	10.5% (11700)	2.5% (2900)	1.6% (1920)	3.0% (3950)
High (3 down to 2)	3.7% (17580)	0.0% (0)	2.8% (3250)	1.4% (1750)	9.7% (12580)
Very High (6 down to 3)	4.7% (22545)	8.6% (9565)	8.6% (9895)	2.5% (3085)	0.0% (0)
Mean Municipality Score	0.55 (254)	0.66 (64)	0.75 (63)	0.42 (63)	0.39 (64)
Organophosphates					
Total	100.0% (479705)	100.0% (111355)	100.0% (115685)	100.0% (122090)	100.0% (130575)
Zero (0)	14.2% (68285)	19.8% (22100)	9.0% (10405)	6.1% (7430)	21.7% (28350)
Low (1 down to 0)	31.9% (153095)	26.5% (29510)	38.9% (44980)	41.3% (50410)	21.6% (28195)
Moderate (2 down to 1)	34.0% (162915)	38.4% (42755)	34.4% (39845)	40.7% (49725)	23.4% (30590)
High (3 down to 2)	12.6% (60340)	7.5% (8385)	9.8% (11350)	6.0% (7340)	25.5% (33265)
Very High (6 down to 3)	7.3% (35070)	7.7% (8605)	7.9% (9105)	5.9% (7185)	7.8% (10175)
Mean Municipality Score	1.48 (254)	1.36 (64)	1.40 (63)	1.46 (63)	1.70 (64)

(1) based on 0-1 km. exposure definition with all exposure years combined

(2) persons living in a different municipality in 1981 from that in 1976

(3) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source: 1981 New Brunswick non-city population [Stats Canada E-574,1983]
Spray data supplied by Forest Protection Ltd. and J.D. Irving Inc.

Table 4.10 New Brunswick (N.B.) Tumour Registry Cases by Site (1) and Disposition, 1977-1980

Site (ICD-9)	All Cases	Not N.B Cases or Missing Geographic Code	New Brunswick Cases: N.B. Coded Unknown	New Brunswick Cases: Cities	New Brunswick Cases: Parishes, Towns and villages
All Sites	12288	272	21	4696	7299
Benign	24	1	0	11	12
Bone & Articular Cartilage	36	0	0	14	22
Brain & Other Nervous System	197	5	0	64	128
Breast	1017	26	1	425	565
Colon	915	20	1	361	533
Connective & Other Soft Tissue	77	2	0	29	46
Eye	25	1	0	6	18
Female Genital	1156	24	1	451	680
Gallbladder	63	5	0	20	38
Hematopoietic & Reticuloendothelial System	215	9	0	82	124
Hypopharynx	13	1	0	5	7
Ill-Defined Cancer	363	10	0	144	209
Larynx	103	5	1	37	60
Lip	117	1	0	25	91
Liver	49	3	0	18	28
Lymphatic & Hematopoietic Tissue	322	10	0	129	183
Melanoma of the Skin	68	1	0	31	36
Mouth	52	1	0	23	28
Nasal, Middle Ear, Sinuses	18	0	0	5	13
Nasopharynx	17	1	0	3	13
Neoplasm of Unspecified Nature of Uterus	564	7	2	248	307
Not Cancer	8	1	0	3	4
Oesophagus	70	0	0	30	40
Oropharynx	30	0	0	17	13
Other & Ill Def. Lip, Oral Cavity & Pharynx	1	0	0	0	1
Other and Ill Def. Digest. Organs & Perit.	25	2	0	8	15
Other Endocrine and Related	14	0	0	5	9
Pancreas	258	3	2	86	167
Penis & Other Male Genital Organs	16	0	0	9	7
Prostate	697	25	1	229	442
Rectum, RS Junction and Anus	445	15	1	166	263
Retroperitoneum & Peritoneum	15	0	0	6	9
Salivary Glands	33	1	0	10	22
Skin Other	2963	45	8	1112	1798
Small Intestine	20	0	0	9	11
Stomach	415	6	1	135	273
Testes	32	0	0	17	15
Thyroid Gland	77	0	0	28	49
Tongue	28	0	0	13	15
Trachea, Bronchus, Lung, Pleura, Thymus	1129	27	1	433	668
Urinary	601	14	1	249	337

(1) ICD-8 was used for 1977-78 and ICD-9 for 1979-80; sites were grouped where necessary to ensure compatibility

Source. New Brunswick Tumour Registry (1977-1980)

Of the 12,016 New Brunswick cases, only .17% (N=21) could not be situated geographically within the province.

Not all of the cases received from the registry pertained to malignant tumours. All cases in which either the topographic code or the morphologic behaviour sub-code indicated a non-malignant neoplasm were excluded. The effects of these exclusions for each site are listed in Table 4.11. As discussed earlier under "Spray Exposure", only non-city populations will be analysed.

Notable among the exclusions are those for female genital tract, unspecified uterus, and "other" skin. Of the 613 combined exclusions from female genital and neoplasms of unspecified nature of the uterus, 608 were carcinoma in situ of the cervix uteri and the remaining 5 were classified as benign within the ICD-8 general rubric for malignant neoplasm of genitourinary organs (180-189). The significance of a 4.6% (N=83) rate of exclusion for tumours of the category "skin other", and with benign behaviour is difficult to assess.

Finally, a system for the classification of cancer cases involving morphology and topography was used to regroup cancer cases into an exhaustive set of mutually exclusive classes. The new site classification is listed in Table 4.12. The categories: brain, leukemia, lymphoma, and sarcoma are based predominantly but not exclusively on morphology using the following ICD-O codes:

Table 4.11 1977-1980 New Brunswick Non-City Tumour Registry Cases; Regrouped by Site and Status (1)

Site	Total	Excluded	Retained
All Sites	7299	772	6527
Benign	12	12	0
Bone & Articular Cartilage	22	4	18
Brain and Other Nervous System	128	2	126
Breast	565	11	554
Colon	533	3	530
Connective & Other Soft Tissue	46	3	43
Eye	18	2	16
Female Genital	680	309	371
Gallbladder	38	0	38
Hematopoietic & Reticuloendothelial System	124	1	123
Hypopharynx	7	0	7
Ill-Defined Cancer	209	2	207
Larynx	60	2	58
Lip	91	3	88
Liver	28	0	28
Lymphatic & Hematopoietic Tissue	183	0	183
Melanoma of the Skin	36	1	35
Mouth	28	2	26
Nasal, Middle Ear, Sinuses	13	0	13
Nasopharynx	13	1	12
Neoplasm of Unspecified Nature of Uterus	307	304	3
Not Cancer	4	4	0
Oesophagus	40	0	40
Oropharynx	13	0	13
Other & Ill Def. Lip, Oral Cavity & Pharynx	1	0	1
Other and Ill Def. Digest. Organs & Perit.	15	0	15
Other Endocrine and Related	9	5	4
Pancreas	167	2	165
Penis & Other Male Genital Organs	7	2	5
Prostate	442	0	442
Rectum, RS Junction and Anus	263	4	259
Retroperitoneum & Peritoneum	9	0	9
Salivary Glands	22	2	20
Skin Other	1798	83	1715
Small Intestine	11	0	11
Stomach	273	2	271
Testes	15	0	15
Thyroid Gland	49	1	48
Tongue	15	2	13
Trachea, Bronchus, Lung, Pleura, Thymus	668	1	667
Urinary	337	2	335

(1) cases were excluded if either their behaviour was classified as non-malignant or their topographic code was not a cancer code

Source: New Brunswick Tumour Registry (1977-1980)

Table 4.12 1977-1980 New Brunswick Non-City Tumour Registry Cases; Regrouped (1) by Site and Microscopic Confirmation

Site	Total	Microscopically Confirmed	Non-Microscopically Confirmed
All Sites	6527	5741	786
Bladder, Kidney, and Other Urinary Organs	333	310	23
Breast	552	523	29
Endocrine	50	44	6
Eye	14	13	1
Female Genital (incl. uterus/unspecified)	363	345	18
Gallbladder	38	31	7
Ill-Defined Cancer	161	94	67
Intestine (small and large)	537	456	81
Larynx	58	54	4
Liver	28	17	11
Male Genital (incl. prostate)	448	397	51
Mouth and Pharynx	146	140	6
Not Cancer	21	20	1
Oesophagus	38	33	5
Pancreas	165	85	80
Rectum, RS Junction and Anus	259	247	12
Respiratory and Intrathoracic Organs	657	510	147
Salivary Glands	18	17	1
Skin (melanotic and other)	1748	1718	30
Stomach	267	210	57
Brain	128	91	37
Leukemia	166	84	82
Lymphoma	217	198	19
Sarcoma	115	104	11

(1) cases were regrouped according to morphology, behaviour, and topography

Source: New Brunswick Tumour Registry (1977-1980)

- Brain (M935-M957);
- Leukemia (M980-M998);
- Lymphoma (M958-M975);
- Sarcoma (M880-M899, M902-M934).

Approximately 6% (N=395) of the 6,527 non-city cases retained were missing morphology codes. Of the 128 cases within the classification brain, 19 are cases with no morphologic code that were topographically coded as brain or other nervous system (ICD-9=191-192). Sixty-two cases within the leukemias are also without morphology but were coded topographically as leukemias (ICD-9=203-208). Within the lymphomas 11 are missing morphology with topographic codes indicating lymphoma (ICD-9=200-202). Finally, only three of the sarcomas were without morphologic coding and these fell topographically within the bone and connective tissue tumours (ICD-9=170-171). All other cases were classified strictly on the basis of topographical coding. Appendix VIII lists the topographic codes for those sites regrouped solely on the basis of topography.

All remaining malignancies (N=6527) were analyzed regardless of whether they were microscopically confirmed. While there may well be some benign tumours included by this procedure, the total error rate is judged to be substantially smaller than the number of malignant tumours wrongly excluded by simply omitting all neoplasms not confirmed microscopically. Table 4.12 shows considerable variation with respect to the percentage of cases

microscopically confirmed, and for several sites these are numerous enough to warrant further attention. These are:

- Gallbladder; 18%
- Liver; 39%
- Pancreas; 48%
- Respiratory; 22%
- Stomach; 21%
- Brain; 29%
- Leukemia 49%

Microscopically confirmed cases for the above sites are analyzed separately to determine whether the results differ.

Melanotic skin cancers were also differentiated and examined separately as they are less subject to reporting bias than "other" skin cancers.

IV. STANDARDIZED INCIDENCE RATIOS (SIR'S)

Standardized Incidence Ratios were calculated using the 6,527 non-city cases and population of New Brunswick. Table 4.13 is the first of a series of tables that examines the ratios of observed to expected values for each grouping of sites by each study variable.

It appears that residence in predominantly English municipalities increases cancer risk to a variable degree, and up to as much as a factor of more than 3 for eye and oesophagus. Both eye and oesophagus are, however, among those sites with the fewest number of cases reported within the predominantly French municipalities. Notable exceptions to this trend are: larynx, pancreas, salivary glands, and

Table 4.13 Ratio of Observed to Expected By Site and Language/Culture (1)

Site	Observed/Expected (observed)		Risk Ratio	
	Predominantly French	Predominantly English	English/French	Confidence Interval (LCL,UCL)
All Sites	0.82 (1927)	1.10 (4600)	1.35	(1.28 - 1.42)
Bladder,Kidney, and Other Urinary Organs	0.74 (89)	1.15 (244)	1.56	(1.22 - 1.99)
Breast	0.92 (180)	1.04 (372)	1.13	(0.95 - 1.35)
Endocrine	0.54 (10)	1.27 (40)	2.37	(1.19 - 4.74)
Eye	0.39 (2)	1.35 (12)	3.43	(0.78 - 15.10)
Female Genital (incl. uterus/unspecified)	0.80 (103)	1.11 (260)	1.40	(1.11 - 1.75)
Gallbladder	0.60 (8)	1.22 (30)	2.04	(0.94 - 4.43)
Ill-Defined Cancer	0.97 (56)	1.02 (105)	1.05	(0.76 - 1.45)
Intestine (small and large)	0.92 (176)	1.05 (361)	1.14	(0.95 - 1.36)
Larynx	1.18 (25)	0.90 (33)	0.76	(0.45 - 1.27)
Liver	0.89 (9)	1.06 (19)	1.20	(0.54 - 2.64)
Male Genital (incl. prostate)	0.81 (134)	1.11 (314)	1.37	(1.12 - 1.68)
Mouth and Pharynx	0.98 (52)	1.01 (94)	1.04	(0.74 - 1.46)
Nasal, Middle Ear, Sinuses, Nasopharynx	0.66 (5)	1.20 (16)	1.82	(0.68 - 4.91)
Oesophagus	0.44 (6)	1.32 (32)	3.01	(1.27 - 7.13)
Pancreas	1.19 (70)	0.90 (95)	0.76	(0.55 - 1.03)
Rectum, RS Junction and Anus	0.86 (80)	1.08 (179)	1.26	(0.97 - 1.64)
Respiratory and Intrathoracic Organs	0.96 (229)	1.02 (428)	1.07	(0.91 - 1.26)
Salivary Glands	1.23 (8)	0.87 (10)	0.71	(0.28 - 1.80)
Skin (melanotic and other)	0.55 (349)	1.25 (1399)	2.27	(2.02 - 2.55)
Stomach	1.16 (111)	0.91 (156)	0.79	(0.62 - 1.01)
Brain	1.05 (50)	0.97 (78)	0.92	(0.64 - 1.31)
Leukemia	0.97 (59)	1.02 (107)	1.05	(0.77 - 1.45)
Lymphoma	0 98 (78)	1.01 (139)	1.03	(0.78 - 1.36)
Sarcoma	0.89 (38)	1.06 (77)	1.19	(0.81 - 1.75)

(1) greater than 50% of municipal population

Source: New Brunswick Tumour Registry 1977-80
1981 New Brunswick non-city population [Stats Canada E-562,1982]

stomach, for which risk is higher in predominantly French municipalities than in English municipalities. None of these sites, however, have confidence intervals that exclude 1.0.

Despite the exclusion of cities from the analysis, urban/rural residence remains a risk factor for the majority of sites (Table 4.14) although, aside from all sites combined, only breast, nasal, middle ear, sinuses, nasopharynx, and skin have confidence limits that exclude 1.0. Oesophagus, pancreas, salivary glands, and stomach are the exceptions to this trend.

Trends within educational attainment are present for a number of sites of cancer (Table 4.15). Aside from all sites combined, bladder, kidney, or other urinary organs, endocrine, gallbladder, intestine, male genital, and skin appear to be associated with educational attainment. All of these sites with the exception of endocrine have confidence limits for upper quartiles relative to the lowest quartiles that exclude 1.0. These are:

- Bladder, kidney, and other urinary organs; 1.29 - 2.55
- Gallbladder; 1.28 - 12.69
- Intestine; 1.18 - 2.0
- Male Genital; 1.2 - 2.0
- Skin; 1.5 - 2.0

Few consistent patterns were observed for incidence of low-income except for negative associations between spray exposure and gallbladder and intestine (Table 4.16).

Table 4.14 Ratio of Observed to Expected By Site and Urban/Rural Residence

Site	Observed/Expected (observed) Population Less than 2500	Population 2500 or more	Risk Ratio =>2500/<2500	Confidence Interval (LCL,UCL)
All Sites	0.97 (4864)	1.10 (1663)	1.14	(1.08 - 1.20)
Bladder, Kidney, and Other Urinary Organs	0.97 (251)	1.09 (82)	1.12	(0.87 - 1.43)
Breast	0.94 (387)	1.19 (165)	1.27	(1.06 - 1.53)
Endocrine	0.88 (33)	1.38 (17)	1.58	(0.88 - 2.83)
Eye	1.02 (11)	0.95 (3)	0.93	(0.26 - 3.33)
Female Genital (incl. uterus/unspecified)	1.02 (278)	0.94 (85)	0.92	(0.72 - 1.17)
Gallbladder	0.94 (27)	1.20 (11)	1.28	(0.63 - 2 57)
Ill-Defined Cancer	1.01 (125)	0.96 (36)	0.95	(0.65 - 1 37)
Intestine (small and large)	0.95 (392)	1.15 (145)	1.20	(1.00 - 1.46)
Larynx	0.86 (39)	1.48 (19)	1.71	(0 99 - 2.96)
Liver	0.97 (21)	1.11 (7)	1.14	(0 49 - 2.68)
Male Genital (incl. prostate)	0 96 (340)	1.16 (108)	1.21	(0.97 - 1.50)
Mouth and Pharynx	1.02 (116)	0.94 (30)	0.92	(0 62 - 1 38)
Nasal, Middle Ear, Sinuses, Nasopharynx	0 75 (12)	1.83 (9)	2.45	(1.03 - 5.82)
Oesophagus	1.08 (32)	0.71 (6)	0.66	(0.27 - 1.57)
Pancreas	1.06 (135)	0.79 (30)	0.74	(0.50 - 1.10)
Rectum, RS Junction and Anus	0.96 (192)	1.12 (67)	1.17	(0.88 - 1.54)
Respiratory and Intrathoracic Organs	0.98 (501)	1.09 (156)	1.11	(0.93 - 1.33)
Salivary Glands	1.08 (15)	0.72 (3)	0.67	(0.19 - 2 30)
Skin (melanotic and other)	0.94 (1266)	1.19 (482)	1.27	(1.14 - 1.41)
Stomach	1.03 (213)	0.89 (54)	0.86	(0.64 - 1.15)
Brain	1.03 (101)	0.91 (27)	0.89	(0.58 - 1.36)
Leukemia	1.00 (128)	0.99 (38)	0.98	(0 69 - 1.41)
Lymphoma	0.97 (161)	1.10 (56)	1.14	(0.84 - 1.55)
Sarcoma	1.01 (88)	0.98 (27)	0.98	(0.63 - 1.50)

Source. New Brunswick Tumour Registry 1977-80

Table 4.15 Ratio of Observed to Expected By Site and Educational Attainment (1) Quartiles (2)

Site	Observed/Expected (observed)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
All Sites	0.84 (1156)	0.89 (1340)	1.00 (1478)	1.17 (2553)
Bladder, Kidney, and Other Urinary Organs	0.64 (45)	1.01 (78)	1.11 (85)	1.15 (132)
Breast	0.80 (88)	1.00 (122)	0.99 (123)	1.12 (219)
Endocrine	0.79 (8)	0.79 (9)	0.88 (10)	1.34 (23)
Eye	1.01 (3)	1.23 (4)	0.31 (1)	1.32 (8)
Female Genital (incl. uterus/unspecified)	0.68 (49)	1.03 (83)	1.16 (95)	1.06 (136)
Gallbladder	0.39 (3)	0.59 (5)	1.18 (10)	1.50 (20)
Ill-Defined Cancer	0.92 (31)	0.79 (29)	1.21 (44)	1.05 (57)
Intestine (small and large)	0.78 (87)	0.94 (115)	0.98 (118)	1.19 (217)
Larynx	1.12 (14)	0.59 (8)	1.12 (15)	1.14 (21)
Liver	0.84 (5)	0.46 (3)	1.44 (9)	1.18 (11)
Male Genital (incl. prostate)	0.82 (81)	0.76 (82)	1.08 (111)	1.25 (174)
Mouth and Pharynx	1.11 (35)	0.87 (30)	0.83 (28)	1.14 (53)
Nasal, Middle Ear, Sinuses, Nasopharynx	0.68 (3)	0.42 (2)	1.46 (7)	1.29 (9)
Oesophagus	1.10 (9)	1.02 (9)	1.03 (9)	0.89 (11)
Pancreas	1.04 (36)	1.06 (40)	0.81 (30)	1.06 (59)
Rectum, RS Junction and Anus	1.01 (55)	0.89 (53)	0.95 (56)	1.10 (95)
Respiratory and Intrathoracic Organs	0.93 (133)	0.88 (136)	1.10 (167)	1.06 (221)
Salivary Glands	1.32 (5)	1.44 (6)	0.74 (3)	0.66 (4)
Skin (melanotic and other)	0.80 (292)	0.81 (326)	0.89 (351)	1.34 (779)
Stomach	1.05 (59)	0.94 (58)	1.16 (70)	0.90 (89)
Brain	0.80 (22)	1.08 (32)	1.02 (30)	1.06 (44)
Leukemia	1.11 (39)	0.73 (28)	0.88 (33)	1.20 (66)
Lymphoma	0.75 (34)	1.16 (58)	0.91 (45)	1.11 (89)
Sarcoma	0.84 (20)	0.91 (24)	1.11 (29)	1.99 (62)

(1) proportion of persons who attended university in the total population 15 or older

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes, quartile 1 is low

Source: New Brunswick Tumour Registry 1977-80

Table 4 16 Ratio of Observed to Expected Cases By Site and Incidence of Low-Income Quartiles

Site	Observed/Expected (observed)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
All Sites	1.15 (1753)	1.01 (1954)	0.94 (1731)	0.91 (1089)
Bladder, Kidney, and Other Urinary Organs	1.24 (95)	1.00 (98)	0.84 (80)	0.96 (60)
Breast	1.02 (139)	1.02 (167)	1.04 (160)	0.88 (86)
Endocrine	1.13 (15)	0.82 (12)	1.13 (15)	0.91 (8)
Eye	1.85 (6)	0.24 (1)	1.00 (4)	1.14 (3)
Female Genital (incl. uterus/unspecified)	1.16 (104)	0.90 (97)	1.05 (106)	0.87 (56)
Gallbladder	1.62 (14)	1.23 (14)	0.81 (9)	0.14 (1)
Ill-Defined Cancer	0.73 (27)	1.26 (60)	0.89 (41)	1.10 (33)
Intestine (small and large)	1.18 (145)	1.06 (169)	0.92 (142)	0 81 (81)
Larynx	0.43 (6)	1.36 (23)	1.05 (17)	1.09 (12)
Liver	1.78 (11)	0.60 (5)	0.98 (8)	0 75 (4)
Male Genital (incl. prostate)	1.38 (132)	1.08 (142)	0.79 (105)	0 78 (69)
Mouth and Pharynx	1.10 (37)	0.94 (40)	0.89 (37)	1.14 (32)
Nasal, Middle Ear, Sinuses, Nasopharynx	0.58 (3)	1.14 (7)	1.55 (9)	0.51 (2)
Oesophagus	1.17 (10)	0.99 (11)	0.63 (7)	1.38 (10)
Pancreas	1.11 (41)	1.00 (49)	0.79 (38)	1.20 (37)
Rectum, RS Junction and Anus	1.08 (65)	0.94 (72)	0.87 (64)	1.20 (58)
Respiratory and Intrathoracic Organs	1.11 (167)	1.04 (201)	0.88 (166)	0.98 (123)
Salivary Glands	0.98 (4)	0.93 (5)	1.16 (6)	0.88 (3)
Skin (melanotic and other)	1.22 (502)	1.02 (527)	0.97 (482)	0.73 (237)
Stomach	1.04 (63)	1.06 (84)	0.81 (63)	1 14 (57)
Brain	0.95 (31)	1.03 (38)	0.95 (33)	1.09 (26)
Leukemia	1.06 (42)	1.05 (51)	0.72 (34)	1.26 (39)
Lymphoma	1.11 (59)	0.93 (59)	1.04 (63)	0.90 (36)
Sarcoma	1.20 (35)	0.66 (22)	1.34 (42)	0.76 (16)

(1) expenditures for food, clothing, and shelter exceed the average level for the region of residence by at least 20%

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source New Brunswick Tumour Registry 1977-80

Endocrine, gallbladder, and liver cancers are positively associated with migration (Table 4.17).

Table 4.18 indicates that the cancer rates do not appear to be associated with level of agricultural activity within New Brunswick. Agricultural activity, defined as the percentage of a municipality's area that is under cultivation, is represented in this table as 4 broad ordinal classes.

No consistent trends in cancer rates are apparent for either DDT or organophosphate forestry pesticide exposure (Tables 4.19 and 4.20). With the exception of all sites combined for both DDT and organophosphates, and of respiratory tract for organophosphates, none of the confidence intervals for the highest score category relative to the lowest excluded 1.0. The confidence interval for DDT, all sites combined was: .76 - .96; for organophosphates, all sites combined: .74 - .90; and for organophosphates, respiratory: .46 - .49.

Table 4.17 Ratio of Observed to Expected By Site and Migration (1) Quartiles (2)

Site	Observed/Expected (observed)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
All Sites	1.03 (1522)	0.82 (1346)	1.07 (1974)	1.08 (1685)
Bladder, Kidney, and Other Urinary Organs	0.97 (73)	0.81 (68)	1.03 (97)	1.21 (95)
Breast	1.05 (128)	0.84 (112)	1.02 (161)	1.09 (151)
Endocrine	0.54 (6)	0.67 (8)	0.96 (13)	1.72 (23)
Eye	1.26 (4)	0.56 (2)	1.01 (4)	1.21 (4)
Female Genital (incl. uterus/unspecified)	1.12 (90)	0.87 (76)	1.06 (110)	0.95 (87)
Gallbladder	0.48 (4)	0.85 (8)	1.07 (12)	1.56 (14)
Ill-Defined Cancer	1.00 (36)	1.09 (44)	0 97 (45)	0.94 (36)
Intestine (small and large)	1.02 (122)	0.83 (112)	1.06 (165)	1.09 (138)
Larynx	1.35 (18)	0.68 (10)	1.06 (17)	0.93 (13)
Liver	0.48 (3)	0.98 (7)	0.99 (8)	1.54 (10)
Male Genital (incl. prostate)	1.10 (114)	0.66 (78)	1 11 (141)	1.15 (115)
Mouth and Pharynx	1.04 (35)	1.07 (40)	1.03 (42)	0.84 (29)
Nasal, Middle Ear, Sinuses, Nasopharynx	0.84 (4)	0.58 (3)	1.20 (7)	1.35 (7)
Oesophagus	1.04 (9)	0.62 (6)	1.29 (14)	1.03 (9)
Pancreas	1.00 (37)	0.99 (41)	0.92 (44)	1.12 (43)
Rectum, RS Junction and Anus	1.30 (76)	0.75 (49)	0.99 (73)	0.99 (61)
Respiratory and Intrathoracic Organs	1.10 (167)	0.81 (136)	1.13 (209)	0.95 (145)
Salivary Glands	0.98 (4)	1.10 (5)	0.97 (5)	0.94 (4)
Skin (melanotic and other)	0.91 (359)	0.75 (330)	1.15 (571)	1.16 (488)
Stomach	1.28 (77)	0.89 (60)	0 86 (66)	1.03 (64)
Brain	1.11 (33)	0.95 (30)	1.11 (38)	0.83 (27)
Leukemia	1.32 (50)	0.75 (31)	0 95 (44)	1.01 (41)
Lymphoma	0.91 (45)	1.04 (56)	1.03 (62)	1.00 (54)
Sarcoma	1.07 (28)	1.21 (34)	0.83 (26)	0.92 (27)

(1) persons living in a different municipality in 1981 from the one they occupied in 1976

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source: New Brunswick Tumour Registry 1977-80

Table 4.18 Ratio of Observed to Expected By Site and Agricultural Activity (1) Quartiles (2)

Site	Observed/Expected (observed)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
All Sites	0.91 (1308)	1.09 (1530)	0 92 (1547)	1 07 (1[illegible])
Bladder, Kidney, and Other Urinary Organs	0.80 (59)	1.31 (93)	0 98 (85)	0.94 (86)
Breast	0 98 (116)	0.98 (118)	0 93 (130)	1 09 (1[illegible])
Endocrine	0.55 (6)	1.21 (14)	0 73 (9)	1 39 ([illegible])
Eye	1.30 (4)	0.67 (2)	0 28 (1)	1 [illegible] ([illegible])
Female Genital (incl. uterus/unspecified)	0.95 (74)	1 11 (88)	0 90 (83)	1 0[illegible] (11[illegible])
Gallbladder	0.61 (5)	1.27 (10)	1 01 (10)	1 09 (13)
Ill-Defined Cancer	1.05 (37)	1.06 (36)	0 86 (36)	1 0[illegible] ([illegible])
Intestine (small and large)	0 86 (100)	1.09 (123)	1 02 (143)	1 02 (171)
Larynx	0 86 (11)	0.63 (8)	1 02 (15)	1 35 ([illegible])
Liver	0.00 (0)	1.56 (9)	0 81 (6)	1.51 (13)
Male Genital (incl. prostate)	0.93 (94)	1.13 (104)	0 90 (107)	1 05 (1[illegible])
Mouth and Pharynx	1.11 (36)	1.02 (32)	1 04 (39)	0 88 (37)
Nasal, Middle Ear, Sinuses, Nasopharynx	0 43 (2)	0 21 (1)	1 51 (8)	1 56 (10)
Oesophagus	1.31 (11)	1.38 (11)	0 51 (5)	0 93 (11)
Pancreas	1.00 (36)	0.64 (22)	1 32 (57)	0.97 (50)
Rectum, RS Junction and Anus	0.90 (51)	0 98 (54)	0 96 (64)	1.12 (90)
Respiratory and Intrathoracic Organs	1.04 (151)	1.09 (154)	1 03 (174)	0 88 (178)
Salivary Glands	1.26 (5)	0.79 (3)	0 85 (4)	1 09 (6)
Skin (melanotic and other)	0.83 (320)	1.21 (456)	0 75 (337)	1 18 ([illegible])
Stomach	0 91 (53)	0.91 (51)	1 17 (82)	0 98 (81)
Brain	1.09 (31)	0.85 (25)	1 04 (33)	1 01 (32)
Leukemia	1.15 (42)	1.11 (40)	0 80 (34)	0.99 (56)
Lymphoma	0.98 (47)	0 92 (44)	1 03 (57)	1 04 (69)
Sarcoma	0.67 (17)	1 23 (32)	0 97 (28)	1 09 (38)

(1) percentage of land under cultivation

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the 254 municipalities in each of 4 classes; quartile 1 is low

Source: New Brunswick Tumour Registry 1977-80

Table 4.19 Ratio of Observed to Expected By Site and DDT Near-Distance Exposure (1)

Site	Observed/Expected (observed)				
	Zero (0)	Low (1 down to 0)	Moderate (2 down to 1)	High (3 down to 2)	Very High (6 down to 3)
All Sites	1.10 (3395)	0.94 (2503)	0.83 (214)	0.53 (104)	0.94 (311)
Bladder,Kidney, and Other Urinary Organs	1.08 (170)	0.96 (130)	1.21 (16)	0.10 (1)	0.94 (16)
Breast	1.15 (309)	0.92 (201)	0.60 (13)	0.23 (4)	0.94 (25)
Endocrine	1.07 (25)	1.12 (23)	0.49 (1)	0.00 (0)	0.42 (1)
Eye	1.22 (8)	0.70 (4)	1.78 (1)	2.39 (1)	0.00 (0)
Female Genital (incl. uterus/ unspecified)	1.12 (198)	0 92 (132)	0.70 (10)	0.26 (3)	1.15 (20)
Gallbladder	1.33 (25)	0.74 (11)	0.00 (0)	0.00 (0)	1.05 (2)
Ill-Defined Cancer	1.01 (78)	0.97 (63)	0.80 (5)	1.67 (8)	0.86 (7)
Intestine (small and large)	1.13 (294)	0.96 (205)	0.54 (11)	0.38 (6)	0.78 (21)
Larynx	1.02 (27)	1.11 (27)	0.82 (2)	0.00 (0)	0.67 (2)
Liver	1.12 (15)	1.07 (12)	0.94 (1)	0.00 (0)	0.00 (0)
Male Genital (incl prostate)	1.16 (240)	0.94 (176)	0.57 (10)	0.80 (10)	0.50 (12)
Mouth and Pharynx	1.01 (68)	0.99 (60)	0.84 (5)	0.92 (4)	1.18 (9)
Nasal, Middle Ear, Sinuses, Nasopharynx	1.33 (13)	0.81 (7)	1.15 (1)	0.00 (0)	0.00 (0)
Oesophagus	1.01 (18)	0.84 (13)	1.34 (2)	1.84 (2)	1.52 (3)
Pancreas	1.21 (96)	0 85 (56)	1.11 (7)	0.42 (2)	0.48 (4)
Rectum, RS Junction and Anus	1.04 (128)	0.95 (100)	1.07 (11)	0.39 (3)	1.29 (17)
Respiratory and Intrathoracic Organs	1.04 (316)	1.00 (273)	1.00 (27)	0.57 (11)	0.88 (30)
Salivary Glands	1.16 (10)	0.97 (7)	0.00 (0)	1.88 (1)	0.00 (0)
Skin (melanotic and other)	1 11 (918)	0.89 (633)	0.81 (56)	0.64 (34)	1.21 (107)
Stomach	1.10 (141)	0.96 (103)	1.16 (12)	0.64 (5)	0.51 (7)
Brain	1.08 (65)	0.99 (53)	0.55 (3)	0.47 (2)	1.11 (7)
Leukemia	1.06 (85)	0.94 (64)	0.76 (5)	0.58 (3)	1.33 (11)
Lymphoma	0.99 (100)	1.15 (102)	0.80 (7)	0.29 (2)	0.56 (6)
Sarcoma	0.99 (53)	1.01 (48)	1.72 (8)	0.53 (2)	0.72 (4)

(1) based on 0-1 kilometer exposure definition

Source New Brunswick Tumour Registry 1977-80

Table 4.20 Ratio of Observed to Expected By Site and Organophosphate Near-Distance Exposure (1)

Site	Observed/Expected (observed)				
	Zero (0)	Low (1 down to 0)	Moderate (2 down to 1)	High (3 down to 2)	Very High (6 down to 3)
All Sites	1.26 (1248)	1.01 (1980)	0.85 (1877)	1.04 (878)	1.03 (544)
Bladder, Kidney, and Other Urinary Organs	1.43 (72)	0.99 (99)	0.75 (84)	1.16 (50)	1.05 (39)
Breast	1.21 (104)	1.02 (169)	0.81 (150)	1.20 (86)	0.99 (63)
Endocrine	1.08 (8)	1.21 (19)	0.71 (12)	1.10 (7)	1.07 (4)
Eye	0.48 (1)	0.47 (2)	1.27 (6)	2.23 (4)	0.88 (1)
Female Genital (incl. uterus/ unspecified)	1.28 (72)	0.99 (108)	0.81 (99)	1.19 (56)	0.98 (38)
Gallbladder	1.51 (9)	0.63 (7)	0.94 (12)	1.38 (7)	0.97 (5)
Ill-Defined Cancer	1.26 (31)	1.08 (52)	0.92 (50)	0.71 (15)	0.99 (13)
Intestine (small and large)	1.47 (122)	1.01 (161)	0.88 (158)	0.80 (56)	0.92 (40)
Larynx	1.53 (13)	1.07 (19)	0.82 (16)	1.36 (10)	0.00 (0)
Liver	0.92 (4)	0.84 (7)	1.28 (12)	1.08 (4)	0.44 (1)
Male Genital (incl. prostate)	1.42 (95)	0.86 (116)	1.03 (155)	0.94 (55)	0.72 (27)
Mouth and Pharynx	1.53 (33)	0.99 (44)	0.77 (38)	0.91 (17)	1.17 (14)
Nasal, Middle Ear, Sinuses, Nasopharynx	2.90 (9)	0.62 (4)	0.71 (5)	0.74 (2)	0.60 (1)
Oesophagus	0.88 (5)	0.79 (9)	1.02 (13)	1.01 (5)	1.90 (6)
Pancreas	1.06 (27)	1.27 (62)	0.81 (45)	0.74 (16)	1.11 (15)
Rectum, RS Junction and Anus	1.27 (50)	0.98 (76)	0.87 (76)	1.04 (35)	1.05 (22)
Respiratory and Intrathoracic Organs	1.38 (134)	1.05 (211)	0.82 (182)	0.97 (82)	0.89 (48)
Salivary Glands	1.08 (3)	0.37 (2)	1.16 (7)	2.55 (6)	0.00 (0)
Skin (melanotic and other)	1.16 (307)	0.98 (516)	0.81 (479)	1.16 (264)	1.29 (182)
Stomach	1.30 (53)	1.13 (90)	0.84 (75)	0.89 (51)	0.82 (18)
Brain	0.91 (17)	1.11 (44)	0.97 (42)	0.87 (14)	1.10 (11)
Leukemia	1.20 (30)	1.05 (53)	0.89 (50)	0.84 (18)	1.14 (15)
Lymphoma	0.99 (32)	1.20 (80)	0.83 (61)	0.93 (26)	1.05 (18)
Sarcoma	0.99 (17)	0.84 (30)	1.29 (50)	0.82 (12)	0.68 (6)

(1) based on 0-1 kilometer exposure destination

Source: New Brunswick Tumour Registry 1977-80

V. APPROACH TO ANALYSIS OF PESTICIDE EXPOSURE DATA

Several broad decisions were made prior to the commencement of analysis. These were necessary due to the large number of cancer sites (N=25), exposure indices (N=4), and other variables under consideration.

The first step was to ascertain the effect of changing index cutoffs (the distances from a sprayed area in which persons were considered exposed). The effect on cancer risk estimates of altering these cutoffs was examined. Separate comparisons were carried out for DDT and for the organophosphates because their different methods of application might affect exposures of humans at a distance. No important differences were noted and the 1 kilometer cutoff was retained.

Secondly, exposure covariates were introduced into the statistical models in sequence by their decreasing importance as potential confounders, as subjectively assessed by the author. All covariates, with the exception of language and urban/rural residence, were expressed as rates, divided into quartiles, and assigned four level scores corresponding to the quartiles. These 4 point scales were then treated as continuous in the analysis. No covariate, once included within a model, was dropped from subsequent models.

Both DDT and organophosphate indices were treated as continuous variates in the regression analyses.

Finally, quartile scores were calculated for the near and moderate-distance exposure indices and used in independent analyses of DDT and organophosphates in order to assess the affect on risk estimates of using more complete and complicated indices that included all of the spray data.

VI. RESULTS OF MULTIVARIATE ANALYSIS

Poisson regression was used to estimate standardized incidence ratios (SIR). As indicated previously (Methods), several preliminary analyses were performed to examine the appropriateness of the multiplicative model and the effectiveness of the age standardization. Statistical significance is defined uniformly as two-tail $p < 0.05$.

The average near-distance exposure score for non-city municipalities in New Brunswick is 0.55 for DDT and 1.48 for organophosphates. In both cases scores range between 0 and 5. Table 4.21 shows the crude SIR estimates for DDT and organophosphate near-distance indices. In no cases are risks significantly elevated and only for eye cancer does the point estimate noticeably exceed 1.0. Overall, the cancer risks associated with exposure to organophosphate forestry spray are lower than those of DDT.

Tables 4.22 and 4.23 present the effects of controlling for all study covariates. Neither table shows a consistent trend towards an increase or a decrease in the magnitude of the estimated effects. In only one case, organophosphate

Table 4.21 Crude (1) Relative Risk Estimates for DDT and Organophosphate Near-Distance Exposure (2) by Site

Site	Cases	DDT Crude Model		Organophosphate Crude Model	
		95% C.I.	Point Estimate	Point Estimate	95% C.I.
All Sites	6527	0.94 - 0.99	0.96	0.98	0.96 - 1.00
Bladder, Kidney, and Other Urinary Organs	333	0.87 - 1.09	0.98	0.97	0.88 - 1.07
Breast	552	0.82 - 1.00	0.91	1.00	0.92 - 1.08
Endocrine	50	0.60 - 1.21	0.85	0.95	0 73 - 1.24
Eye	14	0.44 - 1.64	0.85	1.45	0.96 - 2.20
Female Genital (incl. uterus/unspecified)	363	0.84 - 1.06	0.94	0.95	0.86 - 1.04
Gallbladder	38	0.51 - 1.23	0.80	1.05	0.79 - 1.39
Ill-Defined Cancer	161	0.89 - 1.21	1.04	0.94	0.81 - 1.08
Intestine (small and large)	537	0.80 - 0.98	0.89	0.90	0.83 - 0.97
Larynx	58	0.62 - 1.17	0.85	0.87	0.67 - 1.12
Liver	28	0.22 - 1.19	0.52	1.00	0.71 - 1.40
Male Genital (incl prostate)	448	0.74 - 0.94	0.83	0.91	0 84 - 1.00
Mouth and Pharynx	146	0.91 - 1.23	1.06	0.91	0.78 - 1.06
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.17 - 1.29	0.46	0.60	0.37 - 0.99
Oesophagus	38	0.85 - 1.48	1.13	1.18	0.90 - 1.55
Pancreas	165	0.65 - 0.98	0.80	0.93	0.81 - 1.08
Rectum, RS Junction and Anus	259	0.92 - 1.16	1.03	1.00	0.89 - 1.11
Respiratory and Intrathoracic Organs	657	0.89 - 1.05	0.97	0.90	0.84 - 0 97
Salivary Glands	18	0.31 - 1.46	0.67	1.07	0.71 - 1.61
Skin (melanotic and other)	1748	0.99 - 1.09	1.04	1.07	1.03 - 1.12
Stomach	267	0.77 - 1.02	0.89	0.89	0 79 - 1.00
Brain	128	0.79 - 1.15	0.95	1.01	0.86 - 1.18
Leukemia	166	0.88 - 1.19	1.03	0.96	0.83 - 1.10
Lymphoma	217	0.72 - 1.01	0.85	0.99	0.87 - 1.12
Sarcoma	115	0.80 - 1.18	0.97	0.95	0.80 - 1.13

(1) grand mean and near-distance indices were the only terms in the models

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

Table 4.22 Crude (1) and Full Model (2) Relative Risk Estimates for DDT Near-Distance Exposure (3) By Site

Site	Cases	DDT Crude Model		DDT Full Model	
		95% C.I.	Point Estimate	Point Estimate	95% C.I.
All Sites	6527	0.94 - 0.99	0.96	0.95	0.92 - 0.98
Bladder, Kidney, and Other Urinary Organs	333	0.87 - 1.09	0.98	0.96	0.84 - 1.10
Breast	552	0.82 - 1.00	0.91	0.90	0.80 - 1.03
Endocrine	50	0.60 - 1.21	0.85	0.89	0.59 - 1.36
Eye	14	0.44 - 1.64	0.85	0.62	0.31 - 1.26
Female Genital (incl. uterus/unspecified)	363	0.84 - 1.06	0.94	0.89	0.78 - 1.02
Gallbladder	38	0.51 - 1.23	0.80	0.78	0.48 - 1.27
Ill-Defined Cancer	161	0.89 - 1.21	1.04	1.06	0.88 - 1.28
Intestine (small and large)	537	0.80 - 0.98	0.89	0.93	0.83 - 1.05
Larynx	58	0.62 - 1.17	0.85	0.99	0.68 - 1.44
Liver	28	0.22 - 1.19	0.52	0.59	0.25 - 1.38
Male Genital (incl. prostate)	448	0.74 - 0.94	0.83	0.83	0.72 - 0.95
Mouth and Pharynx	146	0.91 - 1.23	1.06	1.09	0.90 - 1.33
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.17 - 1.29	0.46	0.63	0.19 - 2.02
Oesophagus	38	0.85 - 1.48	1.13	0.90	0.64 - 1.26
Pancreas	165	0.65 - 0.98	0.80	0.81	0.64 - 1.02
Rectum, RS Junction and Anus	259	0.92 - 1.16	1.03	1.04	0.90 - 1.20
Respiratory and Intrathoracic Organs	657	0.89 - 1.05	0.97	0.99	0.90 - 1.10
Salivary Glands	18	0.31 - 1.46	0.67	0.58	0.25 - 1.36
Skin (melanotic and other)	1748	0.99 - 1.09	1.04	0.99	0.94 - 1.05
Stomach	267	0.77 - 1.02	0.89	0.92	0.78 - 1.09
Brain	128	0.79 - 1.15	0.95	0.91	0.73 - 1.13
Leukemia	166	0.88 - 1.19	1.03	1.01	0.83 - 1.21
Lymphoma	217	0.72 - 1.01	0.85	0.83	0.68 - 1.00
Sarcoma	115	0.80 - 1.18	0.97	0.98	0.77 - 1.24

(1) grand mean and DDT near-distance index were the only terms in the models

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) the nearest spray block within 1 kilometer for each spray year were accumulated over years

Table 4.23 Crude (1) and Full Model (2) Relative Risk Estimates for Organophosphate Near-Distance Exposure (3) By Site

Site	Cases	Organophosphate Crude Model 95% C.I.	Organophosphate Crude Model Point Estimate	Organophostate Full Model Point Estimate	Organophostate Full Model 95% C.I.
All Sites	6527	0.96 - 1.00	0.98	0.97	0.94 - 0.99
Bladder, Kidney, and Other Urinary Organs	333	0.88 - 1.07	0.97	0.94	0.84 - 1.05
Breast	552	0.92 - 1.08	1.00	1.02	0.93 - 1.1[illegible]
Endocrine	50	0.73 - 1.24	0.95	0.83	0.62 - 1.1[illegible]
Eye	14	0.96 - 2.20	1.45	1.59	0.97 - 2.61
Female Genital (incl. uterus/unspecified)	363	0.86 - 1.04	0.95	0.96	0.86 - 1.07
Gallbladder	38	0.79 - 1.39	1.05	1.09	0.80 - 1.50
Ill Defined Cancer	161	0 81 - 1.08	0.94	0.91	0.77 - 1.08
Intestine (small and large)	537	0.83 - 0.97	0.90	0.91	0 83 - 1.00
Larynx	58	0.67 - 1.12	0.87	0.90	0.67 - 1.20
Liver	28	0.71 - 1.40	1.00	1.09	0.74 - 1.61
Male Genital (incl. prostate)	448	0.84 - 1.00	0.91	0.94	0 85 - 1.04
Mouth and Pharynx	146	0.78 - 1.06	0.91	0.87	0.73 - 1.05
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.37 - 0.99	0.60	0.55	0 34 - 0.91
Oesophagus	38	0.90 - 1.55	1.18	1.05	0.77 - 1.43
Pancreas	165	0.81 - 1.08	0.93	1.03	0.87 - 1.21
Rectum, RS Junction and Anus	259	0.89 - 1.11	1.00	0.97	0.85 - 1.11
Respiratory and Intrathoracic Organs	657	0.84 - 0.97	0.90	0.90	0.83 - 0.98
Salivary Glands	18	0.71 - 1.61	1.07	1.24	0.78 - 1.98
Skin (melanotic and other)	1748	1.03 - 1.12	1.07	1.00	0.96 - 1.05
Stomach	267	0.79 - 1.00	0.89	0.95	0.83 - 1.09
Brain	128	0.86 - 1.18	1.01	1.08	0.89 - 1.30
Leukemia	166	0 83 - 1.10	0.96	0.96	0.81 - 1.13
Lymphoma	217	0.87 - 1.12	0.99	1.05	0.91 - 1.21
Sarcoma	115	0.80 - 1.13	0.95	0.97	0.79 - 1.19

(1) grand mean and organophosphate near-distance index were the only terms in the models

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) the nearest spray block within 1 kilometer for each spray year were accumulated over years

exposure and all sites combined, did an estimate become statistically significant after controlling for the covariates. In both tables intestine became statistically non-significant after the introduction of covariates into the model, and nasal, middle ear, sinuses, and nasopharynx for DDT, and pancreas for organophosphates, similarly lost statistical significance.

The second and third columns of numbers in Table 4.24 contain deviances from two Poisson regression models. Poisson regression deviances are equivalent to the residual sum of squares in a regular regression and represent the unexplained variability. The deviances in column 2 are from a Poisson regression with the following terms: near-distance exposure for DDT, agriculture, urban/rural, French, income, education, and migration. The deviances in column 3 are from a model with the same terms plus six interaction terms; one for each product of the DDT term and each of the covariates. These product terms (interactions) were included to test whether the effect of DDT varied across covariate levels. A comparison of the deviances from both models indicates that none of the differences are notably large and none are statistically significant with the exception of all cancer sites combined. Results for organophosphates are essentially the same and therefore not presented. These results provide little evidence to support the premise that any of the covariates modify the effects of DDT on any of the specific site groupings examined.

Table 4.24 Deviances for DDT Near-Distance Model With All Covariates In by Site and Presence of Interaction Terms

Site	Cases	Deviance for Model With No Interaction Terms	Deviance for Model With Interaction Terms
All Cancer	6527	1573.000	1539.000
Bladder, Kidney, and Other Urinary Organs	333	340.500	332.300
Breast	552	389.700	384.000
Endocrine Glands	50	142.300	138.500
Eye	14	70 870	61.680
Female Genital (incl. uterus/unspecified)	363	339.200	332.000
Gallbladder	38	115.300	108.100
Ill Defined Cancers	161	239.200	221.100
Intestine (small and large)	537	376.900	366.800
Larynx	58	159.100	151.800
Liver	28	99 710	98.320
Male Genital (incl. prostate)	448	368 800	358.800
Mouth and Pharynx	146	275.200	265.800
Nasal, Middle Ear, Sinuses, Nasopharynx	21	73.050	70.080
Oesophagus	38	134.000	125.100
Pancreas	165	243.100	237.500
Rectum, RS Junction, and Anus	259	272.900	267.200
Respiratory and Intrathoracic Organs	657	415.600	411.300
Salivary Glands	18	87.260	82.810
Skin (melanotic and other)	1748	859.200	826.000
Stomach	267	298.100	293.400
Brain	128	192 600	189.400
Leukemias	166	226.500	224.200
Lymphomas	217	311.000	308.500
Sarcomas	115	224.500	220.000

Tables 4.25 (for DDT) and 4.26 (for organophosphates) present risk estimates for males and females separately. Table 4.25 demonstrates greater consistency between the sexes in the case of DDT exposure than table 4.26. Of all the sites listed, only all sites combined and intestine are essentially the same for both exposures and both sexes. Conversely, breast, eye, gallbladder, and salivary glands demonstrate remarkable site/sex shifts in behaviour. For example, it is remarkable that in the case of gallbladder, DDT exposure appears harmful for males but protective for females while the reverse appears to be the case for organophosphate exposure. It is, however, important to note that these are sites with small numbers of cases, and further analysis is presented below to help determine which differences can reasonably be explained by chance alone.

All previous risk estimates have involved the use of near-distance exposure indices for DDT and organophosphate sprays, in which a municipality receives a score of 1 or fraction thereof (see Methods for a more detailed explanation) for each year that one or more spray blocks is within 1 kilometer. Scores are added over years to obtain a total exposure score.

The calculation of medium-range scores involves all spray blocks within a 5 kilometer radius of each settlement for DDT and a 10 kilometer radius for organophosphates.

Table 4.25 Full Model (1) Relative Risk Estimates for DDT Near-Distance Exposure (2) By Sex and Site

Site	Males			Females		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Sites	3669	0.92 - 1.00	0.96	0.94	0.89 - 0.98	2858
Bladder, Kidney, and Other Urinary Organs	225	0.86 - 1.20	1.02	0.86	0.67 - 1.10	108
Breast	10	0.87 - 3.55	1.76	0.88	0.79 - 0.99	542
Endocrine	14	0.39 - 2.16	0.91	0.87	0.54 - 1.41	36
Eye	8	0.35 - 1.74	0.78	0.35	0.06 - 2.07	6
Female Genital (incl. uterus/unspecified)	NA	NA	NA	0.89	0.78 - 1.02	363
Gallbladder	14	0.64 - 2.29	1.21	0.48	0.19 - 1.22	24
Ill Defined Cancer	86	0.79 - 1.33	1.02	1.10	0.84 - 1.44	75
Intestine (small and large)	265	0.83 - 1.13	0.97	0.89	0.74 - 1.07	272
Larynx	46	0.66 - 1.45	0.98	0.95	0.27 - 3.34	12
Liver	17	0.18 - 2.10	0.62	0.54	0.16 - 1.80	11
Male Genital (incl. prostate)	448	0.72 - 0.95	0.83	NA	NA	NA
Mouth and Pharynx	124	0.89 - 1.35	1.10	1.09	0.62 - 1.92	22
Nasal, Middle Ear, Sinuses, Nasopharynx	11	0.03 - 4.11	0.32	0.79	0.21 - 3.00	10
Oesophagus	26	0.77 - 1.66	1.13	0.29	0.06 - 1.35	12
Pancreas	91	0.60 - 1.11	0.81	0.80	0.56 - 1.14	74
Rectum, RS Junction and Anus	153	0.86 - 1.25	1.04	1.04	0.82 - 1.32	106
Respiratory and Intrathoracic Organs	538	0.90 - 1.12	1.01	0.93	0.73 - 1.17	119
Salivary Glands	11	0.24 - 1.62	0.63	0.43	0.06 - 3.07	7
Skin (melanotic and other)	1043	0.89 - 1.02	0.95	1.06	0.96 - 1.16	705
Stomach	175	0.79 - 1.18	0.96	0.85	0.63 - 1.15	92
Brain	81	0.71 - 1.18	0.92	0.81	0.48 - 1.36	47
Leukemia	97	0.70 - 1.17	0.90	1.15	0.88 - 1.52	69
Lymphoma	127	0.63 - 1.06	0.82	0.83	0.63 - 1.10	90
Sarcoma	59	0.81 - 1.51	1.10	0.84	0.58 - 1.22	56

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms
(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

NA not applicable

Table 4.26 Full Model (1) Relative Risk Estimates for Organophosphate Near-Distance Exposure (2) By Sex and Site

Site	Males			Females		
	Cases	95% C I.	Point Estimate	Point Estimate	95% C I	Cases
All Sites	3669	0.95 - 1.01	0.98	0.96	0.92 - 0.99	[illegible]
Bladder, Kidney, and Other Urinary Organs	225	0.77 - 1.02	0 88	1 03	0 86 1 [illegible]	1 [illegible]
Breast	10	0.32 - 1.40	0 67	1 02	0 9[illegible] 1 1[illegible]	[illegible]
Endocrine	14	0.38 - 1.25	0.69	0.89	0 6[illegible] - 1 [illegible]	[illegible]
Eye	8	0.73 - 2.64	1.39	2.00	0 91 - 4 36	6
Female Genital (incl. uterus/unspecified)	NA	NA	NA	0 96	0 86 1 07	[illegible]
Gallbladder	14	0.44 - 1.45	0.80	1 23	0 8[illegible] 1 80	[illegible]
Ill-Defined Cancer	86	0.78 - 1.23	0.98	0 85	0 67 1 09	[illegible]
Intestine (small and large)	265	0.84 - 1.09	0 96	0 86	0 76 0 99	[illegible]
Larynx	46	0.74 - 1.40	1 02	0.48	0 22 1 04	1[illegible]
Liver	17	0.54 - 1.62	0 94	1 26	0 73 - 2 19	11
Male Genital (incl. prostate)	448	0.85 - 1 04	0 94	NA	NA	NA
Mouth and Pharynx	124	0.69 - 1.03	0 85	1 01	0 64 1 57	[illegible]
Nasal, Middle Ear, Sinuses, Nasopharynx	11	0.39 - 1.42	0 75	0 41	0 17 - 0 98	10
Oesophagus	26	0.62 - 1.43	0 94	1.08	0.68 - 1 71	1[illegible]
Pancreas	91	0.82 - 1 29	1 03	1 02	0 81 1 29	[illegible]
Rectum, RS Junction and Anus	153	0.88 - 1.23	1.04	0 89	0 72 1 09	10[illegible]
Respiratory and Intrathoracic Organs	538	0.80 - 0 96	0 88	0 99	0 82 1 [illegible]	11[illegible]
Salivary Glands	11	0.66 - 2.18	1 20	1 31	0 62 2 77	[illegible]
Skin (melanotic and other)	1043	1.00 - 1.13	1 06	0.92	0 85 - 1 00	[illegible]
Stomach	175	0.79 - 1.11	0 94	0 97	0 78 1 21	[illegible]
Brain	81	0.97 - 1.50	1 20	0 83	0 58 1 17	[illegible]
Leukemia	97	0.79 - 1.21	0.98	0 93	0 72 1 [illegible]	[illegible]
Lymphoma	127	0.91 - 1.32	1.09	1 00	0 81 1 [illegible]	[illegible]
Sarcoma	59	0.70 - 1.28	0 95	0 99	0 [illegible] - 1 [illegible]	[illegible]

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, ethnic, and migration [illegible]
(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

NA not applicable

Near-distance relative risk estimates are easiest to interpret insofar as they represent per year increases in cancer risk. The medium-distance exposure scores were transformed mathematically to reflect spray deposition patterns, and therefore the risk estimates generated from models in which they are used have no simple interpretation. However, because the medium-distance indices use more exposure information than the near-distance indices and because their values are scaled to reflect certain assumptions about deposition rates, relative risk estimates generated from the analysis of each type of index were compared. Their comparison is complicated by the scaling of the medium-distance scores which makes their units non-comparable to those of the near-distance index.

In order to establish uniform units for both indices, the 254 municipalities were assigned scores between 1 and 4 according to which of 4 ordered classes (quartiles) they belonged. This was done for each exposure (near and medium-distance). Thus a score of 1 for a particular index indicated that the municipality was situated in the lowest quartile of the exposure distribution. These scores were treated as continuous variates in Poisson regressions thus providing relative risk estimates per quartile unit. Tables 4.27 (for DDT) and 4.28 (for organophosphates) contain the results of these comparisons.

Table 4.27 Full Model (1) Relative Risk Estimates for DDT Near-Distance and Medium-Distance Exposure (2) By Site

Site	Cases	Near-Distance 95% C.I.	Near-Distance Point Estimate	Medium Distance Point Estimate	Medium Distance 95% C.I.
All Sites	6527	0.92 - 0.96	0.94	0.96	0.9[illegible] 0.[illegible]
Bladder, Kidney, and Other Urinary Organs	333	0.90 - 1.12	1.00	1.02	0.93 1.1[illegible]
Breast	552	0.82 - 0.98	0.90	0.92	0.8[illegible] 1.[illegible]
Endocrine	50	0.84 - 1.58	1.15	1.10	0.80 1.51
Eye	14	0.54 - 1.59	0.93	0.89	0.[illegible] 1.[illegible]
Female Genital (incl. uterus/unspecified)	363	0.77 - 0.95	0.85	0.90	0.81 1.00
Gallbladder	38	0.56 - 1.10	0.78	0.81	0.5[illegible] 1.[illegible]
Ill-Defined Cancer	161	0.81 - 1.11	0.95	0.95	0.80 1.11
Intestine (small and large)	537	0.84 - 1.01	0.92	0.92	0.8[illegible] 1.00
Larynx	58	0.89 - 1.60	1.19	1.24	0.92 1.67
Liver	28	0.68 - 1.57	1.03	1.08	0.71 1.65
Male Genital (incl. prostate)	448	0.82 - 1.00	0.90	0.95	0.87 1.05
Mouth and Pharynx	146	0.79 - 1.11	0.94	1.04	0.88 1.24
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.39 - 1.12	0.66	0.72	0.43 1.[illegible]
Oesophagus	38	0.73 - 1.38	1.00	1.01	0.7[illegible] 1.[illegible]
Pancreas	165	0.68 - 0.94	0.80	0.88	0.74 - 1.04
Rectum, RS Junction and Anus	259	0.91 - 1.17	1.03	1.03	0.90 1.17
Respiratory and Intrathoracic Organs	657	0.91 - 1.06	0.98	1.00	0.92 1.08
Salivary Glands	18	0.45 - 1.21	0.74	1.26	0.76 2.11
Skin (melanotic and other)	1748	0.90 - 0.99	0.94	0.96	0.91 1.[illegible]
Stomach	267	0.80 - 1.03	0.90	0.95	0.8[illegible] 1.[illegible]
Brain	128	0.80 - 1.15	0.96	0.92	0.77 1.[illegible]
Leukemia	166	0.83 - 1.14	0.97	1.07	0.91 1.[illegible]
Lymphoma	217	0.83 - 1.10	0.96	1.00	0.8[illegible] 1.[illegible]
Sarcoma	115	0.85 - 1.25	1.03	1.04	0.86 1.27

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

Table 4.28 Full Model (1) Relative Risk Estimates for Organophosphate Near-Distance and Medium-Distance Exposure (2) By Site

Site	Cases	Near-Distance 95% C.I.	Near-Distance Point Estimate	Medium-Distance Point Estimate	Medium-Distance 95% C.I.
All Sites	6527	0.91 - 0.95	0.93	0.94	0.92 - 0.97
Bladder, Kidney, and Other Urinary Organs	333	0.83 - 1.02	0.92	0.94	0.85 - 1.05
Breast	552	0.89 - 1.05	0.97	1.00	0.92 - 1.08
Endocrine	50	0.63 - 1.05	0.81	0.84	0.65 - 1.09
Eye	14	0.84 - 2.50	1.44	1.60	0.91 - 2.82
Female Genital (incl. uterus/unspecified)	363	0.83 - 1.01	0.92	0.93	0.84 - 1.03
Gallbladder	38	0.79 - 1.44	1.07	1.02	0.76 - 1.37
Ill-Defined Cancer	161	0.78 - 1.04	0.90	0.90	0.77 - 1.05
Intestine (small and large)	537	0.81 - 0.96	0.88	0.88	0.81 - 0.96
Larynx	58	0.70 - 1.17	0.90	0.96	0.74 - 1.24
Liver	28	0.69 - 1.45	1.00	1.06	0.73 - 1.52
Male Genital (incl. prostate)	448	0.84 - 1.01	0.92	0.92	0.84 - 1.00
Mouth and Pharynx	146	0.76 - 1.04	0.89	0.85	0.72 - 0.99
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.36 - 0.85	0.56	0.56	0.37 - 0.86
Oesophagus	38	0.73 - 1.34	0.99	1.08	0.80 - 1.47
Pancreas	165	0.79 - 1.07	0.92	0.87	0.75 - 1.02
Rectum, RS Junction and Anus	259	0.85 - 1.08	0.96	0.96	0.85 - 1.08
Respiratory and Intrathoracic Organs	657	0.83 - 0.96	0.89	0.90	0.84 - 0.97
Salivary Glands	18	0.83 - 2.20	1.36	1.35	0.83 - 2.22
Skin (melanotic and other)	1748	0.92 - 1.00	0.96	0.98	0.94 - 1.02
Stomach	267	0.79 - 1.00	0.89	0.91	0.80 - 1.02
Brain	128	0.85 - 1.20	1.01	0.96	0.81 - 1.14
Leukemia	166	0.81 - 1.08	0.93	0.98	0.84 - 1.13
Lymphoma	217	0.84 - 1.09	0.96	1.00	0.88 - 1.14
Sarcoma	115	0.84 - 1.20	1.00	0.99	0.83 - 1.19

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

An examination of the relative risks for DDT in Table 4.27 indicates remarkable similarities between the index-specific estimates; excepting those of salivary glands. A similar pattern is apparent in Table 4.28 for organophosphates.

Tables 4.29 through 4.32 compare relative risks from all non-city municipalities with relative risks from municipalities with populations < 2500 (rural). The models for all municipalities contain terms for all covariables including urban/rural while models for rural municipalities include all covariables except urban/rural.

Despite the control of the urban effect through the exclusion of cities and the use of an urban/rural factor in the analysis, further analyses restricting observations to rural municipalities were conducted. Given the strength of the urban effect it was important to investigate the degree to which spray effects might be masked as a result of residual urban confounding.

One previously non-significant relative risk, DDT exposure for all sites in males achieved borderline statistical significance in the analysis of rural municipalities (See Table 4.29).

Three relative risks, organophosphate exposure and gall-bladder cancer for males; organophosphate and ill-defined cancer for males (Table 4.31); organophosphate and endocrine cancer for females (Table 4.32), changed direction from negative to positive in the analysis of rural municipalities.

Table 4.29 Male Full Model Relative Risk Estimates for DDT Near-Distance Exposure (1) By Site for All Municipalities (2) and Rural Municipalities (3)

Site	All Municipalities			Municipalities With Populations < 2500		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Sites	3669	0.92 - 1.00	0.96	0.95	0.91 - 0.99	2788
Bladder, Kidney, and Other Urinary Organs	225	0.86 - 1.20	1.02	0.96	0.81 - 1.14	176
Breast	10	0.87 - 3.55	1.76	1.88	0.81 - 4.36	7
Endocrine	14	0.39 - 2.16	0.91	0.76	0.26 - 2.24	8
Eye	8	0.35 - 1.74	0.78	0.83	0.36 - 1.92	6
Female Genital (incl. uterus/unspecified)	NA	NA	NA	NA	NA	NA
Gallbladder	14	0.64 - 2.29	1.21	1.07	0 57 - 2.00	12
Ill Defined Cancer	86	0.79 - 1.33	1.02	0.95	0.71 - 1.27	68
Intestine (small and large)	265	0.83 - 1.13	0.97	0.93	0.78 - 1.09	196
Larynx	46	0.66 - 1.45	0.98	0.91	0.60 - 1.39	31
Liver	17	0.18 - 2.10	0.62	0.69	0.21 - 2.29	12
Male Genital (incl prostate)	448	0.72 - 0.95	0.83	0.86	0.74 - 0.99	340
Mouth and Pharynx	124	0.89 - 1.35	1.10	1.05	0.84 - 1.31	102
Nasal, Middle Ear, Sinuses, Nasopharynx	11	0.03 - 4.11	0.32	0.35	0.03 - 3.78	6
Oesophagus	26	0.77 - 1.66	1.13	1.18	0.78 - 1.77	23
Pancreas	91	0.60 - 1.11	0.81	0.82	0.60 - 1.13	80
Rectum, RS Junction and Anus	153	0.86 - 1.25	1.04	1.02	0.84 - 1.25	114
Respiratory and Intrathoracic Organs	538	0.90 - 1.12	1.01	1.01	0.90 - 1.13	413
Salivary Glands	11	0.24 - 1.62	0.63	0.51	0.15 - 1.73	10
Skin (melanotic and other)	1043	0.89 - 1.02	0.95	0.95	0.88 - 1.02	771
Stomach	175	0.79 - 1.18	0.96	0.99	0.80 - 1.23	141
Brain	81	0.71 - 1.18	0.92	0.94	0.72 - 1.23	63
Leukemia	97	0.70 - 1.17	0.90	0.85	0.64 - 1.13	72
Lymphoma	127	0.63 - .06	0.82	0.77	0.58 - 1.01	92
Sarcoma	59	0.81 - 1.51	1.10	1.02	0.73 - 1.44	45

(1) the nearest spray block within 1 kilometer for each spray year were accumulated over years

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) full model included DDT, organophosphate, agriculture, education, income, french, and migration as terms

NA not applicable

Table 4.30 Female Full Model Relative Risk Estimates for DDT Near-Distance Exposure (1) By Site for All Municipalities (2) and Rural Municipalities (3)

Site	All Municipalities			Municipalities With Population < 2500		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Sites	2858	0.89 - 0.98	0.94	0.92	0.87 - 0.96	903
Bladder, Kidney, and Other Urinary Organs	108	0.67 - 1.10	0.86	0.83	0.64 - 1.08	29
Breast	542	0.79 - 0.99	0.88	0.85	0.75 - 0.97	351
Endocrine	36	0.54 - 1.41	0.87	0.78	0.46 - 1.32	25
Eye	6	0.06 - 2.07	0.35	0.36	0.07 - 1.90	5
Female Genital (incl. uterus/unspecified)	363	0.78 - 1.02	0.89	0.90	0.78 - 1.04	238
Gallbladder	24	0.19 - 1.22	0.48	0.38	0.11 - 1.30	15
Ill-Defined Cancer	75	0.84 - 1.44	1.10	1.09	0.81 - 1.46	57
Intestine (small and large)	272	0.74 - 1.07	0.89	0.88	0.72 - 1.07	196
Larynx	12	0.27 - 3.34	0.95	0.87	0.17 - 4.43	8
Liver	11	0.16 - 1.80	0.54	0.56	0.17 - 1.88	9
Male Genital (incl. prostate)	NA	NA	NA	NA	NA	NA
Mouth and Pharynx	22	0.62 - 1.92	1.09	0.99	0.54 - 1.80	14
Nasal, Middle Ear, Sinuses, Nasopharynx	10	0.21 - 3.00	0.79	0.88	0.17 - 4.65	6
Oesophagus	12	0.06 - 1.35	0.29	0.33	0.08 - 1.31	9
Pancreas	74	0.56 - 1.14	0.80	0.77	0.53 - 1.13	55
Rectum, RS Junction and Anus	106	0.82 - 1.32	1.04	1.04	0.79 - 1.36	78
Respiratory and Intrathoracic Organs	119	0.73 - 1.17	0.93	0.88	0.69 - 1.13	89
Salivary Glands	7	0.06 - 3.07	0.43	0.39	0.06 - 2.79	5
Skin (melanotic and other)	705	0.96 - 1.16	1.06	1.03	0.94 - 1.14	499
Stomach	92	0.63 - 1.15	0.85	0.85	0.62 - 1.17	62
Brain	47	0.48 - 1.36	0.81	0.82	0.49 - 1.37	34
Leukemia	69	0.88 - 1.52	1.15	1.16	0.87 - 1.54	74
Lymphoma	90	0.63 - 1.10	0.83	0.79	0.58 - 1.07	62
Sarcoma	56	0.58 - 1.22	0.84	0.76	0.51 - 1.14	44

(1) the nearest spray block within 1 kilometer for each spray year were accumulated over years

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) full model included DDT, organophosphate, agriculture, education, income, french, and migration as terms

NA not applicable

Table 4.31 Male Full Model Relative Risk Estimates for Organophosphate Near-Distance Exposure (1) By Site for All Municipalities (2) and Rural Municipalities (3)

Site	All Municipalities			Municipalities With Populations < 2500		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Sites	3669	0.95 - 1.01	0.98	0.98	0.94 - 1.02	2788
Bladder, Kidney, and Other Urinary Organs	225	0.77 - 1.02	0.88	0.94	0.79 - 1.11	176
Breast	10	0.32 - 1.40	0.67	0.76	0.28 - 2.03	7
Endocrine	14	0.38 - 1.25	0.69	0.62	0.26 - 1.48	8
Eye	8	0.73 - 2.64	1.39	1.15	0.51 - 2.60	6
Female Genital (incl. uterus/unspecified)	NA	NA	NA	NA	NA	NA
Gallbladder	14	0.44 - 1.45	0.80	1.08	0.58 - 2.00	12
Ill-Defined Cancer	86	0.78 - 1.23	0.98	1.12	0.86 - 1.46	68
Intestine (small and large)	265	0.84 - 1.09	0.96	1.04	0.89 - 1.22	196
Larynx	46	0.74 - 1.40	1.02	1.38	0.94 - 2.04	31
Liver	17	0.54 - 1.62	0.94	0.88	0.44 - 1.77	12
Male Genital (incl. prostate)	448	0.85 - 1.04	0.94	0.87	0.76 - 0.98	340
Mouth and Pharynx	124	0.69 - 1.03	0.85	0.86	0.68 - 1.09	102
Nasal, Middle Ear, Sinuses, Nasopharynx	11	0.39 - 1.42	0.75	0.97	0.42 - 2.23	6
Oesophagus	26	0.62 - 1.43	0.94	0.88	0.54 - 1.42	23
Pancreas	91	0.82 - 1.29	1.03	1.01	0.78 - 1.29	80
Rectum, RS Junction and Anus	153	0.88 - 1.23	1.04	1.10	0.90 - 1.36	114
Respiratory and Intrathoracic Organs	538	0.80 - 0.96	0.88	0.88	0.78 - 0.99	413
Salivary Glands	11	0.66 - 2.18	1.20	1.52	0.83 - 2.78	10
Skin (Melanotic and other)	1043	1.00 - 1.13	1.06	1.02	0.94 - 1.10	771
Stomach	175	0.79 - 1.11	0.94	0.88	0.72 - 1.08	141
Brain	81	0.97 - 1.50	1.20	1.19	0.90 - 1.57	63
Leukemia	97	0.79 - 1.21	0.98	1.05	0.80 - 1.38	72
Lymphoma	127	0.91 - 1.32	1.09	1.17	0.93 - 1.47	92
Sarcoma	59	0.70 - 1.28	0.95	1.00	0.70 - 1.45	45

(1) the nearest spray block within 1 kilometer for each spray year were accumulated over years

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) full model included DDT, organophosphate, agriculture, education, income, french, and migration as terms

NA not applicable

Table 4.32 Female Full Model Relative Risk Estimates for Organophosphate Near-Distance Exposure Indices (1) By Site for All Municipalities (2) and Rural Municipalities (3)

Site	All Municipalities			Municipalities With Population < 2500		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Sites	2858	0.92 - 0.99	0.96	0.97	0.92 - 1.01	2026
Bladder, Kidney, and Other Urinary Organs	108	0.86 - 1.24	1.03	1.07	0.85 - 1.35	75
Breast	542	0.94 - 1.12	1.02	1.08	0.96 - 1.20	391
Endocrine	36	0.64 - 1.24	0.89	1.08	0.70 - 1.65	25
Eye	6	0.91 - 4.36	2.00	1.91	0.86 - 4.23	5
Female Genital (incl. uterus/unspecified)	363	0.86 - 1.07	0.96	0.92	0.81 - 1.06	279
Gallbladder	24	0.84 - 1.80	1.23	1.20	0.76 - 1.92	15
Ill-Defined Cancer	75	0.67 - 1.09	0.85	0.84	0.62 - 1.15	57
Intestine (small and large)	272	0.76 - 0.98	0.86	0.87	0.74 - 1.03	196
Larynx	12	0.22 - 1.04	0.48	0.36	0.11 - 1.14	8
Liver	11	0.73 - 2.19	1.26	1.19	0.63 - 2.25	9
Male Genital (incl. prostate)	NA	NA	NA	NA	NA	NA
Mouth and Pharynx	22	0.64 - 1.57	1.01	1.12	0.64 - 1.96	14
Nasal, Middle Ear, Sinuses, Nasopharynx	10	0.17 - 0.98	0.41	0.28	0.06 - 1.26	6
Oesophagus	12	0.68 - 1.71	1.08	1.16	0.66 - 2.05	9
Pancreas	74	0.81 - 1.29	1.02	1.04	0.79 - 1.38	55
Rectum, RS Junction and Anus	106	0.72 - 1.09	0.89	0.86	0.66 - 1.13	78
Respiratory and Intrathoracic Organs	119	0.82 - 1.20	0.99	0.97	0.77 - 1.23	82
Salivary Glands	7	0.62 - 2.77	1.31	1.46	0.59 - 3.60	5
Skin (melanotic and other)	705	0.85 - 1.00	0.92	0.90	0.82 - 1.00	495
Stomach	92	0.78 - 1.21	0.97	0.98	0.75 - 1.27	72
Brain	47	0.58 - 1.17	0.83	0.86	0.57 - 1.29	53
Leukemia	69	0.72 - 1.20	0.93	0.95	0.71 - 1.28	56
Lymphoma	90	0.81 - 1.23	1.00	1.09	0.84 - 1.40	69
Sarcoma	56	0.75 - 1.31	0.99	1.09	0.78 - 1.53	43

(1) the nearest spray block within 1 kilometer for each spray year were accumulated over year.

(2) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(3) full model included DDT, organophosphate, agriculture, education, income, french, and migration as terms

NA not applicable

These three new positive relative risks remained small and statistically non-significant.

Of the sites of cancer for females where relative risks were greater than 1.0 in the analysis of all municipalities and remained greater than 1.0 in the analysis of rural municipalities, organophosphates and cancer of the larynx and organophosphates and cancer of the salivary glands achieved higher relative risks among rural municipalities than among all municipalities. A similar increase is present for organophosphate exposure and cancer of the salivary glands in males. Of the remaining sites of cancer for males where relative risks were greater than 1.0 in the analysis of all municipalities and remained greater than 1.0 in the analysis of rural municipalities, DDT exposure and breast cancer and organophosphate and cancer of the larynx are larger for rural relative to urban municipalities.

Table 4.33 contains Poisson based power estimates for cancer risks associated with DDT and organophosphate exposure with an alpha set to .05 or less at each of 3 relative risk levels. Thirteen of the 25 DDT/cancer site estimates have more than 80% power to detect a relative risk of at least 1.5 if present. Only 5 out of 25 of the organophosphate/cancer site estimates attain similar power. For a relative risk of 5.0, only 1 DDT/cancer site estimate and 6 organophosphate/cancer site estimates have power less than 80%.

Table 4.33 Power to Detect a Relative Risk at Least as Large as Those Specified for an Alpha of .05 for DDT and Organophosphate Near-Distance Cutoffs (1)

Site	Cases	RR For DDT			RR For Organophosphates		
		1.5	2.5	5.0	1.5	2.5	5.0
All Sites	6527	1.00	1.00	1.00	1.00	1.00	1.00
Bladder, Kidney, and Other Urinary Organs	333	0.97	1.00	1.00	0.73	1.00	1.00
Breast	552	1.00	1.00	1.00	0.91	1.00	1.00
Endocrine	50	0.39	0.92	1.00	0.11	0.39	0.78
Eye	14	0.08	0.30	0.69	0.00	0.00	0.00
Female Genital (incl. uterus/unspecified)	363	0.98	1.00	1.00	0.78	1.00	1.00
Gallbladder	38	0.27	0.80	1.00	0.10	0.31	0.65
Ill-Defined Cancer	161	0.80	1.00	1.00	0.46	0.96	1.00
Intestine (small and large)	537	1.00	1.00	1.00	0.90	1.00	1.00
Larynx	58	0.42	0.95	1.00	0.16	0.51	0.88
Liver	28	0.18	0.63	0.97	0.05	0.17	0.40
Male Genital (incl. prostate)	448	0.99	1.00	1.00	0.86	1.00	1.00
Mouth and Pharynx	146	0.73	1.00	1.00	0.40	0.93	1.00
Nasal, Middle Ear, Sinuses, Nasopharynx	21	0.20	0.59	0.94	0.11	0.26	0.50
Oesophagus	38	0.27	0.80	1.00	0.10	0.31	0.65
Pancreas	165	0.78	1.00	1.00	0.42	0.95	1.00
Rectum, RS Junction and Anus	259	0.94	1.00	1.00	0.65	1.00	1.00
Respiratory and Intrathoracic Organs	657	1.00	1.00	1.00	0.95	1.00	1.00
Salivary Glands	18	0.19	0.54	0.91	0.00	0.00	0.00
Skin (melanotic and other)	1748	1.00	1.00	1.00	1.00	1.00	1.00
Stomach	267	0.94	1.00	1.00	0.66	1.00	1.00
Brain	128	0.70	1.00	1.00	0.37	0.90	1.00
Leukemia	166	0.81	1.00	1.00	0.41	0.94	1.00
Lymphoma	217	0.89	1.00	1.00	0.59	0.99	1.00
Sarcoma	115	0.67	1.00	1.00	0.28	0.82	1.00

(1) near-distance scores >0 relative to scores of 0 were used

Tables 4.34 through 4.37 contain full model (all covariates in) results for sites in this study with a high percentage of non-microscopically confirmed cases and for sites selected from the literature. Relative risk estimates are presented for all cases and for the subset of cases that were microscopically confirmed. For DDT (Tables 4.34 and 4.35), the results are similar under both conditions with the possible exceptions of gallbladder in males and myeloid leukemia in females. For organophosphates (Tables 4.36 and 4.37) the only exceptions to the pattern appear to be liver and myeloid leukemia in females.

Table 4.34 Male Full Model (1) Relative Risk Estimates for DDT Near-Distance Exposure (2) By Site and Microscopic Confirmation

Site	All Cases			Microscopically Confirmed		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Cancer	3669	0.92 - 1.00	0.96	0.95	0.91 - 1.00	3129
Brain	81	0.71 - 1.18	0.92	0.86	0.62 - 1.20	5
Endocrine	14	0.39 - 2.16	0.91	1.08	0.41 - 2.89	11
Gallbladder	14	0.64 - 2.29	1.21	0.92	0.39 - 2.20	12
Leukemia (excluding myeloid)	69	0.68 - 1.30	0.94	1.03	0.63 - 1.69	50
Liver	17	0.18 - 2.10	0.62	0.56	0.10 - 3.08	11
Melanoma	14	0.29 - 1.24	0.60	0.60	0.29 - 1.24	14
Multiple Myeloma	17	0.50 - 1.81	0.95	1.00	0.49 - 2.03	12
Myeloid Leukemia	28	0.52 - 1.27	0.81	0.87	0.55 - 1.36	24
Non-Hodgkins Lymphoma	67	0.56 - 1.13	0.80	0.82	0.57 - 1.16	64
Pancreas	91	0.60 - 1.11	0.81	0.73	0.44 - 1.19	57
Prostate	442	0.73 - 0.96	0.83	0.85	0.73 - 0.98	392
Respiratory System	538	0.90 - 1.12	1.01	0.95	0.84 - 1.09	414
Soft-Tissue Sarcomas	23	0.44 - 1.60	0.84	0.77	0.38 - 1.55	22
Stomach	175	0.79 - 1.18	0.96	0.93	0.74 - 1.17	140
Urinary System	226	0.86 - 1.20	1.02	0.99	0.84 - 1.17	214

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

Table 4 35 Female Full Model (1) Relative Risk Estimates for DDT Near-Distance Exposure (2) By Site and Microscopic Confirmation

Site	All Cases			Microscopically Confirmed		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Cancer	2858	0.89 - 0.98	0.94	0.94	0.89 - 0.99	2546
Brain	47	0.48 - 1.36	0.81	0.99	0.54 - 1.80	35
Endocrine	36	0.54 - 1.41	0.87	0.82	0.50 - 1.36	33
Gallbladder	24	0.19 - 1.22	0.48	0.52	0.20 - 1.37	19
Leukemia (excluding myeloid)	58	0 76 - 1.44	1.05	1.02	0.64 - 1.65	22
Liver	11	0.16 - 1 80	0.54	0.63	0.14 - 2 96	6
Melanoma	21	0.69 - 2.37	1.27	1.27	0.69 - 2 37	21
Multiple Myeloma	13	0 88 - 3.36	1.72	1.71	0.82 - 3.53	11
Myeloid Leukemia	11	0.87 - 3.06	1.63	1.25	0.60 - 2.61	8
Non Hodgkins Lymphoma	55	0.50 - 1.07	0.73	0.74	0.50 - 1.09	53
Pancreas	74	0 56 - 1.14	0.80	0.90	0.58 - 1.41	33
Prostate	NA	NA	NA	NA	NA	NA
Respiratory System	119	0.73 - 1.17	0.93	0.94	0.73 - 1.20	96
Soft Tissue Sarcomas	33	0.30 - 1.24	0.61	0.77	0.39 - 1.55	31
Stomach	92	0.63 - 1.15	0.85	0.73	0.49 - 1.09	70
Urinary System	109	0.67 - 1.10	0.86	0.87	0.66 - 1 14	98

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

NA not applicable

Table 4.36 Male Full Model (1) Relative Risk Estimates for Organophosphate Near-Distance Exposure (2) By Site and Microscopic Confirmation

Site	All Cases			Microscopically Confirmed		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Cancer	3669	0.95 - 1.01	0.98	0.98	0.94 - 1.02	3[illegible]
Brain	81	0.97 - 1.50	1.20	1.17	0.90 - 1.53	5[illegible]
Endocrine	14	0.38 - 1.25	0.69	0.66	0.34 - 1.28	11
Gallbladder	14	0.44 - 1.45	0.80	0.72	0.37 - 1.38	1[illegible]
Leukemia (excluding myeloid)	69	0.69 - 1.15	0.89	1.13	0.77 - 1.65	30
Liver	17	0.54 - 1.62	0.94	1.21	0.55 - 2.64	11
Melanoma	14	0.57 - 1.56	0.95	0.95	0.57 - 1.56	1[illegible]
Multiple Myeloma	17	0.54 - 1.49	0.90	1.02	0.59 - 1.79	1[illegible]
Myeloid Leukemia	28	0.86 - 1.87	1.27	1.39	0.92 - 2.10	2[illegible]
Non-Hodgkins Lymphoma	67	0.95 - 1.60	1.23	1.19	0.91 - 1.55	6[illegible]
Pancreas	91	0.82 - 1.29	1.03	0.88	0.65 - 1.19	5[illegible]
Prostate	442	0.85 - 1.04	0.94	0.92	0.85 - 1.02	39[illegible]
Respiratory System	538	0.80 - 0.96	0.88	0.88	0.77 - 0.98	414
Soft-Tissue Sarcomas	23	0.50 - 1.39	0.84	0.88	0.52 - 1.48	2[illegible]
Stomach	175	0.79 - 1.11	0.94	1.01	0.84 - 1.21	140
Urinary System	226	0.76 - 1.02	0.88	0.90	0.78 - 1.04	2[illegible]

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

NA not applicable

Table 4 37 Female Full Model (1) Relative Risk Estimates for Organophosphate Near-Distance Exposure (2) By Site and Microscopic Confirmation

Site	All Cases			Microscopically Confirmed		
	Cases	95% C.I.	Point Estimate	Point Estimate	95% C.I.	Cases
All Cancer	2858	0.92 - 0.99	0.96	0.96	0.92 - 1.00	2546
Brain	47	0.58 - 1.17	0.83	0.71	0.47 - 1.09	35
Endocrine	36	0.64 - 1.24	0.89	0.96	0.68 - 1.36	33
Gallbladder	24	0.84 - 1.80	1.23	1.27	0.83 - 1.95	19
Leukemia (excluding myeloid)	58	0.70 - 1.22	0.92	0.99	0.63 - 1.56	22
Liver	11	0.73 - 2.19	1.26	0.88	0.37 - 2.11	6
Melanoma	21	0.29 - 0.86	0.50	0.50	0 29 - 0.86	21
Multiple Myeloma	13	0.31 - 1.21	0.61	0.66	0.31 - 1.40	11
Myeloid Leukemia	11	0.45 - 1.93	0.93	1.33	0.61 - 2.92	8
Non-Hodgkins Lymphoma	55	0.90 - 1.51	1.16	1.15	0.89 - 1.50	53
Pancreas	74	0.81 - 1.29	1.02	0.95	0.67 - 1.35	33
Prostate	NA	NA	NA	NA	NA	NA
Respiratory System	119	0.82 - 1.20	0.99	1.03	0.84 - 1.26	96
Soft Tissue Sarcomas	33	0.74 - 1.54	1.07	1.11	0.76 - 1.62	31
Stomach	92	0.78 - 1.21	0.97	1.05	0 82 - 1.35	70
Urinary System	109	0.86 - 1.24	1.03	0.98	0.80 - 1.19	98

(1) full model included DDT, organophosphate, agriculture, urban/rural, education, income, french, and migration as terms

(2) the nearest spray block within 1 kilometer for each spray year were accumulated over years

NA not applicable

CHAPTER V

DISCUSSION AND CONCLUSIONS

I. INTRODUCTION

This study was intended to provide a basis for proposing case-control studies of specific cancer sites, if warranted. It has estimated the level of site specific cancer risk associated with 2 categories of pesticide spray formulations used in the New Brunswick forest protection programme using municipalities as units of analysis.

Two exposure indices were developed for each class of formulations, DDT and organophosphates, and Poisson regression was used to examine the impact of these measures on cancer risk within the context of a global classification of cancers (25 site groupings). Six additional cancer sites were examined based on a review of the pesticide and cancer literature. These are:

a) non-Hodgkin's lymphoma (ICD-O:M959-M964,M969);
b) prostate (ICD-9:T185);
c) soft-tissue sarcoma (ICD-O:M880-M892);
d) myeloid leukemia (ICD-O:M986);
e) leukemia (excluding myeloid) ICD-O:M980-M985,M987-M998);
f) multiple myeloma (ICD-O:M9730).

Seven potential confounders were considered and retained in the final regression models. These are:

a) other forestry spray;
b) agricultural activity;
c) urban/rural residence;
d) migration;
e) education;
f) income;
g) language/culture.

Seven of the 124 exposure/site/sex specific risk estimates were found to have 95% confidence intervals that excluded 1.0. This is about the number expected by chance alone.

The standardized incidence ratios per unit of exposure were:

.94 (.89 - .98) for DDT and all cancers (females);

.96 (.92 - .99) for organophosphates and all cancers (females);

.88 (.79 - .99) for DDT and breast cancer (females);

.86 (.76 - .98) for organophosphates and intestinal cancer (females);

.41 (.17 - .98) for organophosphates and nasal, middle ear, sinuses, nasopharynx cancer (females);

.85 (.73 - .96) for DDT and prostate cancer (males);

.88 (.80 - .96) for organophosphates and respiratory and intrathoracic organs (males).

Values within brackets are 95% confidence limits and all exposure units are per number of times (years) within 1 kilometer of at least 1 spray block.

Five of the seven were for females and all seven indicate a reduced risk of cancer in exposed persons. There is no reason to expect exposure to be protective against cancer, and these seven significant findings are interpreted as the results of chance, urban risks of cancer (and relative protection of rural populations), and/or the effects of unidentified confounders.

All DDT/site analyses, with the exception of salivary glands; nasal, middle ear, sinuses and nasopharynx; liver; and eye, had at least 80% power to detect relative risks of at least 2.5. All organophosphate/site analyses had similar power with the following additional exceptions: oesophagus, larynx, gall bladder, and endocrine organs.

II. COMPARISONS WITH ESTIMATES IN THE LITERATURE

During the period 1952-1976, DDT and organophosphate spray exposure scores ranged between 0 and 5, with each unit of exposure equivalent to a single year in which the population of a municipality was within 1 kilometer of at least 1 spray block. The average DDT score per municipality for the 17 years 1952-1968 was 0.55 and the average organophosphate score for the 14 years 1963-1976 was 1.48.

Risk ratios based on average formulation-specific exposure scores will be used for comparisons with the literature. These are calculated by using the risk ratio values for all cases (microscopically confirmed + others) raised to the power of the average formulation-specific exposure score. For example, a risk ratio of 1.5 per year of DDT exposure becomes 1.25 (1.5 to the power of 0.55) or 1.82 (1.5 to the power of 1.48) if the exposure was to organophosphates.

Nine cancer sites (including 3 from the global classification) were identified from the literature as being of particular interest regarding possible associations with pesticides. These were:

a) brain;
b) mouth and pharynx;
c) non-Hodgkin's lymphoma;
d) prostate;
e) liver;
f) gallbladder;
g) soft-tissue sarcomas;
h) myeloid leukemia and;
i) leukemia.

The largest risk ratio for brain cancer in this study is derived from a risk ratio of 1.2 (Table 4.26) per unit of organophosphate exposure and, assuming average organophosphate exposure, is 1.31 for males, with 95% confidence limits of

0.96 - 1.82. A maximum exposure of 5 years would result in a risk ratio of 2.49.

Risk ratios in the literature for brain cancer ranged from 0.72 to 5.00 [Delzell et al.,1985; Alavanja et al.,1987;Thomas et al.,1986;Blair et al.,1983;Gold et al.,1979;Musicco et al.,1982] with the two studies having the largest estimates (4.0, 5.0) [Gold et al.,1979;Mussico et al.,1982] reaching statistical significance. The 2 lowest estimates have 95% confidence limits that range between 0.26 and 1.8 [Alavanja et al.,1987;Thomas et al.,1986]. The studies with the 2 highest risk ratios were case-control designs [Gold et al.,1979; Musicco et al.,1982].

The largest risk ratio for cancer of the mouth and pharynx in this study is derived from a risk ratio of 1.10 (Table 4.25) per unit of DDT exposure and, assuming average DDT exposure, is 1.05 for males, with 95% confidence limits of 0.94 - 1.18. A maximum exposure of 5 years would result in a risk ratio of 1.61.

Risk ratios in the literature for mouth and pharynx cancer ranged from 0.58 to 1.77 [Gallagher et al.,1984; Williams et al.,1977;Delzell et al.,1985;Blair et al., 1983;Olsen et al.,1987;Wong et al.,1984] with one statistically significant estimate of 1.47 having a 95% confidence interval of 1.12 - 1.93 [Olsen et al.,1987].

The largest non-Hodgkin's lymphoma risk ratio in this study is derived from a risk ratio of 1.23 (Table 4.36) and, assuming average organophosphate exposure, is 1.36 for males, with 95% confidence limits of 0.93 - 2.00. A maximum exposure at 5 years would result in a risk ratio of 2.82.

Risk ratios in the literature for non-Hodgkin's lymphoma range from 0.61 to 2.6 [Olsen et al.,1987;Delzell et al.,1985; Priester et al.,1974;Burmeister et al.,1983; Schumacher,1985; Alavanja et al.,1987;Milham,1971; Cantor, 1982]. The largest upper confidence limit reported in the literature was 8.3 [Cantor,1982].

All risk ratio estimates for prostate cancer for both DDT and organophosphates were below 1.0 (Tables 4.34 and 4.36).

Risk ratios in the literature for prostate cancer range from 0.53 to 1.70 [Gallagher et al.,1984; Williams et al., 1977;Delzell et al.,1985;Blair et al.,1983;Olsen et al.,1987; Alavanja et al.,1987;Burmeister,1983;Brownson et al.,1988]. The largest upper confidence limit reported in the literature was 1.7 [Brownson et al.,1988].

The largest liver cancer risk ratio in this study is derived from a risk ratio of 1.26 (Table 4.26) and, assuming average organophosphate exposure, is 1.41 for females, with 95% confidence limits of 0.63 - 3.19. A maximum exposure of 5 years would result in a risk ratio of 3.18.

Risk ratios in the literature for liver cancer range from 0.77 to 2.38 [Olsen et al.,1987;Blair et al.,1983;Stemhagen et

al.,1983;Austin et al.,1987;Alavanja et al.,1987]. The largest upper confidence limit reported in the literature was 6.9 [Austin et al.,1987].

The largest gallbladder risk ratio in this study is derived from a risk ratio of 1.23 (Table 4.26) and, assuming average organophosphate exposure, is 1.36 for females, with a 95% confidence limit of 0.77 - 2.39. A maximum exposure of 5 years would have resulted in a risk ratio of 2.82.

Risk ratios in the literature for gallbladder cancer range from 0.6 to 2.19 [Olsen et al.,1987] excluding one study in which there was only 1 case [Williams et al.,1977]. The largest upper confidence limit reported in the literature was 3.7 [Olsen et al.,1987].

The largest soft-tissue risk ratio in this study is derived from a risk ratio of 1.07 (Table 4.37) and, assuming average organophosphate exposure, is 1.11 for females, with 95% confidence limits of 0.64 - 1.89. A maximum exposure of 5 years would have resulted in a risk ratio of 1.40.

Risk ratios in the literature for soft-tissue sarcomas range from 3.3 to 6.8 [Eriksson et al.,1981;Hardell,1981]. The largest upper confidence limit reported in the literature was 22.5 [Hardell,1981].

The largest myeloid leukemia risk ratio in this study is derived from a risk ratio of 1.27 (Table 4.36) and, assuming average organophosphate exposure, is 1.42 for females, with

95% confidence limits of 0.80 - 2.53. A maximum exposure of 5 years would have resulted in a risk ratio of 3.30.

Risk ratios in the literature for myeloid leukemia range from 1.69 to 1.72 [Olsen et al.,1987] with the highest upper confidence limit being 3.44.

The largest leukemia (excluding myeloid) risk ratio in this study is derived from a risk ratio of 1.05 (Table 4.35) and, assuming average DDT exposure, is 1.03 for females, with 95% confidence limits of 0.86 - 1.22. A maximum exposure of 5 years would have resulted in a risk ratio of 1.28.

Risk ratios in the literature for leukemia (no studies excluded myeloid) range from 0.43 to 3.00 [Pearce et al.,1986; Williams et al.,1977;Alvanja et al.,1987;Delzell et al.,1985; Blair et al.,1979;Olsen et al.,1987;Blair et al.,1983;Wong et al.,1984] with the highest upper confidence limit being 7.32 [Pearce et al.,1986] excluding certain results of studies in which the number of cases were 2 or less [Wong et al.,1984; Pearce et al.,1986].

The largest multiple myeloma risk ratio in this study is derived from a risk ratio of 1.72 (Table 4.35) and, assuming average DDT exposure, is 1.35 for females, with 95% confidence limits of 0.93-1.95. A maximum exposure of 5 years would result in a risk ratio of 15.05.

Risk ratios in the literature for multiple myeloma range from 0.9 to 1.79 [Delzell et al.,1985;Milham,1971]. The 3

statistically significant risk ratios ranged from 1.4 to 1.79 [Mclaughlin et al.,1988;Burmiester et al.,1983;Milham,1971].

All of the results for those cancer sites selected for study based on the review of the pesticide/cancer literature, with the exception of soft-tissue sarcomas, fall within the range of values reported elsewhere.

Soft-tissue sarcoma relative risks reported in the reviewed literature range between 3.3 and 6.8 [Eriksson et al.,1981]. Rate ratios for soft-tissue sarcomas from the studies reviewed involve herbicide exposure exclusively. Herbicide exposure is not contained within any of the indices developed and used in this study.

The results of this study are also in close agreement with those of a similar but less detailed study of forestry spray exposure (1952-1968) and cancer mortality (1969-1981) in New Brunswick [Spitzer,1985].

III. RATIONALE FOR THE ECOLOGICAL ANALYSIS

The strength of prior evidence and cost were the two main factors that affected the choice of an ecological study design. An initial submission of a case-control study of soft-tissue sarcomas and non-Hodgkin's lymphoma was rejected on the basis that insufficient evidence was available at the time to determine whether these two cancer sites, of those previously studied [Spitzer et al.,1984], were the most likely

to have higher risks associated with the spray programme. An ecological study design was considered to be the most cost-effective strategy to address the criticisms directed at the previous proposal.

Furthermore, ecological analyses have, under certain conditions, been shown to provide useful estimates of associations operating at the individual level [Susser,1973, pg.51;Hakama et al.,1982].

IV. CONTROL OF BIAS

Numerous systems for the classification of bias have been proposed [Sackett,1979;Kleinbaum et al.,1982;Rothman,1988]. The principal biases in this study are considered under the headings "Misclassification" and "Confounding".

Although misclassification is associated with all data collected, it is likely to affect some variables more than others. The measurement of exposure and cancer incidence will be considered under misclassification while the study covariates will be considered under confounding.

A. Misclassification

Misclassification occurs when errors are present in the data. If these errors are associated with both axes (exposure and outcome) they may bias risk estimates in either direction,

while misclassification on one axis only always biases risk estimates in the direction of the null (i.e., toward the no-risk point) [Rothman,1988,pg.84].

1. Spray Exposure

Several important errors are associated with the calculation of exposure indices.

The margin of each spray block used may differ by as much as 1.6 kilometers from the true spray margin even when the information recorded accurately describes the spraying. In the early years of the spray programme, navigation was mainly by landmarks such as roads and rivers rather than by sophisticated electronic equipment, so that reporting errors may also be present. Despite the likelihood of more frequent errors in rural areas where there are fewer landmarks and generally lower cancer rates, exposure is expected to be underestimated as often as overestimated in rural areas and therefore lead to an attenuation of risk ratio estimates.

Wind direction at the time of spraying was not recorded and therefore not available for analysis. The calculation of exposure scores based on distance alone will tend to overestimate actual exposure in settlements upwind to spray blocks and underestimate downwind exposures. Communities with high rates of cancer will be misclassified as often as those with

low rates, resulting in an attenuation of risk ratio estimates.

The estimated geographical location of each settlement centroid was used as a basis for calculating an average settlement score and is subject to important imprecision with respect to the distribution of the settlement population. While the population distribution within some settlements is nuclear in shape, others are spread along highways so that true exposures within the settlement may vary substantially, and any single summary estimate applied to the whole settlement may misclassify a part of the population. Furthermore, as nuclear settlements increase in size they also will be subject to similar exposure misclassification. This aspect of exposure calculation will also act to reduce risk ratio estimates in this study.

The attribution of exposure intensity is based on assumptions regarding the deposition of spray in the environment following its application and has important implications for the estimation of risk. A misspecification of exposure magnitude will lead to non-differential misclassification and a biasing of risk estimates towards the null. Two different exposure models were used for each spray formulation, and results were found to be in close agreement.

2. Cancer Incidence

The estimation of disease rates is affected by the methods and intensity of case ascertainment, which may vary from place to place. The detection of differences between rates is also influenced by the interval between spray exposure and cancer occurrence (incubation period/latency).

a. Ascertainment

The New Brunswick Tumour Registry's main source of data is pathology reports. New Brunswick pathologists are located in urban centers within the province (Fredericton, Moncton, Saint John, Woodstock, and the North Shore). Seventy-eight percent of the hospitals beds in New Brunswick are situated in towns, villages, or cities with populations greater than 2,000 persons (internal NB. Gov. memorandum, March 1980). It is possible that tumours are less likely to be detected in rural areas or that they are less likely to be microscopically confirmed. The latter case is one of the reasons for examining all diagnoses of malignant tumours. With respect to the former it is unfortunate that cases identified by death certificate only were not uniquely identified within the file used for analysis. However, in preliminary analyses the proportion of cases by region of the province were examined and were found to be similar to expected based on the

population distribution. It is expected a priori that under-ascertainment of cancer is greater in rural areas and is therefore differential in nature through the association of urban/rural location with spray exposure. The effect would be to decrease the magnitude of risk estimates, as higher exposure occurs in more rural areas.

b. Latency

The interval between first exposure to DDT and the beginning of the case ascertainment period is 8 (1969-76) to 25 years (1953-76) and between first exposure to organophosphates and the beginning of case ascertainment is 1 (1976) to 13 years (1964-76) with the majority of the exposure occurring during the period of shortest latency.

The latent period between exposure to chemical agents and the onset of cancer is generally between 5 and 50 years [Schottenfeld,1984] and has not been found to vary with dose [Armenian and Lillienfeld,1983].

Latency may, however, be shorter for chemicals that promote rather than initiate cancer. Because DDT has not been shown to react with DNA its effects are suspected to be promotional in nature [Klaassen et al.,1986]. No similar information could be found on the behavior of organophosphate pesticides.

It is possible that the latent period for organophosphate spray in this study was too short to detect an effect on cancer.

B. Confounding

Confounding bias is likely to be important in this study because ecological data are subject to grouping bias [Piantadosi et al.,1988].

Seven factors that might confound estimates of health effects of forestry spray exposures were examined and controlled for in the analysis:

a) urban/rural residence;
b) education;
c) income;
d) ethnicity (language/culture);
e) agricultural activity;
f) migration;
g) other forestry spray.

All of these except agricultural activity, urban/rural residence, and perhaps ethnicity operate at the level of individuals and are best controlled when measured at the individual level. Agricultural activity and urban/rural location are more likely to act globally by affecting the environment in which people live and are probably best measured at the ecological level regardless of the study

design, unless it is possible to measure directly the intervening variables through which the ecological variables operate.

1. Urban/Rural, Education, Income, and Ethnicity

Urban/rural residence, education, income, and ethnicity are important and correlated aspects of social structure and have been shown to affect cancer mortality [Blot and Fraumeni, 1982;Myers and Manton,1977].

New Brunswick is a predominantly rural province with approximately 53% of its population living in communities of less than 2,500. Thirty one percent of the population lives in 6 cities ranging in size from 9,818 - 80,521. The data analyzed in this study excluded cities. Rural residence was defined as habitation within a community of less than 2,500.

Definitions of urban/rural location vary internationally [Smith and Zopf,1976] and the definition used in this study is more similar to that used by the US Census [Spiegelman,1968, pg.295] rather than to the Canadian Census, which defines urban versus rural by population density per square kilometer [Stats Canada E-562,1982].

Standardized incidence ratios for rural residence (excluding specific consideration of pesticide exposure) ranged between 1.09 and 1.83 in 14 of the 25 sites studied in places with populations greater than 2,500. While the results

from all sites combined are in agreement with results for cancer mortality reported elsewhere [Myers and Manton,1977], differences exist between site specific SIR's observed in this study and relationships observed in an ecological mortality study by Blot and Fraumeni [1982]. Allowing for differences in site definitions, results are similar for the following sites:

a) larynx;
b) nasopharynx;
c) endocrine organs;
d) intestine;
e) lymphoma and;
f) leukemia;

with rates for each of these being higher in urban areas. Notable differences exist for brain, pancreas, and salivary glands, for which the ratios are above 1.0 in the literature and below 1.0 in this study. The risk ratio estimate for cancer of the nasal cavity in this study was 2.45 whereas it was approximately 1.1 in the literature. Blot and Fraumeni [1982] found a risk ratio estimate for skin cancer of approximately 1.0 whereas in this study the estimate was 1.27.

Education and income are widely recognized as important and related aspects of socioeconomic status (SES). A number of ecological studies have indicated that SES has an effect on cancer mortality that is independent of the effect of urban/rural residence [Manton and Myers,1977;Blot and Fraumeni,1982]. Education, income, and urban/rural residence are positively associated in this study.

In this study gallbladder, intestine, and skin cancer demonstrate clear risk gradients in which risk increases with both education and income. The risks for these sites are also elevated in urban areas.

Results from this study are not consistent with those of a study conducted at the individual level in which low SES, defined solely in terms of income, was found to be a risk factor for lung, bladder, and stomach cancer [Siemiatycki et al.,1988]. They are in the opposite direction to those of Siemiatycki.

An ecological study of cancer mortality found a positive association between SES and colon cancer [Blot and Fraumeni, 1982]. Similar results were obtained in this study in which intestinal cancer (small and large combined) was found to be positively associated with education, income, and urban/rural residence.

Ethnicity, defined in terms of the majority mother tongue of a municipality, operates at an ecological as well as an individual level. Individual habits as well as the social, and often the physical conditions under which people live often reflect important aspects of cultural identity.

The concentration of French persons within specific areas within the province will inevitably result in the expression of certain cultural traits at the community level. The resulting environment will tend to support and foster those personal characteristics and behaviors that are particular to

the French culture. The indirect measurement of these culturally determined and potentially health related traits through an ecological variable is therefore highly desirable.

Twenty-eight percent of the New Brunswick population are French. They are concentrated along the east coast and north shore of the province. In general the French population is of a lower SES than the English population, and though they tend to be more rural, their communities are largely situated along the coastline, more distant from the forest, and therefore less likely to be sprayed than English communities. Twenty out of the 25 sites examined indicate an increased cancer risk for the English, relative to the French.

2. Agricultural Activity

Agricultural activity within New Brunswick is concentrated along the cleared areas throughout the Saint John river valley. Given that similar pesticides are used in forestry and agriculture, attempts were made to control this potential negative confounder. No consistent cancer trends were observed to covary consistently with agricultural activity. It is possible that municipalities were not sufficiently homogeneous with respect to agriculture or spray exposure to permit its adequate control.

3. Migration

Over time, individuals move from one municipality to another. Municipal out-migration rates have been demonstrated to vary across time period, urban/rural residence, age, education, marital status and sex; with age less than 30, a university education, and rural areas having the highest rates [Wilson,1988].

In the United States during the period 1955 to 1980, age and education specific out-migration from rural areas have decreased dramatically relative to urban areas [Wilson,1988].

The impact of migration on the estimation of cancer risks has been shown to systematically bias the site specific cancer risks towards the null [Polissar,1980]. The degree of bias varies by the length of the latent period, cancer site and type of geographic unit. Based on tables provided by Polissar it is possible that this study may under-estimate risk ratios by about 30-40%.

Out-migration from New Brunswick to elsewhere in Canada between 1976 and 1981 was 7.2% [Stats Canada E-574,1983]. The New Brunswick Tumour Registry does not have data on former New Brunswick residents that develop cancer after their departure from the province. This will bias results in this study as proportionately more persons leave the province from rural areas where cancer risks are lower and spray exposure is

higher than urban areas where cancer risks are higher and exposure lower. This will reduce risk ratio estimates.

V. SAMPLE SIZE

Random errors associated with sampling variation are far less important within the context of this study than are the potential systematic errors discussed previously. With the exception of salivary glands; nasal, middle ear, sinuses, nasopharynx; liver, and eye, all analyses for DDT have a power of 80% or more to detect rate ratios that are 2.5 or greater. Similar statistical power is achieved for organophosphates only for rate ratios of 5 or greater.

VI. GENERALIZABILITY OF RESULTS

The results of this study are generalizable to the extent that the results are free of bias and are relevant to cancer risk at the level of individuals in other jurisdictions.

Several important variables in this study have been measured at the ecological level (spray exposure, urban/rural, and ethnicity) and their effects controlled for in the analysis.

The aggregation of the New Brunswick population into municipalities may have resulted in the confounding of the exposure/cancer associations studied. To the extent that this

grouping bias is associated with spray covariates measured at the ecological level, it is controlled for in the analysis. While it is not possible to address this possibility in the absence of individual level data, the fact that the estimated effect of the strongest spray covariate in the analysis, urban/rural residence, was found to be in general agreement with estimates in the literature, it is interpreted as indicating that the uncontrolled grouping effect is probably small.

The types of substances used in the spray programme are similar to many pesticides used outside of forestry.

VII. CONCLUSIONS

The results of this study do not provide a basis for recommending the implementation of case-control studies of specific cancer sites. Insofar as the conditions of exposure with respect to the substances and quantities used are applicable, the results of this study do not provide evidence in support of the hypothesis that forestry spraying of organochlorine or organophosphate pesticide formulations either directly or indirectly causes cancer. In the case of organophosphate pesticides, however, this must be qualified by pointing out that the biases potentially present in this study operate in the direction of reducing the magnitude of detectable exposure effects.

Due to the relatively short interval of time available between exposure to organophosphate formulations and case ascertainment combined with the relatively low power of certain organophosphate/site analyses, the results should be interpreted with particular caution as it may be too soon to detect organophosphate specific effects.

Despite the exclusion of cities and sub-analyses in which units analyzed were restricted to those with populations less than 2500 persons, it remains possible that rates in sprayed, largely rural areas, would be even lower in the absence of spraying; that is, that pesticide exposure has caused some cancers and have reduced the natural advantage of rural over urban areas in cancer incidence rates. This hypothesis cannot be refuted by the data here due to the absence of a highly rural segment of the New Brunswick population for which exposure estimates could not be calculated. Under these circumstances it appears prudent to:

i) maintain exposure surveillance and improve its quality through the recording of wind direction data at the time of spraying.

ii) situate geographically the presently missing 12% rural segment of the New Brunswick population.

iii) encourage the development of more precise geographical coordinates for places within New Brunswick.

iv) encourage the New Brunswick Tumour Registry to remain abreast of and implement developments in the area of geographical coordinates of places within its jurisdiction.

v) encourage the New Brunswick Tumour Registry to consider extending the categories of data collected to include residential and occupational histories as an aid to health surveillance.

vi) extend the ascertainment period to provide the largest number of cases for study, thereby increasing the statistical power of the analyses and increasing the latent period for organophosphate spray.

vii) identify population sub-groups such as spray applicators and fish/shellfish eaters that are at particularly high risk of exposure.

STATEMENT OF ORIGINALITY

This thesis examined the human cancer risk associated with exposure to pesticidal substances applied to New Brunswick forests. This is the first time that the geographical distribution of incident cases of cancer in New Brunswick has been studied in relation to population based forestry spray exposure. Previous studies have been handicapped by the absence of detailed time, place and formulation specific measures of exposure.

The analysis of the data in this study, unlike previous studies, included other factors that have the potential to confound the spray/cancer associations under consideration.

This study contributes more broadly to knowledge in the field of environmental epidemiology and surveillance by demonstrating the feasibility and usefulness of developing computerized data bases as a means of monitoring risks associated with large-scale environmental exposures.

TABLE OF CONTENTS - APPENDIX I

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1. INTRODUCTION

This Appendix surveys 3 broad substantive areas that are important in attempts to evaluate the impact of the aerial spruce budworm spray programme on the health of New Brunswickers.

While the spray programme is commonly referred to in the singular, it is a haphazard array of different exposures that have occurred over many years. Assessing its impact will present some difficult organizational challenges. Because of the extent of the material covered, even superficial coverage of each area inevitably requires a large volume of factual material. The format and content of this Appendix will provide an overview of the issues involved in studying this type of programme.

The first area, Environmental Considerations, opens with a brief review of the history of the spray programme, as it is potentially relevant to exposure to budworm spray in general. This includes some technical information regarding the evolution of aerial spray application methods. Next is a discussion of issues pertaining to the detection of spray residues in the environment, in order to establish a context within which to evaluate the impact of spray chemicals on aquatic, aerial, and terrestrial fauna. This section concludes with a discussion of the acute toxic effects of specific spray formulations and their components on organisms in the environment. While the ultimate focus of this study is on long-term (chronic) effects on humans of aerially applied pesticides, acute effects in animals other than mammals are included both as an important environmental consideration in themselves and to provide a context for discussion of spray distribution, spray residues, and residue persistence within the environment in general. Chronic effects in mammals are reserved until the section of this Appendix on toxicological considerations.

The second area, toxicological considerations, presents information about the different substances used in the spray programme. The physical characteristics of the spray components are examined, individually and where possible jointly, along with the likely conditions of exposure that are relevant to each chemical's possible route of entry and potential dose. The known aspects of a material's carcinogenicity and mutagenicity within animal systems are also explored.

II. ENVIRONMENTAL CONSIDERATIONS

A. The New Brunswick Spruce Budworm Spray Programme: A Survey of Important Events

Over the period of more than 3 decades there have been many changes in the spray programme. Some of these changes have increased the effects of the spray on the environment and some have decreased them. Table A1.1 provides a summary of the most important events.

During the first 5 years of the programme, small, slow-flying aircraft were used for the aerial application of pesticides on both agricultural crops and forests in New Brunswick. These planes used boom and nozzle spray equipment and flew close to the tree tops at speeds of about 150 kilometers per hour. Unfortunately, no information is available on: a) the droplet spectrum within the spray aerosol generated by these aircraft, b) the amount of spray intercepted by the forest canopy, c) the amount of spray reaching the ground beneath the forest canopy, or d) the amount of spray drifting off target. Despite this, it is probably safe to assume that the droplet spectrum was coarse by current standards. As a result of this coarseness the off-target drift was probably small. Recent, intensive research into off-target spray drift has demonstrated that aircraft height above the canopy, speed, and droplet median

Table A1.1 Important Historical Milestones of The New Brunswick Spruce Budworm Aerial Spray Programme: 1952 - 1983

Year	Event
1952	First year that New Brunswick forests were sprayed on a large scale for budworm control
1952 - 1957	Agricultural aircraft (Stearman) were used for spraying
1952 - 1966	Use of boom and nozzle spray equipment, which generated a coarse droplet distribution
1958	The fast Gruman Avenger World War II torpedo bomber aircraft (TBM) was introduced
1959	Only year since the inception of the programme that spraying did not take place
1963	Establishment of a no-DDT-spray (buffer) area of .5 kilometers around salmon streams and rivers
1967	Introduction of ultra-low-volume (ULV) Teejet nozzles, which produce a finer spray droplet distribution
1968	A 3.5 km. no-fenitrothion-spray buffer area was imposed around commercial blueberry fields
1974	A formal mechanism was established for the authorization of insecticide use in forest insect control under the provisions of the Canadian Pest Control Products Act
1976	The use of phosphamidon, an organophosphate pesticide, was discontinued because of its toxic effects on birds
1978	Buffer zones of 1.6 kilometers were established around areas of permanent human habitation, and zones of 400 meters around bodies of water greater than 40 hectares and all major rivers in the province
	585 oil replaced diesel and #2 fuel oil as diluents in the spray programme
1980	Small private woodlots were included in the spray programme

diameters at point of release are important factors associated with off-target drift.

Early aircraft also operated singly and navigated using rivers, railway tracks, and other geographical markers as a basis for locating designated spray areas. Under these conditions the potential for unintentional contamination was high.

In 1958 the Gruman Avenger aircraft (TBM) was introduced into the spray programme. Because of its size and design, it could carry larger quantities of spray material enabling the spraying of larger areas of forest per flight. In addition, its higher speed (277 km./hr) caused greater wind shear at the nozzle tips and a much finer droplet spectrum than that of slower aircraft. These aircraft also flew at higher altitudes (approximately 100 feet above the treetops), which contributed to greater off-target drift. Soon after the introduction of the Gruman aircraft, more sophisticated and precise navigational methods were developed for spray application. These allowed three TBM aircraft to fly in formation and lay out a joint swath of 610 meters under the direction of a Cessna spotter plane which gives instructions on when to turn the nozzles on and off.

Overswathing, in which two or more of the 3 adjoining spray plane swaths overlap during spraying, has been blamed for sporadic bird kills by organophosphate pesticides. One study found high mortality and severely reduced reproductive success among birds subjected to overswathing [Varty,1980,pg.27].

In 1963 a .5 kilometer zone was established around salmon streams and rivers because of the adverse effect of DDT on this species. This area was sprayed with phosphamidon at a rate of .5 lbs per acre [Kettela,1975].

Ultra-low-volume (ULV) spray nozzles were used on a limited basis before 1968, when they were adopted for large scale use within the spray programme. This decreased, by a

factor of more than 3 the total volume of formulation applied per hectare. Also in 1968 there was a dramatic increase in both the areas sprayed per year and the proximity of spraying to points of human settlement.

In 1974 a formal mechanism was established for the authorization of pesticide use in forest insect control under the provisions of the Pest Control Products Act. Spray programme organizers were required to have the approval of the Department of Agriculture for new formulations.

In 1975 New Brunswick began to spray with aminocarb, a carbamate insecticide, as an alternative to fenitrothion. Aminocarb has become particularly popular for several reasons. Organophosphates in general and fenitrothion in particular are relatively toxic to birds. At an application rate of 210 grams per hectare, fenitrothion comes very close to the lethal dose for many species of birds. It has been suspected for many years that accidental overlapping of fenitrothion spray swaths during aerial spraying is responsible for avian toxicity.

Aminocarb, with an operational application rate of 70 grams per hectare, does not have the same degree of toxicity to birds. Spraying within 400 meters of all bodies of water greater than 40 hectares and all major rivers within the province was also banned in 1978. While this action increased the percentage of unprotected forest, it decreased the likelihood of significant non-target exposure to spray. In 1980, monitoring by the Environmental Protection Agency of Environment Canada showed that the buffer zone resulted in an 80% to 92% reduction in total spray deposits on protected lakes [Ernst et al. EPS-5-AR-81-3,1981,pg.15]. It was also in 1978 that 585 oil was introduced as a replacement for diesel and other fuel oils, which had been used as diluents in oil spray formulations since the beginning of the programme. Because 585 oil was produced at temperatures below those at which polycyclic aromatic

hydrocarbons (PAH) are produced, this change was welcomed by many concerned persons. PAHs have been shown to be carcinogens in several animal systems and are suspected in the etiology of some human cancers such as cancer of the scrotum in chimney sweeps.

In 1980, small private woodlots were included in the spray programme for the first time. An important proportion of the productive softwood forest is located within these privately owned areas.

B. Contamination of Air, Soil, and Water by the Spruce Budworm Spray Programme

Evaluating the potential impact of a large and complex activity such as the annual New Brunswick spray programme is difficult because of the chemical, temporal, and geographic diversity of spraying over the years. Table A1.2 lists all of the substances that have been documented as having been used within the programme, a description of their general nature, and specific information concerning certain important physical characteristics. In subsequent sections these will be considered within certain broad categories: pesticides, formulation solvents, co-solvents, diluents, emulsifiers, and surfactants. Within the category of pesticides, organochlorine pesticides (eg. DDT), organophosphate pesticides (eg. fenitrothion), and carbamate pesticides (eg. aminocarb) will generally be considered separately. Hydrocarbon solvents, co-solvents, and diluents will be considered separately from functionally similar substances such as Dowanol that may cause different toxicological responses. The assessment of long-term environmental effects of individual or combined spray components is often difficult because areas are sprayed repeatedly year after year and different substances are sometimes sprayed from one period to the next, or even in the same year. Consequently, it is often necessary to rely

Table A1.2 Some Important Physical Characteristics Of Chemical Substances Used in the New Brunswick Spruce Budworm Spray Programme

Substance	Nature and Use	Density (gm./ml.)	Molecular Weight	Boiling Point (deg C)	Vapour Pressure (20 deg.C) atmospheres (X 1/100,000,000)
DDT	organochlorine insecticide	1.54	354.51	185-187	0 0168
Fenthion	organophosphate insecticide	1 21	299 69	162	3 3
Trichlorfon	organophosphate insecticide	1.73	257.44	100	1 0
Dimethoate	organophosphate insecticide	NA	229 28	NA	1 0
Malathion	organophosphate insecticide	1.23	330 36	156-157	16 0
Fenitrothion	organophosphate insecticide	1 32	277 24	109	6 9
Aminocarb	carbamate insecticide	1 10	208.30	NA	2 2
Atlox 3404F	emulsifier	1 03	NA	NA	NA
Toximul MP-9	emulsifier	NA	NA	NA	NA
Nonyl Phenol	solvent	0 95	215 00	NA	NA
Aromex 3472	hydrocarbon co-solvent	0 93	NA	NA	NA
Exxol D 65	hydrocarbon co-solvent	0 89	NA	179-207	NA
Dowanol TPM	glycol methyl ether co-solvent	0.96	206 30	NA	NA
Toluene	chemical solvent	0 86	NA	109-110	NA
Xylene	chemical solvent	0 87	NA	137-139	NA
Naphthalene	hydrocarbon diluent	1 05	NA	230-260	NA
Fuel Oil #1	hydrocarbon diluent	0 92	NA	NA	NA
Fuel Oil #2	hydrocarbon diluent	0 81	NA	177-343	NA
Oil 585	hydrocarbon diluent	0.83	NA	176-307	NA

NA not available or applicable, because in some cases they are not just one chemical compound

on laboratory data. The difficulties of extrapolating laboratory results to the environment, including possible differences in actual exposure or susceptibility, are noted but will not be elaborated on any further.

1. Drift, Detection, and Persistence of Residues

a. Drift of Residues

Two separate spray time periods can be usefully differentiated. The DDT period extended from the inception of the spray programme in 1952 until DDT was banned in 1969. The organophosphate period technically began in 1968, and was in use on a large scale by 1969. There are several important differences between these two periods. Most important, DDT was applied at relatively high volumes in an oil solution while fenitrothion and other organophosphate pesticides were applied at low volumes in aqueous solution. Therefore, as can be seen in Table A1.3 and Table A1.4, the quantities of both pesticide and organic diluent decreased dramatically. The decrease in application rates per hectare was primarily due to the adoption of ultra-low-volume (ULV) spray technology.

ULV concentrate spray generated by the teejet nozzles used during the fenitrothion period are calibrated to generate droplet median diameters of between 70 and 100 microns compared to droplet median diameters of 250-300 microns during the DDT period [NRCC 16073,1977,pg.177]. These have been found to be similar for both water and oil based formulations [Crabbe et al. LTR-UA-61,1982,pg.17]. Extensive research into the behavior of spray aerosols has also indicated that while differences in droplet median diameters exist between applications by small aircraft such as the Cessna C-188 and large aircraft such as the Grumman TBM's, about the same percent of spray mass is contained

Table A1.3 Quantity of Pesticide Applied (1) (gr./ha) by 4 Year Spray Period

	Organochlorine	Organophosphate			Carbamate
	DDT	Phosphamidon	Trichlorfon	Fenitrothion	Aminocarb
Spray Period					
1952 1955	1168 7 584 4	0 0	0 0	0 0	0 0
1956 1960	584 4 292.2	0.0	0.0	0.0	0.0
1961 1964	584 4 (2)	0 0	0.0	0.0	0 0
1965 1968	584 4 (2)	35.0 (2)-140.0	0 0	140.2 (2) 280 1	0 0
1969 1972	0 0	35 0 (2) 140 0	0 0	140 2-280 1	0 0
1973 1976	0 0	35.0-140 0	448 1-560 2	140 2-210 0	52 5 70 0
1977 1980	0 0	0 0	0 0	210 0	52 5 80 0
1981 1985	0 0	0 0	0 0	210 0	70 0

(1) Calculations based on data supplied by Forest Protection Ltd.

(2) Indicates that no information was recorded on the spray maps from which data in this table were calculated, data from the most recent preceeding or succeeding period were substituted at the estimated rate of the quantity

Table A1.4 Quantity of Pesticide Adjuvants (1) Used in the New Brunswick Spruce Budworm Spray Programme

Spray Period	Co-solvents (gm./ha.)	Non-Water Diluents (gm /ha)	Emulsifiers (gm /ha)
1952-1955	1835.41-917.70 (2)	5484.48 2742 24 (2)	0 0
1956-1968	917 70 (2)	2742.24 (2)	0 [illegible]
1969-1972	20 28	0.0	2. [illegible]
1973-1976	113 57-20 28	329.87	22 [illegible]
1977-1980	64 94-20 28	915.42-809 42	45 11 [illegible]
1981-1983	703 72-21 11	809.42 650 43	22 [illegible]

(1) Adjuvants are defined as chemicals other than water used in spray formulations, calculations based on data supplied by Forest Protection Ltd (FPL)

(2) Because the actual co solvents and diluent oils used with DDT during the period from 1952-1968 (inclusive) are unknown and because the percentage of each formulation component (v/v) is known only for some of the years in this period, the following values were substituted in the calculations as best estimates

percentage co-solvent	20%
percentage diluent oil	67.5%
co-solvent density*	.98 gm /ml
diluent oil density	.87 gm /ml.

within droplets greater than 25 microns [Crabbe et al. LTR-UA-56,Sept.1980,pg.21].

The volatile components of all formulations evaporate rapidly after release from the spray nozzles. One study estimated that the droplet median diameter of a ULV water-based fenitrothion formulation was reduced from 100 to approximately 50 microns within a few minutes of release from the aircraft [Kristmanson and Picot,Jan.1983,pg.17]. Formulations have been developed so that no more than 50% of the formulation will evaporate before contact with the forest.

At 500 meters downwind of the point of ULV spray release, droplets with diameters of about 4 microns contribute the most to suspended spray aerosol with only approximately 1% of the spray mass being in droplets larger than 25 microns [Crabbe et al. LTR-UA-56,Sept.1980,pg.20]. Several factors, aside from evaporation, are responsible for this phenomenon. Teejet nozzles produce many droplets less than 6 microns in diameter [Crabbe et al. LTR-UA-61,1982, pg.22] and while the forest canopy is an effective filter for certain droplet sizes it has little effect on these small droplets. Even under ideal conditions anywhere from 25-85% of the spray mass gets deposited on the targeted forest. Furthermore, climatic conditions such as wind velocity and humidity along with local differences in terrain may change deposits as much as 10-fold [NRCC 14104,1975,pg.35;NRCC 16073,1977,pg.128]. Research by Picot and Kristmanson suggests that droplet release height is one of the most important factor affecting deposition rates [Picot and Kristmanson,June 1981,pg.17]. Operational spray plane elevation during the fenitrothion period is about 30 meters [Besner et al.,1982,pg.94]. However, due to variations in local terrain this may vary substantially. Variations in wind speed complicate the calculation of the offset (drift distance of swath to target) leading to navigational error. These factors combined with

irregularities in forest cover also contribute to variations in deposition rates.

Other than the fact that those droplets under 25 microns are poorly intercepted by the forest canopy, little is known about their distribution due to limitations in the methods used to sample them. Kromekote cards, cascade impactors, and rotorod samplers are the methods commonly employed to collect data on droplet distributions. Because these field methods are insensitive to droplet sizes below 30 microns in diameter, the experimental results of Tomm, are used to extrapolate below this cut-off [Picot and Kristmanson,June 1981,pg.16].

Crabbe et al. found that 21% of the sub-canopy suspended material during 1 hour following spraying was fenitrothion vapor and the remainder aerosol [LTR-UA-56,Sept.1980,pg.25]. Over the period of a day, vapor exposure may exceed droplet exposure, but is highly variable, and depending on ambient temperatures the amount of vapor can vary as much as 10 fold [Crabbe et al. LTR-UA-56,Sept.1980,pg.25]. DDT vapor can be detected for more than 6 months after agricultural spraying [WHO,1979,pg.17]. The significance of vapor as a source of exposure will be discussed in more detail within the context of worst-case and computer generated exposure estimates in the toxicology section.

The most sophisticated drift models suggest that 84% of the active ingredient is deposited within .5 kilometers of the flight line and that .3% of the active ingredient is still airborne as vapor and small droplets at 80 kilometers [Varty,1980,pg.67]. On the basis of laboratory data supplied by Picot et al. in 1980, results from computer simulations apply primarily to active ingredient; evaporation of co-solvents and diluents is rapid due to their relatively high vapor pressures. One hundred percent of these substances is expected to have evaporated within 7.5 kilometers from the spray line [Crabbe et al. LTR-UA-

52,1980,pg.17]. Small aerosol particles, in the 2-20 micron range, contribute most to long-distance drift and generally travel for many tens of kilometers, before they are removed from the atmosphere. Fenitrothion residues in rain downwind of spray blocks in the order of .34 ppb have been detected and a sample collected 85 kilometers from the nearest spray block contained a residue level of .16 ppb. Residues in rain collected within spray blocks has been found to contain as much as 77 ppb [Varty,1980,pg.68]. Furthermore, Crabbe has demonstrated that the percentage of active ingredient remaining airborne downwind beyond the area affected by droplet sedimentation (approx. 500 meters) is affected by the meteorologic conditions at the time of spraying. He demonstrated that approximately 6% of fenitrothion remains airborne at 7.5 kilometers downwind of a spray block when spraying takes place under turbulent conditions versus 16% when application takes place under stable conditions [LTR-UA-52,1980,pg.11]. Traditionally, budworm spraying has taken place in the morning and evening when conditions are generally stable, on the assumption that drift would be minimized under these conditions.

Although similar data are not available for DDT use within the spray programme, residues of between .02 and .07 ppb in rain water have been detected in agricultural areas where DDT was sprayed [WHO,1979,pg.13]. In view of similarities between agricultural and forestry spraying during the DDT period, it seems reasonable to assume that these values would approximate those resulting from forestry spraying.

b. Detection of Residues

The mobility, persistence, accumulation, and biological concentration of chemicals, their isomers, and their degradation products are important features of environmental impact assessments. Fairly extensive information is

available for the organophosphate and carbamate pesticides used in the New Brunswick forestry spray programme, but less is known about the activity of their isomers or degradation products, and still less about the substances used in their formulation. However, the organophosphate and carbamate pesticides are generally viewed as non-persistent.

Detection limits vary according to methods of analysis used. Table A1.5 lists the limits most commonly reported in the literature for some of the pesticides used in the spray programme and shows that levels of detection for organophosphate and carbamate insecticides are similar in all media. However, accurate measurement of aminocarb in water is difficult because of its instability in that medium [Varty,1980,pg.63].

Table A1.6 lists the half-lives of some of the spray components in air, water, soil, sediment, and certain animal tissues. With the exception of DDT, these substances appear to have residence times in the environment in the range of minutes to days. While fenitrothion, dissolved in water, has the longest half-life except for DDT, the proportion of the total amount in this form is probably small in view of its relative insolubility in water and its rapid evaporation from the surface of water.

c. Biologic Persistence of Residues

An important aspect of biologic persistence is the rate at which a compound is absorbed relative to its rate of excretion. Table A1.7 lists the accumulation coefficients for some of the most common budworm spray compounds used in the past. From these figures, aminocarb appears unlikely to attain high tissue levels or to remain sequestered in tissues for extended periods of time. Care, however must be exercised in the interpretation of these results because of the importance that time since initiation of exposure exert

Table A1.5 Detection Limits for New Brunswick Forestry Spray Components

Substance	Foliage	Water	Soil	Tissue
Pesticides				
Aminocarb	10 ppb (3.)	.01 ppb (3.)	10 ppb (3.)	10 ppb (3.)
Fenitrothion	10 ppb (5.)	.01 ppb (3.)	10 ppb (3.)	10 ppb (3.)
Phosphamidon	NA	10 ppb (1.)	5 ppb (1.)	5 ppb (1.)
Trichlorfon	NA	10 ppb (1.)	5 ppb (1.)	5 ppb (1.)
Co-solvents, Solvents, Emulsifiers				
Nonyl Phenol	200 ppb (4.)	1.0 ppb (2.)	100 ppb (4.)	1000 ppb (4.)

References:

1. Ernst et al. EPS-7-AR-81-1,1981
2. Ernst et al. EPS-5-AR-81-3,1981
3. Varty, UNB, 1980
4. NRCC No.18979,1982

NA not available

Table A1.6 Half-Lives of Certain Spray Components in Different Media

Substance	Medium	Half-Life	Reference
Aminocarb	air (vapour)	38 mins.	4.
	water (river)	1-18 days	1.
DDT	air	3.3 yrs.	
	water	4.4 yrs.	
	soil	5.3 yrs.	
Fenitrothion	air (vapour)	61 mins.	4.
	water (dissolved) (1)	60 days	1.
	water (surface)	18 mins.	1.
	foliage (surface)	4 days	5.
	sediment	10-15 hrs.	2.
Nonyl Phenol	water (pond,stream)	3 hrs.	3.
	foliage (surface)	3 hrs.	3.
	salmon	6.0 hrs.	1.
	mussels	8.5 hrs.	1.
585 Oil	sea water	1.0 hr.	2.

References:

1. Ernst et al.,1981
2. Varty,UNB,1980
3. NRCC No.18979,1982
4. Besner et al.,1982
5. Crabbe et al.,LTR-UA-56,Sept.1980

(1) fenitrothion's half-life in acidic media is much longer

Table A1.7 Accumulation Coefficients of Some Spray Components

Spray Component	Species	Accumulation Coefficient (1)	Time Period	Reference
Pesticides				
Aminocarb	mussels	4	NA	1.
Fenitrothion	mussels	78-130	NA	1.
	clams	19-35	NA	1.
	trout	400	12 hrs.	2.
		84	72 hrs.	2.
Pesticide Adjuvants				
Nonyl Phenol	mussels	10	NA	1.
	salmon	250	NA	2.
585 Oil	mussels	153	NA	1.

References:

1. Varty,1980
2. Ernst et al.,1981

(1) accumulation coefficient is the ratio of the rate of uptake to the rate of excretion

NA not available

on coefficient estimates and because of widely differing potencies of these toxins.

Information on environmental residue levels after budworm spraying is fairly extensive, but does not include residue levels for DDT.

(1) Residue Levels Detected in Air

It is apparent from Tables A1.8 and A1.9 that neither aminocarb or fenitrothion is present in high concentrations beneath the forest canopy. This is not particularly surprising in view of the effective filtering action of foliage. Concentrations vary according to both hour of application (morning or evening) and hour of measurement. Typically, an evening application results in a high initial peak that declines over a period of hours, followed by a rise the next day to a level of about 10% of the previous evening peak. Morning applications result in initial peak values somewhat higher than those of evening applications, followed by a gradual dissipation over time [Varty, 1980,pg.68]. As mentioned earlier, one hour after fenitrothion spray was applied by TBM aircraft, approximately 30% of the sub-canopy suspended material was in the form of fenitrothion vapor and the remainder as aerosol. The aerosol droplets are expected to be in the sub-25 micron range as they are poorly filtered by the forest canopy. The pesticide vapor continues to drift downwind with the aerosol cloud but it is suspected that eventually all of the downwind fenitrothion concentration is in the form of vapor [Crabbe et al. LTR-UA-56,Sept.1980, pg.27].

Temperature affects the relative amounts of a compound in its vapor and liquid phase. Thus, fenitrothion vapor levels tend to rise over the course of the day as ambient temperatures rise. Neither fenitrothion nor aminocarb are expected to persist for long because of their short

Table A1.8 Chemical Residue Levels of Aminocarb and Adjuvants Detected In the Environment and Different Animal Species

Residue	Medium	Level	Time Period	Reference
Aminocarb	sub-canopy air	< 1 ppb	< 1 hr.	4.
	pond water	2.1 ppb	NA	1.
	stream water	2.6 ppb	NA	1.
	river water	3.3-24.2 ppb	5 hrs.	1.
	lake water	2.4 ppb	48 hrs.	1.
	water reservoir	.9 ppb	1 week	1.
	sediment	20.2 ppb	5 min. post-spray	2.
	sediment	3.0 ppb	30 min. post-spray	2.
	sediment	.1 ppb	1 hour post-spray	2.
	sediment	3.0 ppb	1 hour post-spray	2.
	foliage	17-37 ppb	1 year	3.
	fish tissue	500.0 ppb	12-24 hrs. post-spray	1.
	fish tissue	< 20.0 ppb	96 hrs. post-spray	1.
Aminocarb Adjuvants				
Nonyl Phenol	flowing water	2.3-9.1 ppb	1-4 hrs.	3.
	flowing water	< 2 ppb	5 days	3.
	stagnant water	1100 ppb	4 hrs	3.
	stagnant water	110-2.4 ppb	6-48 hrs.	3.
	sediment	50 ppb	NA	3.

References:

1. Ernst et al.,1981
2. Besner et al.,1982
3. NRCC 18979,1982
4. Crabbe et al.,LTR-UA-61,1982

NA not available

Table A1.9 Chemical Residue Levels of Fenitrothion Detected In the Environment and Different Animal Species

Pesticide Residue	Medium	Level	Time Period	Reference
Fenitrothion	sub-canopy air	< 1 ppb	< 1 hr.	7.
	stream water	40-50 ppb	NA	1.
	brook water	1.9 ppb	9 hrs. post-spray	3.
	brook water	< .1 ppb	5 days post-spray	3.
	lake water	.4 ppb	14 hours	3.
	lake water	.2 ppb	3 days post-spray	3.
	lake water	.1 ppb	25 days post-spray	3.
	soil	40.0 ppb	same day	2.
	foliage	2000-4000 ppb	same day	2.
	foliage	350 ppb	1 yr.	6.
	moss	8890 ppb	same day	4.
	moss	10-170 ppb	2 days post-spray	4.
	terrestrial insects	1840-5900 ppb	2 days post-spray	4.
	spiders	1130 ppb	2 days post-spray	4.
	shellfish	20-660 ppb	10 days post-spray	1.
	frogs	30-170 ppb	same day	5.
	trout tissue	200.0 ppb	12 hours	1.
	bird tissue, no canopy	45-244 ppb	8 hours post-spray	5.
	bird tissue, canopy	19-39 ppb	8 hours post-spray	5.
	bird brains	.01-7.05 ppb	NA	3.

References:

1. Ernst et al.,1981
2. NRCC 14104,1975
3. Varty,1980
4. Besner et al.,1982
5. NRCC 16073,1977
6. NRCC 18979,1982
7. Crabbe et al. LTR-UA-61,1982

NA not available

half-lives in the vapor phases. DDT vapor levels of less than 1 part per billion [WHO,1979,pg.12], however, have been detected more than 6 months after agricultural spraying.

(2) Residue Levels Detected in Water

Aminocarb and fenitrothion residues in water appear similar and range downward from 50 ppb to less than 1 ppb. over periods of hours to weeks. Partitioning of parent compounds, their isomers, and degradation products across water, suspended matter, and sediments has been reported for DDT, aminocarb, and particularly fenitrothion [Varty,M-X-67,1976,pg.15;Besner et al.,1982,pg.7]. Fenitrothion has been shown to bind at a rate of 500 micrograms per gram of sediment, dry weight, and has a half-life of 10 to 15 hours [Varty,1980,pg.70]. It is, therefore, somewhat surprising that many studies have consistently failed to detect fenitrothion residue levels in sediments [Ernst et al. EPS-7-AR-81-1,1981,pg.50]. Trichlorfon, another organophosphate used in the past, does not seem to accumulate to any appreciable degree in sediment.

(3) Residue Levels Detected on Foliage

Under optimal conditions, anywhere from 25 to 85% of emitted spray is deposited on the forest canopy with residue deposits on foliage in the order of 2 to 4 ppm [NRCC 14104,1975,pg.35]. Results of studies conducted by Yule and Duffy [1972] indicate that 50% of the deposit evaporates within 4 days, 70-85% disappears after 4 weeks, but that as much as 10% persists for up to 1 year [Crabbe et al. LTR-UA-56,Sept.1980,pg.17]. These levels after one year are sufficient to cause 36-68% mortality among sawfly larvae which fed on the foliage [NRCC 18979,1982,pg.88]. Furthermore, there is evidence to suggest that there are fewer macro-invertebrates responsible for the decomposition

of forest litter in areas with a history of fenitrothion spraying [Varty M-X-87,1978,pg.15]. As can be seen in Table A1 8, aminocarb is much less persistent in this medium, perhaps as a result of its rapid breakdown when exposed to light; its main decomposition products from foliage deposits being methylamino matacil [Ernst et al. EPS-7-AR-81-1,1981, pg.57]. Trichlorfon, used primarily in forests adjoining blueberry producing districts, is considered to persist on foliage for times on the order of days [Varty M-X-87,1978, pg.21]. The high levels of fenitrothion residues detected in tree moss have been of some concern because of the importance of was in the diets of certain bird species, such as the white throated sparrow. The amount of moss and contaminated insects consumed by this species could deliver dosages high enough to impair growth [Besner et al.,1982, pg.63]

(4) Residue Levels Detected in Soil

Soil beneath the forest is not considered a major site of contamination. No more than 5% of emitted spray is expected to reach the soil beneath the forest canopy [NRCC 14104,1975,pg.35]. However, washout can cause secondary contamination of soil. Both fenitrothion and aminocarb are degraded by microorganisms in the soil with fenitrothion being degraded principally to amino fenitrothion [NRCC 14104,1975] and aminocarb principally to des-aminocarb and aminocarb phenol [Ernst et al. EPS-7-AR-81-1,1981,pg.57]. Although similar residue data for DDT could not be found, residues of 750 to 2,030 have been reported in agricultural soils [WHO,1979,pg.46].

(5) Residue Levels Detected in Animal Tissue

Organisms inhabiting the upper regions of the forest canopy are at the greatest risk of exposure to spray substances (Table A1.9). Of all the residue data obtained from the literature, arthropods were consistently found to have the highest residue levels. Although reports of residue levels for aquatic invertebrates were not found, their effects on these populations are documented for phosphamidon, trichlorfon, fenitrothion, and aminocarb [Varty,1980,pg.52;Ernst et al. EPS-7-AR-81-1,1981,pg.34; Varty M-X-87,1978,pg.8].

C. Impact of the Spray Programme on Organisms Inhabiting Different Environments

Tables A1.10, A1.11, A1.12, and A1.13 list mean lethal doses for many of the substances used in the New Brunswick spruce budworm spray programme. These provide a frame of reference against which to evaluate the plausibility of harmful effects within the context of potential levels of contamination within the environment.

While acute effects are only one aspect of possible injury, very little information is available on the chronic effects of long-term exposure on many of the organisms under consideration. In the case of mammalian species in general, laboratory research is sometimes available to help bridge some of these gaps. In general, prolonged exposures to either the organophosphate pesticide fenitrothion or the carbamate pesticide aminocarb have not been linked to chronic effects such as slower responses to predators, growth restriction, or reproductive irregularities, as has been the case for DDT [Varty,1980,pg.16].

Table A1.10 Acute LC50's for Aminocarb and DDT in Different Animal Species

Substance	Species	Exposure	LC50	Reference
Aminocarb	marine shrimp	contact	.2 ppm	1.
	daphnia (1)	contact	.02 ppm	5.
	salmon	contact	8.7 ppm	5.
	trout	contact	8.9 ppm	5.
	bobwhite	oral	31-41 ppm	5.
	starling	oral	212 ppm	5.
	ducks	oral	2552 ppm	5.
	rats	oral	20-30 ppm	5.
	rats	contact	275 ppm	2.
	rats	inhalation (2)	.10 ppm	5.
DDT	salmon	contact	.05 ppm	2.
	ducks	oral	> 2240 ppm	2.
	rats	oral	87-500 ppm	2.
	rats	dermal	1931-3263 ppm	2.
	rats	intravenous	47 ppm	3.
	rabbits	dermal	2820 ppm	2.
	rabbits	intravenous	30-41 ppm	3.
	cat	intravenous	32 ppm	3.
	dog	intravenous	68 ppm	3.
	monkey	intravenous	55 ppm	3.

References:

1. Ernst et al.,1981
2. Prebble,1975
3. WHO,1979
4. Health and Welfare Canada,1975
5. NRCC 18979,1982

(1) daphnia is a water flea
(2) 4 hour exposure period

Table A.1.11 Acute LC50's for Organophosphates in Different Animal Species

Substance	Species	Exposure	LC50	Reference
Dimethoate	trout	contact	20 ppm	4.
	ducks	oral	41.7 ppm	5.
	rats	oral	155-500 ppm	1.
	rats	dermal	< 150-1150 ppm	4.
Fenitrothion	daphnia	contact	<.32 ppm	2.
	bees	contact	.04 micrg/bee	3.
	salmon	contact	1.4 ppm	4.
	trout	contact	1.9 ppm	1.
	ducks	oral	1190 ppm	4.
	rats	oral	250-670 ppm	4.
	guinea pig	oral	1850.0 ppm	3.
Phosphamidon	salmon	contact	11.0 ppm	4.
	trout	contact	6.0 ppm	2.
	ducks	oral	3.05 ppm	4.
	rats	oral	15-33 ppm	4.
Trichlorfon	salmon	contact	6.3 ppm	4.
	trout	contact	3-4.8 ppm	2.
	rats	oral	450-699 ppm	4.
	rabbits	dermal	5000 ppm	4.

References:

1. EPS-5-81-3,1981
2. Ernst et al.,1981
3. NRCC 14104,1975
4. Prebble,1975
5. WHO,1979

Table A1.12 Acute LC50's for Spray Components in Different Animal Species

Substance	Species	Exposure	LC50	Reference
Co-solvents and Diluents				
Aerotex 3470D	trout	contact	2.7-5.0 ppm	2.
Cyclosol 63	daphnia	contact	13.0 ppm	1.
	trout	contact	17-20.0 ppm	1.
Diesel Oil, Fuel Oil #2, #4	trout	contact	1000.0 ppm	2.
	rats	oral	> 8000.0 ppm	4.
	rats	contact	> 4000.0 ppm	4.
585 Oil	trout	contact	206.0 ppm	2.
Emulsifiers (surfactants)				
Atlox 3409F	trout	contact	4-56 ppm	2.
Nonyl phenol	marine shrimp	contact	.4 ppm	2.
	daphnia	contact	.14-.19 ppm	1.
	clams	contact	5.0 ppm	3.
	trout	contact	.56-.92 ppm	1.
	salmon	contact	.9 ppm	2.
	rats	oral	400-2462 ppm	4.
	mice	oral (1)	1231 ppm	4.
	rabbits	contact	1900 ppm	4.
Toximul MP-8	Mammals	oral	> 1000 ppm	5.

References:

1. EPS-5-81-3,1981
2. EPS-7-AR-81-3,1981
3. Varty,UNB,1980
4. NRCC 18979,1982
5. ECPHOMA,1981

(1) in corn oil solution

Table A1.13 Acute LC50's for Spray Formulations in Different Animal Species

Formulation	Species	Exposure	LC50	References
Aminocarb/Nonyl Phenol/ Hydrocarbon Oil (Matacil 1.8D)	daphnia	contact	.1-.4 ppm	3.
	salmon	contact	3.5 ppm	1.
	trout	contact	1.58-5.6 ppm	1.
	rabbit	dermal	164-132 ppm	3.
	rat	inhalation(1)	.42-.44 ppm	3.
Aminocarb/Ethanol/ Propylene Glycol	rats	oral	30 ppm	3.
	guinea pigs	oral	60 ppm	3.
Aminocarb/Ethanol/ Propylene Glycol/ Hydrocarbon Oil	rats	oral	17.1-25.5 ppm	3.
	rats	dermal	148 ppm	3.
Aminocarb/Water	daphnia	contact	1.1 ppm	3.
	trout	contact	21 ppm	3.
DDT/Oil (2)	rats	oral	250 ppm	2.
Fenitrothion/Aerotex/ Fuel Oil	trout	contact	5.6-18.0 ppm	1.
Fenitrothion/Cyclosol 63 (23%/76.4%)	daphnia	contact	< .03-.18 ppm	1.
	trout	contact	4.2-5.7 ppm	1.

References:

1. Ernst et al.,1981
2. WHO,1979
3. NRCC 18979,1982

(1) 1 hour exposure period
(2) type of oil not specified

(1) Impact of Spray on Terrestrial Invertebrates

The arthropod inhabitants of the upper forest canopy, such as the budworm, are at the greatest risk of exposure to spray compounds. DDT is well known for its lack of specificity with respect to insects. The organophosphate pesticides in general and fenitrothion in particular cause extensive mortality.

Of all insect species, bees seem to be the most sensitive to fenitrothion. The contact LC50 for bees has been determined experimentally to be 0.15 micrograms per bee [Besner et al.,1982,pg.68]. Data showing a low abundance of bumble bees in blocks sprayed with fenitrothion compared to untreated areas led, in 1968, to a ban on fenitrothion spraying of forests near commercial blueberry fields. Trichlorfon was sprayed in these areas because of its low toxicity to honey bees [Varty M-X-87,1978,pg.11] and in 1976 the buffer area was increased to 7 kilometers. Trichlorfon is not, however, of low toxicity to some other insect species. Mayflies, stoneflies, blackflies, caddisflies and midges appear to be particularly susceptible to trichlorfon residues within the environment approaching the LC50's for these species [Ernst et al. EPS-7-AR-81-1,1981,pg.10].

One study concluded that although fenitrothion reduced bee populations in May and June, recuperation appeared to occur later in the summer [Varty,1980,pg.60]. Interestingly, areas sprayed with aminocarb show an abundance of bumble bees. Exposure cage experiments have also demonstrated the low order of aminocarb's toxicity to bees and some have speculated that the abundance of bees in aminocarb sprayed areas may result from the destruction of bee predators such as spiders [Varty M-X-87,1978,pg.14]. Aminocarb is toxic to spiders and adult chalcid wasps [Varty M-X-87,1978,pg.15].

Conversely, the results of a 4 year study of forest arthropods indicates that spider populations are unaffected by either fenitrothion or aminocarb [Besner et al.,1982, pg.6].

(2) Impact of Spray on Aquatic Invertebrates

Surface waters such as lakes, rivers, streams, and reservoirs become contaminated by spray residues by either direct surface contact or washout from contaminated soil. Many aquatic invertebrate species are susceptible to pesticides; for example, DDT at spray rates of 560 gm./ha. completely suppressed insect emergence for up to 5 weeks [NRCC 16073,1977,pg.393]. The effects of pesticides on aquatic invertebrates have been extensively studied. Again, little is known about the effects of other spray formulation components or their combined effects as formulated. In 1978 aerial spraying in New Brunswick was banned within 400 meters of all bodies of water greater than 40 hectares and all major rivers. Therefore, with the exception of streams and rivers too small to be seen, navigational error, or contamination through accidental spillage, the overall situation described below has changed since that time. An evaluation of the effectiveness of the no-spray (buffer) zones by the Environmental Protection Service of Environment Canada indicated reductions in lake water of about 56% [Ernst et al.,EPS-5-AR-81-3,1981,pg.15].

Of particular interest has been the category of benthic insects, which are a principal part of the diet of many predacious species of fish such as trout and salmon. As can be seen from Table A1.8 and Table A1.9, fenitrothion and aminocarb residues range between < 1 ppb and 50 ppb, Nonyl phenol (an emulsifier used in some aminocarb formulations) attains levels of over 1 ppm which, exceeds the LC50 level

for certain invertebrate species such as marine shrimp and daphnia (Table A1.12).

Nonyl phenol was first used in the spray programme with the introduction of aminocarb formulations in 1974. Like other polyethoxylate non-ionic surfactant agents contained in many of the spray formulations, such as atlox and toximul, nonyl phenol acts biologically to increase lipophilicity which probably partially accounts for its accumulation coefficient of 10 in mussels (Table A1.7). However, despite its initial residue levels it is not very persistent in water, as indicated by its 3 hour half-life in this medium (Table A1.6).

Fenitrothion decreases the population size of stream invertebrates (benthos) [Ernst et al. EPS-7-AR-81-1,1981, pg.34]. The threshold for the induction of benthic movement downstream caused by fenitrothion has been estimated to be 20 ppb [Besner et al.,1982,pg.74] which is within the range of residues detected in streams (Table A1.9). Monitoring of aquatic insects following spray indicates that the actual kill rate may only be about 5% [Varty M-X-67,1976,pg.9], and one study found that population levels had returned to normal within one month of spraying [Varty M-X-87,1978,pg.8] though another found that the population had not stabilized by 6 weeks [Ernst et al. EPS-7-AR-81-1,1981,pg.34].

The highest aminocarb residue level detected in water was 24.2 ppb (Table A1.8). This is below the estimated threshold level for the induction of benthic drift [Besner et al.,1982,pg.74]. The accumulation coefficient of 4 for aminocarb in mussels is low compared with other substances for which this type of data is available (Table A1.7). Not surprisingly, therefore, reports in the literature do not indicate that aminocarb, at levels resulting from its typical operational application rate of 70 gm./ha. has a significant impact on aquatic invertebrates [Varty M-X-67,1976,pg.9;Ernst et al. EPS-7-AR-81-1,1981,pg.34;Varty M-X-87,1978,pg.8]. Even experimental introduction of more

than 3 times the amount expected under operational spray conditions failed to demonstrate adverse effects on aquatic invertebrate populations [Varty,1980,pg 49].

Practically no information on residue levels or the effects of sprav formulation adjuvant oils on aquatic invertebrates could be found in the literature. Table A1.6 indicates that 585 oil, which replaced fuel oil #2 as an adjuvant oil in 1978, is not very persistent in water, but has a very high accumulation coefficient (Table A1.7). Also, hydrocarbon oils are insecticidal and have even been used in agriculture because of this property, so it is plausible that the petroleum oil components of spray formulations may disrupt certain aquatic invertebrate populations. However, given the fact that a large proportion of the mass of these compounds is likely to have evaporated before contact with ground based surfaces, the degree of disruption is probably small.

(3) Impact of Spray on Fish

In 1963 DDT spray was banned within 0.8 kilometers of major salmon producing streams because of the toxicity of DDT on this species. An organophosphate pesticide, phosphamidon, replaced DDT spraying in these areas and thereby heralded not only the operational introduction of this new class of pesticide into the spray programme but also what was to become a series of pesticide substitutions as each new compound was found to have new toxicity problems. While Tables A1.10 and A1.11 indicate that DDT is more than 200 times more toxic to salmon than phosphamidon, it also was discontinued, in 1976 because of its toxicity to perching birds [Ernst et al. EPS-7-AR-81-1, 1981,pg.45]. The substitution of trichlorfon for fenitrothion in 1968 around blueberry fields [Wood,1980] is another example of this trend.

In general, the LC50 levels for all organophosphate pesticides, aminocarb, and the formulation adjuvants for which data are available are an order of magnitude greater than any water residue levels reported for these substances. This situation also applies to those listed in Table A1.13. Of all these substances, the safety margin appears to be the narrowest for the organophosphate pesticide fenitrothion and the emulsifier nonyl phenol. The fact that these 2 compounds also have relatively high accumulation coefficients qualifies them for special attention.

Matacil, a commercial budworm spray formulation, contains 18% aminocarb, 50% nonyl phenol, and 35% 585 oil. One study indicated that this formulation was 10 times as toxic to rainbow trout than aminocarb alone [Varty,1980, pg.58]. As a result of this and other work in the area, nonyl phenol is no longer used as a formulation adjuvant in the spray programme.

Despite its relatively narrow margin of safety, the comparison of fish populations from areas with and without a history of intensive spraying suggests that fenitrothion has not depleted the populations or biomass of trout or salmon [Varty M-X-87,1978,pg.8]. Furthermore, direct mortality of fish caused by either fenitrothion or aminocarb at operational levels has not been documented in New Brunswick [Varty,1980,pg.2].

(4) Impact of Spray on Birds

Many species of birds inhabit the upper canopy of the forest, and are exposed to chemical contamination through direct body contact as well as consumption of insects or vegetation. Spraying takes place in May and June when birds are also subjected to the physical and psychological stresses of migration and the onset of breeding [Varty M-X-67,1976,pg.3]. Problems with pesticide toxicity in birds have led to changes in the choice of pesticide sprays.

DDT is known for its negative effects on the reproductive success of several species of birds of prey. DDT applied at rates of 1,121 to 5,607 grams per hectare also causes extensive mortality among many different bird species [Dunlap,1981,pg.77]. Table A1.3 indicates that quantities of DDT used in the early years of the New Brunswick forestry spray programme are within this range. Research carried out in 1951 on a tract of land sprayed at a rate of 2 pounds DDT per acre per year (2 times the annual rate applied on New Brunswick forests in the early 50's) over a 5 year period indicated a 26% decrease in the breeding population of birds [Dunlap,1981,pg.93]. Other research showed that the ingestion of 20 ppm DDT by quail decreased both the hatching of eggs and survival of hatched chicks [Dunlap,1981,pg.93]. Tissue concentrations of DDT in predacious fish and birds can reach tens of thousands of times the concentrations in their habitats.

With the exception of dimethoate and phosphamidon, experimental research into the oral toxicity of spray programme pesticides in ducks indicates acute toxicity occurs above 1000 ppm (Table A1.10 and Table A1.11). The maximum air concentration of pesticide detected following spraying is .44 ppb of fenitrothion [Besner et al.,1982, pg.101]. Other data collected in the field indicate that the threshold of fenitrothion for acute effects in sensitive bird species is just above application rates of 210 grams per hectare, and some very sensitive species show effects at about 140 grams per hectare [NRCC 14104,1975,pg.62]. Other organophosphate pesticides used in the past were more toxic to birds than fenitrothion; both dimethoate and phosphamidon were discontinued because of their impact on sensitive bird species.

Kinglets and white throated sparrows are considered to be the species most vulnerable and sensitive to the toxic effects of spray because they inhabit the upper forest canopy and eat contaminated insects.

III. TOXICOLOGICAL CONSIDERATIONS

A. Introduction

An important feature of the budworm spray programme in New Brunswick is the large number of different substances and mixtures of substances employed over the years. Table A1.2 contains a list of important compounds used operationally and some of their physical characteristics. This list does not include substances that may have been used on an experimental basis in the past, but even if this information were available, it would be of questionable importance in view of the relatively small amounts used and the extremely remote location of the experimental areas. For purposes of study, these compounds are classified into general groupings that reflect the formulations actually applied and their distribution in time and space, including the association of various classes of adjuvants with particular types of pesticides. This approach is to facilitate understanding of those aspects of exposure that are of greatest relevance to the assessment of cancer risk in New Brunswick. Particular classes of compounds, such as oils or emulsifiers, are discussed in the context of the category within which they most commonly occurred. The classification of formulations is:

1. organochlorine
2. organophosphate
3. carbamate

The potential public health significance of compounds within each of these categories depends on such matters as their physical characteristics, conditions of human exposure, and their toxicity.

B. Physical Characteristics of Spray Compounds

Information about the physical characteristics of individual compounds within each formulation category can be useful in understanding a compound's physical behavior in the environment. To the extent that this behavior is predictive of either the compound's available dose or probable route of entry into the body, it will be useful in the assessment of exposure. Important physical attributes of chemical compounds include:

a) vapor pressure
b) photolability
c) stability at various pH levels
d) susceptibility to hydrolysis
e) polarity
f) molecular weight
g) lipid/water partition coefficient

Compounds with high vapor pressures evaporate rapidly from surfaces with which they come into contact. This characteristic has important implications for substances released into the air in the form of aerosols at a distance from their point of contact. Under these conditions, only a small proportion of the total quantity released is likely to reach its target. The vaporized component, depending on its stability may undergo rapid phototransformation or remain in the atmosphere where it may react with other substances or be washed out.

The chemical reactivity of a compound is mainly determined by its degree of polarity. Highly electrophilic compounds are generally the most reactive.

Once a compound leaves the air to enter a water system, its persistence is most affected by its susceptibility to hydrolysis and to biologic degradation and transformation. The speed with which it undergoes chemical changes is commonly affected by the pH of the water, while the degree of

biologically determined activity is proportional to the compound's lipophilicity. After highly lipophilic compounds such as pesticides enter a body of water, they may become relatively unavailable for direct ingestion by humans because of their adsorption to microorganisms and highly lipoidal sediments, but can nonetheless be a serious indirect problem if they concentrate within the food chain and are eventually ingested by humans. Similar processes, to a lesser extent, occur within the soil.

C. Conditions and Levels of Exposure to Spray

Secondly, it is necessary to define as precisely as possible the conditions of exposure, especially the route(s) of entry into the human body and the intensity, duration, and frequency of exposure. The routes of entry are important in evaluating the likelihood of a toxicological response insofar as they affect the processes of detoxification. For example, a compound that enters the body by way of the respiratory system or skin by-passes the portal circulation of the liver, which is the main site of detoxification. Very little is known about detoxification within the lung or skin. In the spray programme, the general conditions of exposure are the same for all substances under consideration and are primarily via the skin and respiratory system.

Between mid-May and the end of June each year, certain areas of forest are sprayed from the air with pesticide formulations. For the first 10 years of the programme (1952-1962) DDT was used exclusively in hydrocarbon oil formulations. Since that time many different pesticide formulations have been used. Table A1.14 contains a listing of these. These changes in the types of pesticides used over time complicate the evaluation of the public health significance of the spray programme.

Exposure to chemical compounds contained in aerially applied pesticide formulations can occur by absorption from

Table A.1.14 List of Spruce Budworm Chemical Spray Formulations Used in New Brunswick

Active Ingredient, Carrier (1)
Organochlorine Formulations
DDT, Oil (2)
Organophosphate Formulations
Phosphamidon, Water
Trichlorfon, Water
Dimethoate, Water
Malathion, Water
Fenitrothion, Water
Fenitrothion, Oil
Carbamate Pesticides
Aminocarb, Oil
Aminocarb, Water

(1) when water is used, emulsifiers are also used as adjuvants. Note that a small amount of solvent is used even in the case of water-based formulations. Aerotex, a hydrocarbon solvent, is the most common solvent used in fenitrothion and water formulations.

(2) the term oil is used in the generic sense, and includes both hydrocarbon solvents and pure solvent compounds such as Dowanol.

the skin, or respiratory system, or through oral ingestion. Spray exposure is in the form of both aerosol droplets and vapor. Although estimates vary [NRCC 18979,1982,pg.74; Varty 1979;WHO,1979,pg.200], aerosol droplets less than 5 microns penetrate deeply into the lung and are deposited in the bronchioles and alveoli. Droplets between 5 and 10 microns are deposited in the upper airways where again, depending on their solubility, they are either absorbed or swept into the pharynx to be swallowed or expectorated. Aerosol droplets ranging in size from 10 to 50 microns are most likely to be deposited in the nasal passages and can be considered to add to oral exposure. Table A1.15 contains a listing of the distribution of spray mass by droplet size ranges at time of release from the spray nozzles. These data are derived from the research of Crabbe et al. and are specific to the ultra-low-volume (ULV) spray technology using TBM aircraft in the New Brunswick spruce budworm spray programme and are therefore most relevant to spraying after 1966.

The use of small, relatively slow flying agricultural aircraft (90-152 km./hr.) causes a shift in the median diameter of droplets but does not affect the distribution of the amount of formulation in droplets greater than 25 microns [Crabbe et al. LTR-UA-56,1980,pg.28]. Wind speed exerts a significant effect on droplet deposition, particularly with respect to droplets less than 50 microns in size. For these droplets, a doubling of the wind speed was found to reduce aerosol dosage levels by 50% [Crabbe et al. LTR-UA-56,1980,pg.18].

Picot et al. have found that approximately 40% of the volume of the ULV spray vaporizes before it is deposited on the forest canopy or ground, or drifts past 300 meters [1980,pg.18]. Hopewell found that droplets from DDT formulations with initial droplet diameters of 100 microns decreased in size by 50% within approximately four minutes [Hopewell,1959]. A large proportion of the solvents

Table A1.15 Approximate Distribution of Spray Mass By Those Droplet Size Classes Considered to be Relevant to Route-Specific Exposure As Generated by Ultra Low Volume Teejet Nozzles (1)

Size Range (microns)	Percentage of Spray Mass at Point of Release	Relevant Route of Exposure
< 5	.5%	inhalation
5 - 50	6.5%	oral
50 - 75	18.0%	(2)
> 75	75.0%	dermal

(1) NRCC 18979, 1982
(2) not documented as contributing to inhalation, oral, or dermal exposure

and diluents which make up the greatest percentage of the volume of spray formulations evaporate within minutes of their release from the spray nozzles and travel within the spray cloud in the form of vapor. Alternatively, very little of the mass of the pesticide component of the spray cloud is in the form of vapor [Crabbe et al. LTR-UA-56,1980,pg.23]. Crabbe et al. found that during the first hour following spraying from 10% to 30% of the mass of fenitrothion was vapor and the remainder was in the form of aerosol droplets [LTR-UA-65,1983,pg.21]. The vapor arises from the evaporation of pesticide deposits from contact points and is highly dependent on ambient environmental temperatures. Over a 10 hour post-spray period vapor exposure at the spray line can exceed aerosol exposure levels (Table A1.16 and Table A1.17). A spray line is defined as the track formed by a layer of spray aerosol generated from a single spray plane. Operational spray application involve 3 spray planes that release separate spray tracks at 100 meter intervals. Under the influence of cross-winds these tracts join to form a single swath. In a typical multi-swath operation the term spray line applies to the track nearest to the outer limit of a given spray block and is considered to be the equivalent of direct overhead spraying.

Two approaches to the estimation of aerosol pesticide exposure have been used within the context of the New Brunswick spray programme. The first is commonly referred to as the "worst-case scenario" approach in which it is assumed that 100% of the mass released from the aircraft is available for exposure. The second approach to exposure estimation uses computer simulation techniques to model the behavior of aerosol droplets in the environment after their release from spray nozzles. Table A1.16 contains worst-case estimates of exposure at the spray line for DDT, fenitrothion, and aminocarb and computer model estimates for aminocarb.

Table 1.16 Franklin Worst-Case Scenario and Crabbe Computer Model Estimates of 1 Hour, Unsheltered, Spray Line Aerosol Exposure to DDT, Fenitrothion, Aminocarb (1)

Route of Exposure	Spray Line Aerosol Exposure (micro gr./kg./bw.)			
	DDT Worst-Case	Fenitrothion Worst-Case	Aminocarb Worst-Case	Aminocarb Computer
Dermal (2)	188.00	67.56	22.50	6.678
Inhalation (3)	NA	0.87	0.29	0.00091
Oral	NA	12.18	4.06	0.01330
Total	188.00	80.61	26.85	6.69221

(1) all calculations based on figures from NRCC 18979,1982,pg.78
(2) assumes 75% of spray mass available rather than the less realistic 100% used in the Franklin worst-case scenario
(3) aerosol exposure only (does not include vapour)

NA not available

Table A1.17 Sub-Canopy Fenitrothion Vapour Inhalation Exposure (1)

	Vapour Exposure (micro gr./kg/bw.) Distance (meters) (2)				
	Spray Line - 200	300	500	700	1000 (3)
Period After Spray (hours)					
0 - 1	.448	.307	.245	.205	.150
1 - 3	5.368	3.081	2.444	2.195	1.788
3 - 6	21.476	12.713	10.701	9.129	8.946
6 - 10	53.690	30.826	24.452	21.932	17.904
Total for 10 Hour Work Day	80.982	46.927	37.842	33.461	28.788

(1) based on inhalation rate of 29 litres per minute [NRCC 18979,1982,pg.74] for a 70 Kg person using measured sub-canopy fenitrothion vapour [LTR-UA-56,1980,pg.25.]

(2) weights were applied to figures at each distance to adjust the data to reflect values expected from operational multi-swath spraying (20 swaths). Test results are based on 1 swath only. [LTR-UA-56,1980,pg.27]

(3) extrapolated by Crabbe et al. based on test data [LTR-UA-56,1980,pg.25]

It is interesting to note, although not surprising, that the computer model provides lower estimates for all routes, and in particular for inhalation and oral routes, despite the fact that the worst-case scenario estimates were modified to reflect that only 75% of the spray mass is contained within a droplet spectrum likely to adhere to the relevant body tissue. The computer model uses a series of algorithms to calculate the time-integrated changes as the droplets evaporate. The worst-case scenario does not take into consideration the effects of evaporation on the droplet spectrum. It has been shown that a 150 micron diameter droplet containing 70% #2 fuel oil and 20% aromatic co-solvent decreases to 50% of its size in approximately 6 minutes [NRCC 16073,1977,pg.176].

Dermal exposure differs between models to a much lesser degree because it is much more affected by larger droplets whose velocities are less dramatically altered by the process of evaporation. The worst-case scenario and the computer model also differ slightly with respect to the amount of exposed skin used in their calculations. This difference may account for a small part of the disagreement.

Absorption of substances deposited on the skin is through passive diffusion and is affected by mechanisms in the lipid and protein structure of the skin.

Absorption of aerosols entering the body through the oral route has been assumed to be 100% [NRCC 18979,1982, pg.80]. This assumption should be qualified in the case of DDT and perhaps other pesticides by considering the nature of the solvent in which the substance is dissolved. DDT is less toxic when dissolved in petroleum products than when dissolved in either animal or vegetable oils [WHO,1979, pg.117]. This may be due to a laxative effect of the petroleum oil and might therefore also apply to other pesticides dissolved in oil.

Table A1.18 provides additional computer model estimates of aminocarb exposure at 400 and 800 meters beyond

Table A1.18 Crabbe Computer Model Aminocarb Exposure Estimates By Distance From the Spray Line (1)

Route and Wind Speed	Aerosol Exposure (micro gr./kg./bw.) (2)		
	Spray Line	400 meters	800 meters
Dermal (3)	6.67800	0.003000	0.00000
Inhalation	0.00091	0.000077	0.00004
Oral	0.01330	0.013300	0.00840
Total	6.69221	0.016377	0.00844

(1) treetop wind speed was 50 cm./sec. [NRCC 18979,1982,pg.79]
(2) based on 70 gr./ha. aminocarb
(3) calculations are based on model's use of estimated area of head, neck, forearms and hands [NRCC 18979,1982,pg.205]

the spray line. While aminocarb was chosen because of the availability of computer estimates for this pesticide, the shape of the curve is not expected to change. Field trials involving both aminocarb and fenitrothion indicated that the differences in the dosages in the spray was almost entirely due to differences in their application rates [Crabbe et al. LTR-UA-65,1983,pg.21]. The duration of the passage of a single swath in light winds has been estimated to be from 20 to 30 minutes [Crabbe et al. LTR-UA-56,1980,pg.23].

Data collected in the field confirm that the concentration of aerosol in the atmosphere follows a log normal distribution up to 7.5 kilometers as predicted by the computer model [Crabbe et al. LTR-UA-52,1980,pg.ii]. These results are also consistent with what is already known about the distribution of aerosol masses in general [Brain et al. 1974,pg.2]. Under calm spraying conditions it was found that approximately 16% of the pesticide mass of the spray formulation drifts beyond 7.5 kilometers while 6% drifts beyond this point under more turbulent conditions [Crabbe et al. LTR-UA-56,1980,pg.28]. The droplets that were found to drift beyond 7.5 kilometers were found to range below 30 microns and are therefore likely to drift for an indefinite period of time before being removed from the atmosphere. Additional sampling at 22 kilometers from the spray line suggests that droplets become mono-dispersed at around 5 microns in size [Crabbe et al. LTR-UA-52,1980,pg.23]. In view of the fact that spraying has historically taken place during periods of relative calm, the 16% value is the most meaningful for the purposes of this study. It should be emphasized that the above values also apply specifically to the period since ULV spray nozzles were introduced into the New Brunswick forestry spray programme in 1967, and therefore applies exclusively to organophosphate and carbamate pesticide sprays. Organochlorine (DDT) formulations were applied using high-volume nozzles and, although no documentation on the droplet spectrum of DDT

forestry sprays could be located, it is reasonable to assume that a much smaller percentage of the spray mass would be contained within the very small droplets that are subject to long-range drift. The same spray technology was used in forestry spraying as in agricultural spraying during the DDT period with the exception that faster planes were introduced into forestry spraying in 1958. Because of the greater shear force acting at the spray nozzles of these faster planes, a larger percentage of the spray mass in small droplets is expected in the context of forestry spraying than is likely to occur in agricultural spraying.

Neither the worst-case scenario nor the computer model estimates produced so far include vapor exposure. Data collected in the field could be found only for fenitrothion; these are contained in Table A1.17. This table is based on data collected following a morning spray. Spraying takes place both in the morning and in the evening to take advantage of the calm created by temperature inversions during these periods. Although, not discussed in the literature it is probably safe to assume a similar pattern for evening spray, except for an initial lag of several hours. Other important features of this table include the fact that exposure was standardized to a 70 kg. person breathing at a rate of 29 litres per minute. This figure appears high when compared with amounts reported elsewhere but may accurately reflect excercise rates in exposed persons, and was used to retain consistency with what has been reported for aerosol inhalation in both exposure model estimates for aminocarb. Clinical investigators associated with the Newfoundland Medical Association used 20 liters in their estimates [NMAC,1979,pg.31] and Crabbe et al. used 6 liters on one occasion [Crabbe et al. LTR-UA-56,1980,pg.i] and 10 litres on another [Crabbe et al. LTR-UA-65,1983, pg.i]. Finally the Task Group of the International Commission on Radiological Protection used 21.75 litres per minute in their report [Brain et al.,1974,pg.8]. The data

in this table show clear trends. Vapor exposure decreases with distance and increases over time as ambient temperatures in the environment rise.

It has been shown that 70-85% of fenitrothion deposited on the forest disappears within 2 weeks after spraying. Although DDT vapor has been detected for 6 months following agricultural spraying [WHO,1979,pg.12], vapor is not considered to be an important source of exposure for this class of pesticide.

It can be argued that all exposure values presented so far should be multiplied by 2 in view of the fact that most spray blocks are sprayed a second time, usually after a period of about 1 week. The bio-accumulation of DDT in animal tissues is well established whereas organophosphate and carbamate pesticides are generally excreted rapidly. Research carried out on rats by investigators at the University of New Brunswick demonstrated that usually more than 60% of fenitrothion was excreted in the urine within 3 days of exposure to 10 mg. per kilogram body weight, with some residues remaining in the blood, brain, liver, and fat for up to 16 days post-exposure [Varty,1979]. Assuming similar processes in humans, some accumulation of exposure from one application to the next is plausible for organophosphate and probably carbamate pesticides as well. Bio-accumulation from year to year is much less plausible except for DDT.

All exposure figures should be considered as order of magnitude estimates only. The magnitude of the error potentially associated with these types of estimates is best exemplified by the report that variation by as much as a factor of 10 was recorded within a single spray block and that in some situations spray deposits equal in degree to direct over-spray were observed at least 1.6 kilometers beyond the nearest spray block boundary [Varty M-X-67,1976].

The issue of long-range drift has been inadequately covered in the literature. Worst-case estimates have not

been extended to this area and the Crabbe computer model is not reliable for exposure estimates beyond 7.5 kilometers. By applying the worst-case model assumptions to long-range aerosol exposure it was found that this type of exposure was approximately 1.7 times the total exposure expected at the spray line. This is based on an adjustment for the fact that at the spray line only 0.5% of the mass of the pesticide is in a respirable size range (< 5 microns) while beyond 7.5 kilometers this proportion is probably closer to 16%. Because of the fact that a typical spray operation would involve 20 swaths, each of which would pass over a point in about 30 minutes, there would potentially be a 10 hour exposure period at any point downwind as the spray cloud passed overhead. In the case of fenitrothion, the total exposure under these conditions would be approximately 278 micrograms per kilogram body weight. You will recall that exposure at the spray line is almost entirely dermal exposure while beyond 7.5 kilometers it is almost entirely by inhalation.

D. Toxicity of Spray Compounds

Because the focus of this inquiry is on cancer, only data which is considered to be relevant to the induction of and or promotion of somatic events leading to the development of a cancer will be considered. These include short-term in vitro mutagenicity studies and long-term studies of carcinogenicity in mammals. Factors affecting the evaluation of evidence from these types of studies include:

(a) Long-term studies almost exclusively involve ingestion as the route of exposure. Because this route exposes potential carcinogens to biochemical processes otherwise absent or operating at lower levels of efficiency in other routes such as the lung or skin, results should be generalized with care.

(b) Toxicological responses to chemical compounds vary across mammalian species. For example, 2-naphthylamine is a potent bladder carcinogen in dogs, hamsters, and man but not in the rat, rabbit, or guinea pig [WHO,1979]. Arsenic and benzene are human carcinogens but appear not to be rodent carcinogens [Weinstein,1983].

(c) Test animals are administered very high doses of compounds relative to the amounts likely to be encountered by humans. The biological mechanisms involved in detoxification or transformation at high doses are frequently different from those operating in response to a chronic low-dose exposure. These different conditions may result in entirely different organ system responses.

Despite these caveats, long-term chronic studies in animal species are generally considered to be useful predictors of the carcinogenic effects of chemicals in humans.

Exposure within the context of the New Brunswick spruce budworm spray programme involves more than a single compound and the array of substances involved is discussed below.

E. Spruce Budworm Spray Formulations

In general, forestry spray formulations contain three types of compounds:

a) solvents and diluents

b) emulsifiers

c) pesticides

While all formulations contain solvents and diluents, only those formulations that contain water as a diluent also contain emulsifiers. Furthermore, DDT (organochlorine) was used almost exclusively for the first 17 years of the New Brunswick programme and was formulated only with organic diluent oils. Organophosphate pesticides replaced DDT

beginning in 1969 and were formulated almost entirely using water as their diluent. Finally, carbamates were not introduced until 1972 and have been until very recently formulated solely with an oil diluent.

The pesticides are frequently referred to as the active ingredient of the formulation. This is a misnomer in the sense that some of the members of the other two categories also possess pesticidal and other biologic properties. Those pesticides that have been used within the aerial budworm spray can also be grouped into 3 categories:

a) organochlorine pesticides
b) organophosphate pesticides
c) carbamate pesticides

1. Solvents and Diluents

There is a fine distinction between the terms diluent and co-solvent. The distinction is generally made with respect to the quantity of the compound contained within the spray formulation rather than a result of any chemical differences, and many of the compounds used as co-solvents are also used as diluents. Pesticides are frequently produced in a powdered form and co-solvents are used to produce liquid concentrates for certain types of applications. Diluents, however, are usually added by the applicator in order to produce a desired formulation viscosity. The function, therefore, of all spray diluents and co-solvents is to produce pesticide solutions. Because most pesticides are not miscible with water, they require at least a small amount of organic solvent to form solutions. Prior to the introduction of organophosphate pesticides, hydrocarbon solvents were most commonly used as diluents.

Hydrocarbon solvents are not pure compounds but mixtures of hydrocarbons derived from petroleum, coal, or shale. Both the source of the hydrocarbon oils and the

manner in which they are refined can modify their carcinogenic behavior.

Crude oils are initially subjected to a distillation process in which constituent materials are separated according to boiling range. Some of these products are then subjected to a secondary refining stage. One common secondary stage is treatment with hydrogen to lower the aromatic content of the final product. Another involves catalytic cracking operations that use heat catalysts and/or hydrogen to split molecules into smaller units or to create entirely new molecules. Various light and heavy oils and residues result from this process. The heavy oils and residues with higher boiling points usually contain high concentrations of highly carcinogenic polycyclic aromatic hydrocarbons (PAH) such as benzo(a)pyrene and phenanthrene.

Oils boiling above 370 degrees centigrade are carcinogenic to the skin of mice [Bingham et al., 1980]. Their carcinogenic potency appears to be determined mainly by the concentration of PAH with boiling points above this limit. Temperature, however, should be used only as a rough guide to the carcinogenic potency of these oils as the type and concentration of PAH also varies according to the source of the hydrocarbon oils (petroleum, coal, shale). It is also a common practice to blend oils with different maximum boiling points to obtain products with desired physical characteristics. This type of activity has important implications for the carcinogenic potency of the final product insofar as hydrocarbon distillates with boiling temperatures in the range of 315 to 425 degrees celsius, although not themselves carcinogenic, appear to be capable of enhancing the carcinogenic activity of oils with higher boiling points. The interested reader is referred to a comprehensive review of this topic by Bingham Trosset, and Warshawsky [1980] for more detailed information.

During the period from 1952 to 1968, DDT was formulated with a variety of hydrocarbon co-solvents and diluents.

Prominent among the co-solvents were toluene, xylene, and methylated naphthalenes, while fuel oils #2 and #4 were among the most popular diluents during the latter part of this period. Unfortunately, no information is available on the nature of pesticide diluents used during the early years of the spray programme.

Methylated naphthalenes are obtained from coal tar and petroleum sources. While their exact composition varies, they generally consist of a mixture of aromatic and aliphatic hydrocarbons. Toluene is used extensively as a solvent in a wide range of coatings and adhesives. Xylene and naphthalene are used as solvents for rubber, polystyrene, and many resins. Outside of occupational settings where these substances are used it would be extremely difficult to evaluate the amount of background exposure to which a typical New Brunswicker is likely to be exposed.

Fuel oil #2 and #4 are domestic heating oils produced from direct distillation or cracking, or as residual by-products of other processes. These oils in particular are highly variable in their composition and boiling points. They are commonly blends of simple low and high boiling distillates; some may have been subjected to catalytic cracking. Fuel oil #2 has a boiling range of from 177 - 343 degrees celsius and is generally composed of 30 - 32% aromatics, 37 - 43% paraffins, and 26 - 32% naphthalenes [Bingham et al.,1980]. Diluent oil 585 is a highly refined oil that was introduced into the spray programme in 1978 as a pesticide diluent. Laboratory tests conducted by the Canadian Department of Agriculture indicated that, at a limit of detection of 1.0 to 2.0 parts per million, no polycyclic aromatic hydrocarbons of the type suspected of having some association with cancer were detected [Ag Canada,1983].

Aerotex 3470, a high boiling point petroleum distillate, is a complex mixture of alkylated benzenes,

naphthalene, alkylated naphthalenes, alkylated polynuclear aromatic hydrocarbons, and alkylated bibenzyls [Safe et al.,1977]. It has been used annually as a co-solvent for both oil and water-based organophosphate formulations since its introduction in 1969. The relatively high degree of water solubility and lipophilicity of its alkylated naphthalene fraction has been found to promote its bio-accumulation in the environment [NRCC 16073,1977,pg.,73].

Cyclosol 63, another hydrocarbon product, was first used on an operational basis in 1982 and has been used since that time both as a co-solvent and as a diluent. It is not a fuel oil but a mixture of hydrocarbons manufactured in the refinery. At a limit of detection of 5 parts per million (w/w), Cyclosol 63 does not contain any tri-cyclic aromatics or other potentially carcinogenic polycyclic aromatic hydrocarbons [Granville,1982].

Dowanol (tripropylene glycol methyl ether) was operationally introduced into the spray programme in the same year as Cyclosol 63 and like Cyclosol 63 has been used both as a co-solvent and as a diluent. Unlike all of the other co-solvents and diluents employed in the spray programme Dowanol is a pure compound and for this reason has been recommended by as a more desirable substance for use in the spray programme [Spitzer et al.,1982].

Nonyl phenol is a mixture of monoalkyl phenols and was used as the primary solvent for aminocarb. Matacil (aminocarb 1.8D) oil soluble concentrate contained 50.5% (by weight) nonyl phenol. For every 70 grams of aminocarb sprayed, 182 grams of nonyl phenol was also sprayed. Its function is to keep aminocarb in suspension when mixed with fuel oils. Because aminocarb is a polar compound and therefore only moderately soluble in aromatic solvents nonyl phenol acts as an emulsifier to bind aminocarb to the hydrocarbon solvent [Thurlow,1979,pg.43]. A great deal of interest in nonyl phenol was generated by the finding that aminocarb formulations containing nonyl phenol are 10 times

more toxic to rainbow trout than aminocarb formulations without. It is possible that part of its toxicity may be due to the nonyl group of phenol which is known to increase lipophilicity [Varty,1980,pg.57]. Although field studies in Ontario suggested that even in the worst case of contamination there would be a 100 fold factor of safety for salmon, a new formulation was developed that did not require nonyl phenol [Varty,1980,pg.2]. Nonyl phenol and other similar compounds are used in a wide range of commercial products and acute toxicity is generally greater than 1000 mg/kg body weight [ECPHOMA,1981,pg.29].

2. Emulsifiers

Emulsifiers are complex mixtures of polyoxyethylene ethers and benzene sulphonate esters. They belong to a class of chemical compounds known as surface active agents. Their primary activity is to alter energy relationships at interfaces, usually by lowering surface or interfacial tension. This is achieved by the structural arrangement within the emulsifier molecule of a hydrophilic group and a hydrophobic residue. The function of emulsifiers within the spray formulation is to facilitate the dispersion of the pesticide/solvent solution within the water component of the formulation.

The chemical activities of emulsifiers within biological systems include:

1. alteration of membrane permeability;
2. interaction with and alteration of antigens;
3. inhibition of enzymes;
4. interaction with proteins resulting in precipitation, complex formation and denaturation.

An evaluation of the presence of emulsifiers in the environment indicates that these substances are ubiquitous.

They originate from such varied sources as household detergents, toothpaste, shampoo, paints, floor polishes, textile coatings, leather coatings, and processed foods.

3. Organochlorine Pesticides: DDT

The best known members of the organochlorine family of pesticides are DDT, aldrin, dieldrin, chlordane, endrin, lindane, BHC, heptachlor, methoxychlor, toxaphene, and endosulfan. These pesticides are known to be persistent in soil, food, and feed and tend to accumulate in the fatty tissues of animals and man.

DDT was the only organochlorine pesticide used for forest protection in New Brunswick. Its use was discontinued in 1969 as a consequence of its persistence in the environment and its negative effects on certain animal species, particularly on the breeding of birds of prey.

The main acute toxicological effects of organochlorine pesticides are on the nervous system and the liver. Both the central and peripheral nervous system are affected. Single or repeated doses lead to hyperexcitability, tremo , ataxia, and convulsions in animals. Sufficiently high doses are lethal, with death usually due to respiratory failure brought on by the convulsive stage of the toxic response. Nervous system effects are due to the action of these substances on tissue membranes. DDT also causes focal necrosis of liver cells in several animal species [WHO,1979,pg.16].

a. Physical and Chemical Properties

DDT or [1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethano], is relatively non-volatile compared with other pesticides used in the spray programme. It is also highly lipophilic and very resistant to oxidative, reductive, and hydrolytic enzymes. These properties account for its

extreme mobility, persistence, biological concentration, lipid storage, and remobilisation in the environment [Varty,M-X-87,1978,pg.22]. The only exception is that DDT decomposes rapidly under biologically active anaerobic conditions.

b. Sources, Routes, and Levels of Exposure

Organochlorine pesticides, particularly in the form of DDT, have been the most extensively used pesticides in history. DDT was introduced on a limited basis by the US military in 1939 for use against vector-borne diseases such as malaria but was not made commercially available until 1945. In North America, it was used extensively prior to the 1970's.

DDT has been used extensively in agriculture in North America, and forestry sprays have not been the most important source of exposure within the New Brunswick population. While it is highly unlikely that as many hectares of agricultural land were sprayed as were hectares of forest, a larger proportion of the population live closer to farmer's fields than to areas of susceptible soft-wood forests.

Ingestion of food is considered to be the major route of DDT's entry into the body. The daily intake of DDT in food in the US from 1953 to 1954 was estimated to have been from .184 to .286 mg./person. Ten years later it had decreased to from .038 to .087 mg./person and by 1970 was in the order of .015 mg./person [WHO,1979].

Occupational exposure to DDT is mainly via the skin and the respiratory system. Levels in the occupational environment have been recorded to reach 104 micrograms per litre of air [WHO,1979]. Assuming an inspiration rate of 29 litres/min., a worker's respiratory exposure would be approximately 26,000 micrograms of DDT per kilogram body weight per 10 hour working day of exposure. Dermal contact

is also a source of exposure in this context, but of lesser importance because DDT is poorly absorbed through the skin.

The New Brunswick budworm spray programme used DDT as its "active ingredient" from 1952 until 1968. More than 6.5 million kilograms were sprayed over approximately 11.75 million hectares. Table A1.19 contains information on the extent of spraying during the 17 year period during (1952-1968) which it was used. Of all the area sprayed, over 99% was sprayed with DDT. Worst-case scenario estimates of DDT dermal exposure range from 376.03 micrograms per kilogram body weight during the early spray years down to as low as 94.02 micrograms per kilogram body weight during the latter years of its use. If we were to assume that the proportion of the mass of DDT contained in respirable aerosols was 50% of that generated by ULV spray equipment then the amount of respirable DDT aerosol could be calculated as ranging between 24.19 and 6.14 micrograms per kilogram body. Vapor exposure is expected to add .000061 micrograms per kilogram body weight for a total exposure ranging between 400 and 100 micrograms per kilogram body weight.

c. Evidence of Mutagenicity and/or Carcinogenicity

While DDT does not appear to be a mutagen [WHO,1979,pg.115], animal studies indicate that DDT causes cancer of the liver, lung, and lymphatic system in mice [Terracini et al.,1973;Kashyap et al.,1977] and liver cancer in rats [Rossi et al.,1977]. Recent research by Rossi and his colleagues [Rossi et al.,1983] indicated that DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene], a proximal metabolite of DDT, causes liver cancer in hamsters. The fact that hamsters are not as efficient as mice in converting DDT to DDE [Gold et al.1983] may explain a

Table A1.19 Spray Area (1) by Formulation

Formulation	Cummulative Area (in hectares)	Average Annual Percent of Total Provincial Area (2)
DDT	11,749,534.1	9.41%
Organophosphate	28,720,593.4	27.94%

(1) accumulated over the 17 year period 1952-1968 for DDT and over the 21 year period 1963-1983 for organophosphates
(2) total provincial area years = 7,343,700 ha.

previous report of non-carcinogenicity in hamsters [Cabral et al.,1982] and reinforces the importance of the metabolic activation of pro-carcinogens.

4. Organophosphate Spray Pesticides: Fenitrothion, Phosphamidon, Trichlorfon

Organophosphate pesticides like DDT are powerful acetylcholine esterase inhibitors. They were first introduced into the New Brunswick spray programme on an operational basis with the use of phosphamidon, followed in 1965 with dimethoate and malathion, fenitrothion in 1967, and trichlorfon in 1974. Dimethoate and malathion were sprayed on an operational basis for one year only, 1965, and were applied to only 3,000 and 25,000 hectares of forest respectively and for this reason will not be considered in the section to follow.

Organophosphate pesticides used in the spray programme have been formulated with water as well as with oil. With the exception of one non-hydrocarbon diluent, Dowanol, the diluents used for organophosphate pesticides are similar chemically to those used for DDT except that in most cases they are lighter and have lower boiling ranges.

Phosphamidon was first applied along 335 meter strips along the borders of rivers and streams because of DDT's toxicity to salmon. It soon became a popular pesticide for general application to forests and ranks second to fenitrothion as the most extensively sprayed organophosphate pesticide. Extensive bee mortality led to its discontinuation after the 1976 spray year. Unfortunately, very little information on the toxicity of this compound is available.

Fenitrothion is the most extensively applied pesticide for forest protection in New Brunswick with more than 28 million hectares of forest having been sprayed between 1967 and 1983. This is more than twice the total area sprayed

with DDT and almost 6.5 times the area sprayed with the second most commonly used organophosphate pesticide, phosphamidon.

Trichlorfon was applied to approximately 336,000 hectares of forest between 1975 and 1977. It was used mainly in areas adjacent to fruit crops, in particular blueberries, because of its relatively low toxicity to pollinating insects such as bees. Despite trichlorfon's relatively limited use it will be considered in more detail because it is on the US Environmental Protection Agency list of chemicals that will not be re-registered without review, for reasons of possible carcinogenicity in mice, teratogenicity in rats, mutagenicity in microorganisms, and possible bone marrow effects in other mammals [Ernst et al. EPS-5-AR-81-3,1981].

a. Physical and Chemical Properties

Fenitrothion [O,O-dimethyl-O-(4-nitro-m-tolyl) phosphorothioate], is a yellowish brown liquid that is soluble in aromatic hydrocarbon solvents, of low solubility in aliphatic hydrocarbons, and poorly soluble in water [Spencer,1982,pg.289].

Technical grade fenitrothion contains about 5% of impurities of which s-methyl fenitrothion [O,S-dimethyl-o(3-methyl-4-nitrophenyl)phosphorothioate], whose level rarely exceeds 0.05%, is considered to be the most important [NRCC 16073,1977,pg.30].

Fenitrothion is metabolized by soil microorganisms to amino fenitrothion and reaches non-detectable levels within 32 - 64 days [NRCC 14104,1975,pg.31] following aerial application.

Trichlorfon [2,2,2 trichloro-1-hydroxyethyl-phosphonate], as a pure substance, consists of colorless crystals which are soluble in water, benzene, ethanol, and most chlorinated hydrocarbons but are insoluble in petroleum

oils. It is stable at room temperature (22 degrees celsius), undergoes dehydrochlorination in alkaline and neutral solutions to dichlorvos (2,2-dichlorovinyl demethylphosphate), or to dimethyl phosphonic acid and trichloroethanol in acidic solutions. Technical grade trichlorfon is reported to be 98% pure with dichlorvos (0.2%) and dimethyl trichlorfon (0.3%) representing the largest proportions of impurities other than water. Dichlorvos is a powerful alkylating agent and therefore a member of a class of highly reactive substances with the potential to directly damage genetic material [IARC mono.30,1983].

Mammals rapidly absorb and excrete trichlorfon with from 70 to 80% being excreted by mice within 12 hours of exposure. Its biological half-life is approximately 80 minutes.

b. Sources, Routes, and Levels of Exposure

Fenitrothion is used for the control of insects in cereals, cotton, small fruit, orchard fruit, forestry, rice, and vegetables. It has also been used as a contact spray for the control of cockroaches, flies, and mosquitoes [Hartley & Kidd,1983]. In Canada, however, fenitrothion is registered only for commercial use in forestry [NRCC 14104,1975,pg.91].

Trichlorfon is used on a variety of agricultural crops, and in animal husbandry for the treatment of ecto-parasites in cattle, in silviculture against the gypsy month and spruce budworm, and in medicine for the treatment of various intestinal parasites.

Daily therapeutic dosages in humans are as high as 70 mg./kg./day for periods of up to 12 days.

While trichlorfon has been detected in the liver tissue of food producing animals in the US, it was not detected in a total diet study conducted in Canada from 1976 to 1978.

While many other organophosphate pesticides are used for agricultural purposes in New Brunswick, fenitrothion is registered in Canada for commercial use in silviculture only. More than 5 million kilograms was sprayed over extensive areas of the province during the 17 year period from 1967 to 1983, nearly all of it in areas remote from human settlement.

c. Evidence of Mutagenicity and/or Carcinogenicity

Results from short-term bacterial mutagenesis assays of fenitrothion are conflicting. Yadav, Vashishat, and Kakar [1982], found fenitrothion to be non-mutagenic in Saccharomyces cerevisiae, but Kawachi and colleagues [1981] reported positive Ames tests with Salmonella typhimurium. While both studies report using technical grade fenitrothion, the purity of the compounds used is not described. In view of the possible presence of as much as 5% impurities, with known batch to batch variation in the amounts of these compounds, it is possible that the different results reflect differences in the amount of impurities present in the compounds tested.

The Kawachi research also indicated positive results in other short-term mutagenesis tests, specifically a) in vivo chromosome breaks in rat bone marrow cells, b) errors in sister chromatid exchange in Chinese hamster cells, and c) sister chromatid exchange in human embryo cells. Their findings were negative for a) DNA damage in Bacillus subtilis, b) abnormalities in micronucleus development in Chinese hamster cells and human embryo cells, and c) mutation in Drosophila melanogaster.

A two year dietary study of fenitrothion in the rat conducted by Hazelton laboratories Inc. and reviewed by toxicologists affiliated with the New Brunswick Task Force on the Environment and Cancer did not find fenitrothion to

be a carcinogen [Spitzer et al.,1984]. No other carcinogenicity studies reviewed by the Task Force were considered to be of sufficient quality or reliability to be interpretable [Spitzer et al.,1984].

Trichlorfon is known to be a mutagen in a variety of in vitro and in vivo short-term mutagenesis assays but the findings from these studies are not consistent. In general, the quality of chronic studies of trichlorfon in mammals is poor. The majority of studies were conducted over too short a time span and the fact that they reported no carcinogenic effects is not particularly surprising. Two lifetime studies, one skin application study in mice and one subcutaneous and/or intramuscular injection study in rats, reported an excess of malignant tumours in the treatment groups. The IARC review committee appeared to have little faith in these findings because of inadequacies in reporting, but I feel that in view of the paucity of data in this area that these results should be given greater weight. The predominant tumour type in the mouse study were myeloid leukaemia. The monograph does not report the tumour type(s) for the rat study.

5. Carbamate Spray Pesticides: Aminocarb

Carbamate pesticides, such as the organochlorines and the organophosphates, are acetylcholine esterase inhibitors and can cause similar although frequently less severe acute toxicological responses.

Aminocarb is the only carbamate pesticide to have been used in the New Brunswick spray programme. It was first used operationally in 1975, by 1979 it replaced fenitrothion as the principle insecticide for budworm control [Varty,1980,pg.40].

Prior to 1977 aminocarb was formulated with a variety of different diluents including Dowanol (glycol methyl ether),

Aerotex, mixtures of light petroleum hydrocarbon fractions, and diesel oil. In 1977 and 1978 fuel oil #2 was used and 585 oil has been used since that time. Until very recently formulations included 50.5% by weight of nonyl phenol as a primary solvent.

a. Physical and Chemical Properties

Aminocarb [4-(dimethylamino)-3-methylphenyl methylcarbamate], is a tan colored crystalline solid which is moderately soluble in aromatic solvents, soluble in most polar organic solvents, and unstable in strongly alkaline media [Spencer,1982]. Hydrolysis is the major route for transformation of aminocarb in animal tissues [Varty,1980, pg.54]. Acute toxicity has been studied few several metabolites of aminocarb:

4-(dimethylamino)-3-methyl phenol	(C)
3-methyl-4-(methylamino)phenyl-N-methyl carbamate	(MAA)
N-(4-hydroxy-2-methylphenyl)formamide	(FC)
N-(4-hydroxy-2-methylphenyl)-N-methyl formamide	(MFC)
4-amino-3-methylphenyl-N-methylcarbamate	(AA)

MFC and FC are less active than their parent compound, aminocarb, MAA and AA are as or more toxic than the parent compound. [NRCC 18979,1982,pg.163]. Experimental work indicated that 70% of aminocarb given to rats was expired as carbon dioxide within 48 hours, 25% was eliminated in the urine and 4% in the feces. The (C) and (AA) metabolites were found to be 10 times more potent anticholinesterase inhibitors than aminocarb [ECPHOMA,1981,pg.28].

b. Sources, Routes, and Levels of Exposure

No information could be found on the usage of carbamate pesticides outside of forestry.

c. Evidence of Mutagenicity and/or Carcinogenicity

Research findings conflict over whether aminocarb is a carcinogen. In one report, the Ames test (salmonella/microsome test) was negative [Spitzer et al.,1984,pg.62]. Elsewhere, in an abstract reviewed by the New Brunswick Task Force on the Environment and Cancer, aminocarb was found to produce dose-related increases in mutations using the Ames test. However, aminocarb did not cause mutations in 3 strains of yeast as measured by reversion from histidine and methionine auxotrophy [Spitzer et al.,1984,pg.62]. Alternatively, aminocarb was found to cause large dose-related chromosome aberrations in chinese hamster ovary cells [Spitzer et al.,1984,pg.63]. Furthermore, Matacil (aminocarb + nonyl phenol) was found to be mutagenic using the Ames screening test [Spitzer et al.,1984,pg.68]. Matacil Flowable (aminocarb + 585 oil), which does not contain nonyl phenol, was also found to be mutagenic, but only in the presence of hepatic oxidative enzymes [Spitzer et al.,1984,pg.68].

A 25 month chronic feeding study in rats, 2 other chronic feeding studies in rats involving 0 to 800 mg/kg/day for up to 84 weeks, and a 2 year chronic oral toxicity study in beagle dogs were all negative with respect to carcinogenicity [Spitzer et al.,1984;NRCC 18979,1982, pg.170].

Appendix I

References

Agriculture Canada. Internal memorandum 1983.

Besner D, Eidt DC, MacLaggan C, Pearce PA (eds.). Environmental surveillance of spray operations for forest protection in New Brunswick 1980-81: EMOFICO 1982.

Bingham E, Trosset RP, Warshawsky D. Carcinogenic potential of petroleum hydrocarbons; A critical review of the literature. J Environ Path Toxicol 1980;3:483-568.

Brain JD, Valberg PA. Models of lung retention based on ICRP Task Group report Arch Environ Health 1974; 28:1-11.

Cabral JR, Hall RK, Rossi L Bronczyk SA, Shubik P. Lack of carcinogenicity of DDT in hamsters. Tumori 1982; 68:5-10.

Crabbe RS, Krzymien M, Elias L, Davie S. New Brunswick forestry spray operations: measurement of atmospheric fenitrothion concentrations near the spray area. NRCC 1980 (Technical Report No. NRC-NAE LTR-UA-56).

Crabbe RS, Davie SJ, Elias L, Krzymien MK. Field study of atmospheric stability on target deposition and effective swath widths for aeriel forest sprays in New Brunswick Part 1: NRCC National Aeronautical Establishment 1982 (Rep. No. NRC-NAE LTR-UA-61).

Crabbe RS, Elias L, Davie. Field study of effect of atmospheric stability on target deposition and effective swath widths for aerial forest sprays in New Brunswick Part II NRCC Laboritory Technical Report LTR-UA-65 January 1983.

Crabbe RS. Spray operations: Field study of the effect of atmospheric stability on long-range pesticide drift: NRCC National Aeronautical Establishment 1980 (b). (Rep. No. NRC-NAE LTR-UA-52).

Dunlap TR. DDT: Scientists, citizens and public policy. Princeton University Press, Princeton 1981.

ECPHOMA: Expert committee of the committee on public health of the Ontario Medical Association. A study of the possible relationship of Matacil spraying and Reye's Syndrome in Ontario Unpublished report October 1981.

Ernst W, Julien G, Doe, K, Parker R. Environmental Investigations of the 1980 spruce budworm spray program in New Brunswick. Environmental Protection service, Atlantic Region 1981 (report no. EPS-5-AR-81-3).

Ernst W, Hall H, Matheson R, Osborne J, Wilson P. A review of environmental impacts associated with particular forestry practices in eastern Canada. Environmental Protection Service, Atlantic Region 1981 (report no. EPS-7-AR-81-1).

Gold B, Brunk G. Metabolism of, 1, 1-trichloro-2, 2-bis (p-chlorophenyl)ethane (DDT), 1, 1-dichloro-2, 2-bis(p-chlorophenyl)ethane, and 1-chloro-2, 2-bis (p-chlorophenyl) Cancer Res 1983;43:2644-2647.

Granville, GC. Personal communication 1982.

Hartley D, Kidd H (eds.). The agrochemicals handbook. Unwin Brothers 1983 Surrey UK.

Hopewell WW. Evaporation rates of small drops of two DDT oil solutions. Canadian J. Plant Sci. 1959;39:204-09.

IARC monograph no. 30: Cancer epidemiology of pesticide manufacturers, formulators and users. IARC 1983.

Kashyap SK, Nigam SK, Karnick AB, Gupta RC, Chaterjee SK. Carcinogenicity of DDT (dichlorodiphenyltrichloroethane) in pure inbred Swiss mice. Int J Cancer 1977; 19:725-729.

Kawachi T, Hoshikawa K, Kada T, Tanooka H, et al. Development of screening techniques of carcinogenic substances based on their mutagenic properties. (Translation from Dr. Emmanuel Farber, Showa Nendo Gen-Kenkyu Kokoushu 1981;2:803-820.

Kettela EG. Aerial spraying for protection of forests infested by spruce budworm. The Forestry Chronicle 1975; 51:7-8.

Kristmanson DD, Picot JJC. Dunphy drift trials Measurements of Airborne drops and kromecote card deposits at ground level; foliage simulator tests Unpublished Report from University of New Brunswick Dept. of Chem Eng Jan 1983.

NMAC: Newfoundland Medical Association Committee. Report of the NMAC formed to review the medical aspects of the spruce budworm epidemic and control program May 1979.

NRCC Long-term toxicological effects of fenitrothion in mammals including carcinoge nicity and mutagenicity. In: Fenitrothion: the long-term effects of its use in NRCC Publication #:NRCC 16073 1977.

NRCC Subcommittee on pesticides and related compounds Fenitrothion: the effects of its use on environmental quality and its chemistry NRCC 1975 Report No. 14104.

NRCC Subcommittee on pesticides and industrial organic chemicals Aminocarb: the effects of its use on the forest and the human environment NRCC 1982 Report No. 18979.

Picot JCC, Kristmanson DD, Chitrangad B, Henderson G. Nearfield drift in aerial spraying. University of New Brunswick Dept. of Chemical Engineering 1980.

Picot JCC, Kristmanson DD. Aerial spraying of coniferous forests - A model for dispersion and deposition Unpublished Report from University of New Brunswick Dept. of Chem Eng Jun 1981

Rossi L, Barbieri O, Sanguineti M, Cabral JR, Bruzzi P, Santi L. Carcinogenicity study with technical-grade dichlorodiphenyltrichloro-etha and 1, 1-dichloro-2, 2-bis (p-chlorophenyl)ethylene in hamsters. Cancer Res 1983;43:776-781.

Rossi L, Ravera M, Repetti G, Santi L. Long-term administration of DDT or phenobarbitol Na in Wistar rats. Int J Cancer 1977;19:179-185.

Safe S, Plugge H, Crocker JFS. Chemosphere 1977;6:641-.

Spencer EY. Guide to chemicals used in crop protection. Agriculture Canada 1982 Publication # 1093 7th ed.

Spitzer WO (Chairman), Archer M, Hill GB, Horwitz RI, et al. Final Report of the New Brunswick Task Force on the Environment and Cancer Submitted March 16, 1984 to New Brunswick Department of Health.

Spitzer WO, Brouzes R, Hattwick MA, Hurwitz E, Kramer M, Larke RPB, Shank R, Seliske P. Report of the New Brunswick Task Force on the Environment and Reye's Syndrome Clinical and Investigative Medicine 1982; 5(2/3):203-214.

Terracini B, Testa MC, Cabral JR, Day N. The effects of long-term feeding of DDT to BALB/c mice. Int J Cancer 1973;11:747-764.

Thurlow W. Matacil Spray Report Gander Environmental Group 1979.

Varty IW. Environmental effects of the spruce budworm spray program in New Brunswick, 1976: A preliminary report by EMOFICO Canadian Forestry Service, Department of the Environment (Rep.M-X-67) 1976.

Varty IW. Environmental surveillance of insecticide spray operations in New Brunswick's budworm-infested forests 1977 Canadian Forestry Service, Dept. of Fisheries and Envir. (Rep. M-X-87) 1978.

Varty IW. Environmental Surveillance in New Brunswick, 1978-79. Effects of spray operations for forest protection against the spruce budworm Department of Forest Resources, University of New Brunswick 1980.

Varty IW. Environmental Surveillance in New Brunswick, 1977-78. Department of Forest Resources, University of New Brunswick, 1979.

Wood GW. Monitoring insecticide drift from forest spray operations and its effect on lowbush blueberry in New Brunswick in 1980: Agriculture Canada Research Station, Fredericton, New Brunswick 1980.

World Health Organization DDT and its Dervatives WHO Environmental Health Criteria 9, Geneva 1979.

Yadav AS, Vashishat RK, Kakar SN. Testing of endosulfan and fenitrothion for genotoxicity in Saccharomyces cerevsiae. Mutation Research 1982;105:403-407.

Yule WN, Duffy JR. The persistence and fate of fenitrothion insecticides in the forest environment. Bull Env Cont Toxicol 1972;8.

Appendix II
Laboratory Centers for Disease Control
ICD Conversion Table

Site	ICD-8	ICD-9
Lip	140	140
Buccal cavity and pharynx	140-149	140 142-149
All cancer	140-209	140-208
Tongue	141	141
Tongue mouth and pharynx	141 143-149	141 143-149
Salivary gland	142	142
Mouth	143-145	143-145
Oropharynx	146	146
Pharynx (oro naso hypo)	146-149	146-148 149.0
Nasopharynx	147	147
Hypopharynx	148	148
Pharynx unspecified	149	149.0
Esophagus	150	150
Digestive	150-159	150-159
Stomach	151	151
Small intestine	152	152
Colon (excluding rectum)	153	153
Large intestine and rectum	153 154	153 154
Rectum and rectosigmoid junction	154	154
Liver and gallbladder	155 156	155 156
Liver	155	155.0 155.1
Gallbladder	156	156
Pancreas	157	157
Peritoneum	158	158
Digestive NS	159	159
Nose sinuses	160	160
Respiratory	160-163	160-163 164.2 164 3 164 8 164.9 165
Larynx	161	161
Trachea bronchus lung and other	162 163	162 163 164.2 164.3 164.8 164.9 165
Bronchus and lung	162.1	162.2 162.3 162.4 162.5 162.8 162.9
Pleura	163.0	163
Other endocrine	194	164.0 194
Connective tissue	171	164.1 171
Bone	170	170
Malignant melanoma	172	172
Melanoma of the lip	172.0	172.0
Melanoma of the eyelid	172.1	172.1
Melanoma of the ear	172.2	172.2
Melanoma, other face	172.3	172.3
Melanoma of scalp and neck	172 4	172.4
Melanoma of trunk	172.6	172.5
Melanoma of upper limbs	172.7	172.6
Melanoma of lower limbs	172.8	172.7
Melanoma, site not specified	172.9	172.8 172.9
Other skin	173	173

Site	ICD-8	ICD-9
Breast	174	174 175
Chorionepithelioma and uterus NS	181 182.9	179 181
Chorionepithelioma and other uterus	181 182	179 181 182
Other uterus	182	179 182
Uterus (including cervix)	180 182	179-182
Cervix uteri	180	180
Female genital	180-184	180-184
Chorionepithelioma	181	181
Corpus uteri	182.0	182
Ovary fallopian tube broad ligament	183	183
Ovary	183.0	183.0
Prostate	185	185
Male genital	185-187	185 187.1-187 9
Testis	186	186
Melanoma of scrotum	172.5	187.7
Bladder	188	188
Urinary	188 189	188 189
Bladder and other urinary	188 189.9	188 189.3 189 4 189 8 189 9
Kidney	189.0 189 2 189.2	189.0 189 1 189 2
Eye	190	190
Brain	191	191
Brain and other nervous system	191 192	191 192
Nervous system (benign and malignant)	191 192 225 238	191 192 225 237.5 237.6 239.6
Thyroid	193	193
Ill-defined cancer	195-199	195-199
Neoplasms (secondary, ill-defined, and benign)	195-199,210-239	195-199,210-229,233.1,235-238
Non-Hodgkin's Lymphomas	200 202	200 202
Lymphoid	200 203	200 203
Reticulum cell sarcoma	200.0	200 0
Lymphosarcoma and reticulum cell sarcoma	200	200 0 200.1
Lymphosarcoma	200.1	200 1
Other lymphoid	202	200.2
Hodgkin's disease	201	201
Multiple myeloma	203	203
Lymphatic leukemia	204	204
Lymphatic and myeloid leukemia	204 205	204 205
Leukemias	204-207	204-206 207 0 207.2 207 8 208
Myeloid leukemia	205	205
Monocytic leukemia	206	206
Other and unspecified leukemia	207	207 0 207.2 207.8 208
Polycythemia vera	208	207.1 238.4
Benign neoplasms	210-228	210-229
Neoplasms of unspecified nature	230-239	233.1 235-238
Neoplasms of lymphatic and hematopoietic tissue	200-209	NA

NA not applicable

Appendix III

List of Exposure Labels Used in the Epidemiological Literature Reviewed

Pesticide Exposure Term	Reference(s)
Farming Occupations	
Agricultural crop industry	9
Agricultural livestock industry	9
Cattle inventory	6
Cattle ranchers	19
Cattle treated with pesticides	6
Chicken farmers	19
Chicken inventory	6
Corn acreage	6
Dairy farm	29,30
Dairy farmers	19
Dairy farming	7
Dairy farms	27
Dairy products inventory	6
Delivery and routemen	19
Farm	18
Farm laborers	19,33
Farm labourers and farm foremen	22
Farm no animals	27
Farm NOS	30
Farm owners and managers	33
Farm workers	23
Farmers	9,26
Farmers and farm managers	22
Farmers and foresters	23
Farmers farm managers and laborers	19
Farmers nec	19
Farmers(owners and tenants)	19
Farming	2,10,11,14,16,17,24,32,40
Farmworkers	9
General or unspecified farm	29
Grain millers	1
Hog inventory	6
Insecticides acres treated	6
Insecticides/pesticides/herbicides	8
Livestock farm	29,30
Major occupation farm	38
Orchard farm	29,30
Orchard laborers	19
Orchardists	19
Orchardists,farmers	37
Other animal husbandry farming	27
Pig farms	27
Poultry farm	27,30

Pesticide Exposure Term	Reference(s)
Farming Occupations cont'd	
Poultry population	31
Sugar beet production	12
Use of herbicides on farms	13
Use of insecticides on farms	13
Wheat acreage	6
Wheat and grain farmers	19
Forestry and Agriculture Occupations	
Foresters and loggers	23
Forestry	29,30
Forestry, fishing, agriculture	34
Hunting forestry and fishing, agriculture	28
Loggers	19
Occupational Exposure to Pesticides Other Than Farming, Forestry or Agriculture	
Agricultural chemical handlers	25
Chlordane heptachlor	35
DBCP	21
DDT	39
Gardeners	19,23
Non termite control operator	36
Pest control operators-fumigators	25
Pesticide applicators	5
Pesticides for fumigation	5
Pesticides for lawn and ornamental	5
Pesticides for household pests	5
Pesticides for rodents	5
Production of agricultural pesticides	4
Railroad herbicide sprayers	3
Termite control operators	36
Termite pesticide applicators	5

Pesticide Exposure Term	Reference(s)
Other Miscellaneous Pesticide Exposures	
Chlorophenols	15,20
Herbicides	2
Herbicides acreages treated	6
Insecticides	18
Pesticides	2
Phenoxy acids	15,20
Phenoxy acids or chlorophenols	20
Phenoxyacetic acids	20

Appendix IV

New Brunswick Forestry Pesticide Formulations

Formulation/Adjuvant/Number of Application	Code	Hectares
DDT/Oil/1	102010	9416123.8
DDT/Oil/2	102020	2322776.2
DDT/Oil/1+Fenitrothion/Water/1	132111	10634.1
Phosphamidon/Water/1	201010	900928.8
Phosphamidon/Water/2	201020	904198.7
Fenitrothion/Water/1	301010	7137153.2
Fenitrothion/Water/2	301020	9566598.1
Fenitrothion/Oil/1	302010	661011.1
Fenitrothion/Oil/2	302020	1094409.7
Fenitrothion/Cyclosol/2	303020	1438123.4
Fenitrothion/Dowanol/2	304020	1868490.7
Fenitrothion/Water/1+Phosphamidon/Water/1	321111	2018216.9
Fenitrothion/Water/2+Phosphamidon/Water/1	321121	848.7
Fenitrothion/Water/1+Fenitrothion/Oil/1	331211	76506.2
Fenitrothion/Water/1+Aminocarb/Oil/1	341211	5620.4
Fenitrothion/Water/1+Aminocarb/Oil/2	341212	306134.7
Fenitrothion/Water/2+Aminocarb/Oil/1	341221	14032.3
Fenitrothion/Water/1+Trichlorfon/Water/1	351111	79095.8
Aminocarb/Water/2	401020	408.4
Aminocarb/Oil/1	402010	1540532.6
Aminocarb/Oil/2	402020	1442921.7
Aminocarb/Oil/2+Phosphamidon/Water/1	422121	95913
Aminocarb/Oil/3+Phosphamidon/Water/1	422131	68025.5
Trichlorfon/Water/2	501020	256655
Dimethoate/Water/1	600010	3319.4
Malathion/Water/1	700010	24742.1
Bacillus	800000	6791.9

Appendix V

1981 New Brunswick Population by Municipality, Standard Geographical Code, and Type of Municipality (1)

Code	Municipality	Type of Municipality	Population
	NEW BRUNSWICK		696225
101	SAINT MARTIN	par	1050
102	ST. MARTINS	vl	530
104	SIMONDS	par	2765
106	SAINT JOHN	c	80520
116	MUSQUASH	par	1270
201	GRAND MANAN	par	690
202	SEAL COVE	vl	550
203	NORTH HEAD	vl	665
204	CAMPOBELLO	par	1420
206	WEST ISLES	par	860
208	LEPREAU	par	1060
211	PENNFIELD	par	2025
212	BLACKS HARBOUR	vl	1360
216	SAINT GEORGE	par	2145
218	ST. GEORGE	t	1155
221	SAINT PATRICK	par	615
224	SAINT ANDREWS	par	370
226	SAINT ANDREWS	t	1760
228	SAINT-CROIX	par	535
231	DUFFERIN	par	455
234	SAINT STEPHEN	par	1745
237	ST.STEPHEN	t	5105
239	SAINT JAMES	par	1325
242	SAINT DAVID	par	1585
244	DUMBARTON	par	485
248	GRAND HARBOUR	vl	640
301	BLISSVILLE	par	875
304	GLADSTONE	par	345
305	TRACY	vl	640
306	FREDERICTON JUNCTION	vl	735
308	LINCOLN	par	2920
311	BURTON	par	3675
312	OROMOCTO	t	9065
314	SHEFFIELD	par	725
316	MAUGERVILLE	par	1215
318	NORTHFIELD	par	865
401	PETERSVILLE	par	810
404	GAGETOWN	par	280
405	GAGETOWN	vl	605
406	HAMPSTEAD	par	350
408	WICKHAM	par	410

Code	Municipality	Type of Municipality	Population
411	CAMBRIDGE	par	795
413	CAMBRIDGE-NARROWS	vl	415
414	JOHNSTON	par	745
416	BRUNSWICK	par	280
418	WATERBOROUGH	par	805
421	CANNING	par	760
422	MINTO	vl	3390
424	CHIPMAN	par	940
425	CHIPMAN	vl	1820
501	HAMMOND	par	290
504	UPHAM	par	1100
506	HAMPTON	par	1730
507	HAMPTON	vl	3135
508	ROTHESAY	par	1150
509	ROTHESAY	t	1775
510	RENFORTH	vl	1490
511	WESTFIELD	par	1905
512	GRAND BAY	vl	3165
513	WESTFIELD	vl	1105
514	KINGSTON	par	2175
516	NORTON	par	1030
518	NORTON	vl	1380
521	SUSSEX	par	2050
522	SUSSEX	t	3975
523	SUSSEX CORNER	vl	1035
524	WATERFORD	par	440
526	CARDWELL	par	1045
528	HAVELOCK	par	1325
531	STUDHOLM	par	3085
534	SPRINGFIELD	par	1325
536	KARS	par	355
538	GREENWICH	par	1060
551	EAST-RIVERSIDE-KINGSHURST	vl	1005
553	FAIRVALE	vl	3955
556	QUISPAMSIS	vl	6020
558	GONDOLA POINT	vl	3075
601	HOPEWELL	par	790
603	RIVERSIDE-ALBERT	vl	480
604	HARVEY	par	470
606	ALMA	vl	325
608	ELGIN	par	880
611	HILLSBOROUGH	par	1450
614	COVERDALE	par	3060
620	RIVERVIEW	t	14905
625	HILLSBOROUGH	vl	1255

Code	Municipality	Type of Municipality	Population
701	WESTMORLAND	par	1090
702	PORT ELGIN	vl	515
704	BOTSFORD	par	2965
707	CAP-PELE	vl	2175
708	SACKVILLE	par	1160
709	SACKVILLE	t	5645
711	DORCHESTER	par	4765
712	DORCHESTER	vl	1110
713	SAINT-JOSEPH	vl	640
716	SHEDIAC	par	7520
719	MONCTON	par	6260
722	MONCTON	c	54735
724	SALISBURY	par	3160
728	SALISBURY	vl	1680
729	PETITCODIAC	vl	1400
745	DIEPPE	t	8520
752	SHEDIAC	t	4280
801	DUNDAS	par	5475
804	WELLINGTON	par	3585
805	BUCTOUCHE	vl	2475
806	SAINT MARY	par	2040
807	SAINT-ANTOINE	vl	1230
808	SAINT-PAUL	par	1070
811	HARCOURT	par	560
814	WELDFORD	par	2535
816	RICHIBUCTO	par	1910
817	REXTON	vl	925
818	RICHIBUCTO	vl	1720
819	SAINT CHARLES	par	1895
821	SAINT-LOUIS	par	1935
822	SAINT-LOUIS-DE-KENT	vl	1165
824	ACADIEVILLE	par	1050
826	CARLETON	par	1190
901	HARDWICKE	par	2695
904	GLENELG	par	2040
906	CHATHAM	par	3740
907	LOGGIEVILLE	vl	790
908	CHATHAM	t	6775
911	DERBY	par	1190
914	NELSON	par	1065
915	NELSON-MIRAMICHI	vl	1440
916	ROGERSVILLE	par	1480
917	ROGERSVILLE	vl	1240
918	BLACKVILLE	par	2465
919	BLACKVILLE	vl	885
921	BLISSFIELD	par	725
922	DOAKTOWN	vl	1005
924	LUDLOW	par	1850

Code	Municipality	Type of Municipality	Population
926	SOUTHESK	par	1930
928	NORTHESK	par	3415
931	NEWCASTLE	par	2915
932	NEWCASTLE	t	6250
933	DOUGLASTOWN	vl	1075
936	AINWICK	par	7365
938	NEGUAC	vl	1755
1001	NEW MARYLAND	par	4100
1004	MANNERS SUTTON	par	1685
1005	HARVEY	vl	355
1006	MCADAM	vl	1860
1007	MCADAM	par	100
1008	NORTH LAKE	par	290
1011	CANTERBURY	par	655
1012	CANTERBURY	vl	470
1013	MEDUCTIC	vl	265
1014	DUMFRIES	par	415
1016	PRINCE WILLIAM	par	775
1018	KINGSCLEAR	par	3135
1021	QUEENSBURY	par	1095
1024	SOUTHAMPTON	par	1750
1025	MILLVILLE	vl	300
1026	BRIGHT	par	2500
1028	DOUGLAS	par	4070
1031	SAINT MARYS	par	2785
1032	FREDERICTON	c	43715
1036	STANLEY	par	2115
1037	STANLEY	vl	435
1054	NACKAWIC	t	1350
1101	RICHMOND	par	1125
1104	WOODSTOCK	par	1735
1106	WOODSTOCK	t	4635
1108	NORTHAMPTON	par	1120
1111	BRIGHTON	par	1645
1112	HARTLAND	t	855
1114	WAKEFIELD	par	2370
1118	WILMOT	par	1170
1119	CENTREVILLE	vl	575
1121	SIMONDS	par	525
1123	FLORENCEVILL	vl	705
1124	PEEL	par	1195
1126	ABERDEEN	par	1250
1128	KENT	par	2365
1129	BRISTOL	vl	825
1130	BATH	vl	780
1131	WICKLOW	par	1760
1201	ANDOVER	par	1035
1202	AROOSTOOK	vl	405

Code	Municipality	Type of Municipality	Population
1204	PERTH	par	1705
1206	PERTH-ANDOVER	vl	1870
1208	GORDON	par	1805
1209	PLASTER ROCK	vl	1220
1211	LORNE	par	715
1214	DENMARK	par	1760
1216	GRAND FALLS	par	1210
1219	GRAND FALLS	t	6205
1221	DRUMMOND	par	2030
1223	DRUMMOND	vl	845
1301	SAINT-ANDRE	par	1625
1303	ST.ANDRE	vl	380
1304	SAINT-LEONARD	par	925
1306	SAINT LEONARDS	t	1575
1308	NOTRE-DAME-DAME-DE-LOURDES	par	545
1311	SAINTE-ANNE	par	1245
1312	SAINTE-ANNE-DE-MADAWASKA	vl	1340
1314	RIVIERE-VERTE	vl	1045
1315	RIVIERE-VERTE	par	820
1318	SAINTE-BASILE	par	580
1319	SAINTE-BASILE	vl	3225
1322	SAINT-JOSEPH	par	1440
1324	ST. JACQUES	par	1340
1326	SAINT-JACQUES	vl	2305
1328	MADAWASKA	par	810
1329	EDMUNSTON	c	12030
1332	SAINT-HILAIRE	par	455
1333	ST.HILAIRE	vl	255
1334	BAKER BROOK	par	490
1335	BAKER BROOK	vl	520
1336	LAC BAKER	par	375
1337	LAC BAKER	vl	270
1338	CLAIR	par	275
1339	CLAIR	vl	915
1341	SAINT-FRANCOIS	par	865
1342	SAINT-FRANCOIS-DE-MADAWASKA	vl	745
1401	DURHAM	par	2645
1402	JACQUETRIVER	vl	780
1403	COLBORNE	par	390
1404	CHARLO	vl	1610
1405	BALMORAL	par	725
1406	BALMORAL	vl	1825
1408	DALHOUSIE	par	3405
1409	DALHOUSIE	t	4970
1411	EEL RIVER CROSSING	vl	1445
1412	ADDINGTON	par	3035
1413	ATHOLVILLE	vl	1675

Code	Municipality	Type of Municipality	Population
1414	CAMPBELLTON	c	9810
1415	TIDE HEAD	vl	955
1416	ELDON	par	1290
1418	GRIMMER	par	1055
1419	KEDGWICK	vl	1210
1421	SAINT-QUENTIN	par	1430
1422	SAINT-QUENTIN	vl	2335
1501	SAUMAREZ	par	8715
1504	TRACADIE	t	2445
1506	ALLARDVILLE	par	3080
1508	BATHURST	par	4910
1511	BATHURST	c	15710
1512	BERESFORD	par	5785
1513	POINTE-VERTE	vl	1335
1514	PETIT-ROCHER	vl	1855
1515	BERESFORD	vl	3645
1516	NEW BANDON	par	3660
1519	PAQUETVILLE	par	2910
1520	PAQUETVILLE	vl	620
1521	SAINT-ISIDORE	par	2525
1524	INKERMAN	par	4450
1526	CARAQUET	par	1775
1527	BAS-CARAQUET	vl	1860
1528	CARAQUET	t	4325
1529	SHIPPAGAN	par	8635
1531	SHIPPAGAN	t	2480
1532	LAMEQUE	vl	1565
1534	BELLEDUNE	vl	700
1536	BERTRAND	vl	1280
1537	NIGADOO	vl	1085
1538	GRANDE ANSE	vl	815

(1) par is parish; t is town; vl is village; c is city

Appendix VI

Recoding of Indian Reservation Numerators & Denominators by SGC (1)

Original SGC	Reservation	1981 Population	Merged Into SGC
0381	Ormocto 26	115	0313
0881	Buctouche 16	95	0803
0882	Richibucto 15, Big Cove	965	0815
0883	Indian Island 28	60	0820
0981	Red Bank 4	205	0923
0982	Red Bank 7	0	0925
0983	Big Hole Tract 8	45	0934
0984	Eel Ground 2	295	0935
0986	Burnt Church 14	635	0944
0987	Tabustinac 9	0	0947
1081	Kingsclear 6	260	1019
1082	Devon 30	355	1034
1083	St. Mary's 24	0	1035
1181	Woodstock 23	170	1104
1281	Tobique 20	455	1207
1381	St. Basile 10	0	1320
1481	Eel River 3	190	1410
1581	Pabineau 11	40	1510

(1) Standard geographical Code

Note: Fort Folly (SGC81:0714) is not included because it was created only in 1980; no population was reported for this SGC in 1981.

Source: Statistics Canada (1969-73)

Appendix VII
Socio-Demographic Information for the New Brunswick Population

Table A7.1 gives the population by census district within New Brunswick for the past 3 decennial censuses. Most counties showed consistent growth across these periods.

Major geographical shifts in the population would necessarily reduce the validity of the exposure estimates. Major shifts would also imply possible changes in the demographic and exposure characteristics of those populations affected. These in turn would reduce the credibility of characterising municipalities on the basis of 1981 data. Table A7.1 can only suggest that important features affecting cancer risk may have occurred.

Table A7.2 contains the distribution of the New Brunswick population by sex and age group. The age groups indicated are those used for calculating expected values for the data analysis. A more detailed breakdown of the population is available only on special request from Statistics Canada.

The New Brunswick population includes two major cultural groups; for convenience, these are designated by their predominant language as English and French. Approximately 33% of the New Brunswick Population reported their mother tongue as French and only 1.3% reported their mother tongue to be other than French or English [Stats. Canada E-562,1982]. These two populations may vary with respect to lifestyle, and do vary in terms of their geographic distribution within the province.

The French population within New Brunswick is concentrated along the east coast and within the northern regions of the province. Among the predominantly French municipalities, 78.6% of the population lives in rural areas compared to 42.2% population of predominantly English municipalities (Table A7.3).

Table A7.1 New Brunswick Population by County for Census Years 1951, 1961, 1971, 1981

County	Percent of Total Population (persons)			
	1951	1961	1971	1981
Entire Province	100.0% (515697)	100.0% (597936)	100.0% (634557)	100.0% (696225)
Albert	1.9% (9910)	2.1% (12485)	2.6% (16307)	3.4% (23615)
Carleton	4.3% (22269)	3.9% (23507)	3.8% (24428)	3.5% (24635)
Charlotte	4.9% (25136)	3.9% (23285)	3.9% (24551)	3.8% (26550)
Gloucester	11.1% (57489)	11.1% (66343)	11.8% (74752)	12.4% (86165)
Kent	5.2% (26767)	4.5% (26667)	3.9% (24901)	4.4% (30760)
Kings	4.4% (22467)	4.3% (25908)	5.2% (33285)	7.4% (51180)
Madawaska	6.7% (34329)	6.5% (38983)	5.5% (34976)	5.2% (36395)
Northumberland	8.3% (42994)	8.4% (50035)	8.1% (51561)	7.8% (54090)
Queens	2.6% (13206)	1.9% (11640)	2.0% (12486)	1.8% (12405)
Restigouche	7 0% (36212)	6.9% (40973)	6.5% (41289)	5.8% (40590)
Saint John	14 4% (74497)	14.9% (89251)	14.5% (92162)	12.4% (86135)
Sunbury	1.8% (9322)	3 8% (22796)	3.4% (21268)	3.0% (21060)
Victoria	3.6% (18541)	3.3% (19712)	3.1% (19796)	3.0% (20805)
Westmorland	15.5% (80012)	15.7% (93679)	15.5% (98669)	15.5% (107620)
York	8 3% (42546)	8.8% (52672)	10.1% (64126)	10.7% (74220)

Sources 1951: 9th Census of Canada 1951; Ottawa, Jan 30, 1953
1961: Census of Canada Vol.1 Part 1; Population; Ottawa March 29, 1963
1971: Statistics Canada Catalogue # 92-704 Vol. 1 Part 1 Sept. 1972
1981: Extracted for thesis from Statistics Canada Catalogue # E-562 Ottawa August 1982

Table A7.2 1981 New Brunswick Population by Sex and Age Group

	Population (%)					
	Total		Males		Females	
Total	696225	(100.0%)	345785	(100.0%)	350440	(100.0%)
0 Up to 5	53030	(7.6%)	27140	(7.8%)	25890	(7 4%)
5 Up to 10	58485	(8.4%)	29900	(8.6%)	28585	(8 2%)
10 Up to 15	62040	(8.9%)	31905	(9.2%)	30135	(8.6%)
15 Up to 20	72145	(10.4%)	36905	(10.7%)	35240	(10 1%)
20 Up to 25	64460	(9.3%)	32285	(9.3%)	32175	(9.2%)
25 Up to 35	116420	(16.7%)	57990	(16.8%)	58430	(16.7%)
35 Up to 45	77445	(11.1%)	39360	(11.4%)	38085	(10.9%)
45 Up to 55	62500	(9.0%)	30860	(8.9%)	31640	(9 0%)
55 Up to 65	59225	(8.5%)	28480	(8.2%)	30745	(8 8%)
65 Up to 70	24735	(3.6%)	11785	(3.4%)	12950	(3.7%)
70 & up	45740	(6.6%)	19175	(5.5%)	26565	(7 6%)

Source: 1981 Census [Stats Canada E-562,1982]

Table A7.3 1981 New Brunswick Population by Urban/Rural Residence and Language (1)

Urban/Rural Residence	All Municipalities	Population With Pre... Municipalities ...nce of (persons) French	English
Total	100.0% (696225)	100.0% (196910)	100.0% (499315)
Parishes, Towns, or Villages Less Than 2500	52.5% (365440)	78.6% (154680)	42.2% (210760)
Towns or Villages Greater Than 2500	16.4% (114265)	15.3% (30200)	16.8% (84065)
Cities	31.1% (216520)	6.1% (12030)	41.0% (204490)

(1) Mother tongue French or English greater than 50% of the municipal population

Source 1981 Census [Stats Canada E-574,1983]

Undefined and unmeasured lifestyle factors may increase or decrease cancer risk within the French population relative to the English. The coastal location of French settlements is probably correlated with low spray exposure and their rural nature implies a decreased cancer risk. Approximately 13 (N=68,620) of the New Brunswick population 15 years or over has attended or is now at university, and 31 155 or about 15% of these have obtained a degree. It is evident from Table A7.4 that a higher proportion of persons having attended university are situated within cities than in more rural areas. According to Table A7.5, municipalities in which there are large numbers of French also tend to have smaller numbers of persons who have attended university. Finally, predominantly French areas within the province have higher proportions of persons with low-income than predominantly English areas (Table A7.6). Table A7.7 shows a clear positive correlation between income and educational attainment. Income distribution and urban/rural residence are also correlated. A higher proportion of low-income is present in rural areas (Table A7.8).

The picture that emerges from these tables is that New Brunswick there appears to include two fairly distinct populations. The French live in more rural areas, are less well-educated, and have lower incomes on average than their English counterparts.

Table A7.9 shows that larger proportions of populations within towns and villages and cities migrate than populations in rural areas. Migration is lower within predominantly French municipalities relative to English municipalities (Table A7.10). Migration is also positively associated with percent who attended universities (Table A7.11) and migration is highest where the incidence of low income is lowest (Table A7.12).

Table A7.4 1981 New Brunswick Population 15 Years and Over by Educational Attainment (1) Quartiles (2) and Urban/Rural Residence

Educational Attainment Quartile (3)		Percent of Total Population 15 Years and Over in (persons)			
			Parishes, Towns or Villages		Cities
		All Municipalities	Less Than 2500	Greater Than 2500	
Total	(10.1)	100.0% (522670)	100.0% (266825)	100.0% (84860)	100.0% (170985)
Quartile 1	(4.4)	14.2% (74195)	27.8% (74195)	0.0% (0)	0.0% (0)
Quartile 2	(7.5)	16.5% (86130)	31.3% (83465)	3.1% (2665)	0.0% (0)
Quartile 3	(10.4)	15.6% (81485)	27.3% (72720)	10.3% (8765)	0.0% (0)
Quartile 4	(18.0)	53.7% (280860)	13.7% (36445)	86.5% (73430)	100.0% (170985)

(1) Proportion of persons who attended university in the total population 15 or older
(2) Calculated by ranking values and establishing class boundaries to provide 25% of the municipalities in each of 4 classes
(3) Mean rate per 100 persons within each quartile

Source: 1981 Census [Stats Canada E-574,1983]

Table A7.5 1981 New Brunswick Population 15 Years and Over by Educational Attainment (1) Quartiles (2) and Language (3)

Educational Attainment Quartiles (4)		Population 15 Years and Over in Municipalities With Large Proportions of (persons)		
		All Municipalities	French	English
Total	(10.1)	100.0% (522670)	100.0% (144315)	100.0% (378355)
Quartile 1	(4.4)	14.2% (74195)	24.5% (35335)	10.5% (38860)
Quartile 2	(7.5)	16.5% (86130)	30.3% (43795)	11.2% (42335)
Quartile 3	(10.4)	15.6% (81485)	18 2% (26305)	14.6% (55180)
Quartile 4	(18.0)	53.7% (280860)	26 9% (38880)	64.0% (241980)

(1) Proportion of persons who attended university in the total population 15 or older
(2) Calculated by ranking values and establishing class boundaries to provide 25% of the municipalities in each of 4 classes
(3) Mother tongue French or English greater than 50% of the municipal population
(4) Mean rate per 100 persons within each quartile

Source: 1981 Census [Stats Canada E-574,1983]

Table A7.6 1981 New Brunswick Population by Incidence of Low-Income (1) Quartiles (2) and Language (3)

Incidence of Low Income Quartiles (4)	All Municipalities	Population in Municipalities With Large Proportions of (persons)	
		French	English
Total (18 1)	100.0% (696225)	100.0% (196910)	100.0% (499315)
Quartile 1 (8 9)	19 1% (132840)	13.4% (26395)	21.3% (106445)
Quartile 2 (15.0)	26 4% (183920)	33.7% (66295)	23.6% (117625)
Quartile 3 (19 7)	41.5% (288660)	25.1% (49375)	47 9% (239285)
Quartile 4 (28 8)	13.0% (90805)	27.9% (54845)	7.2% (35960)

(1) Expenditures for food, clothing, and shelter exceed the average level for the region of residence by at least 20%

(2) Calculated by ranking values and establishing class boundaries to provide 25% of the municipalities in each of 4 classes

(3) Mother tongue French or English greater than 50% of municipal population

(4) Mean rate per 100 persons within each quartile

Source 1981 Census [Stats Canada E-574,1983]

Table A7.7 1981 New Brunswick Population 15 and Over and Number of Persons by Incidence of Low-Income (1) Quartiles (2) and Educational Attainment (3) Quartiles(2)

Incidence of Low-Income Quartiles (4)	Percent of Total Population 15 Years and Over Within Educational Attainment (persons)			
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Total (18.1)	100.0% (74195)	100.0% (86130)	100.0% (81485)	100.0% (280860)
Quartile 1 (8.9)	13.2% (9815)	14.1% (12120)	27.4% (22350)	18.4% (51750)
Quartile 2 (15.0)	21.3% (15835)	34.1% (29335)	39.5% (32215)	21.8% (61145)
Quartile 3 (19.7)	23.9% (17735)	32.0% (27535)	24.2% (19695)	56.1% (157425)
Quartile 4 (28.8)	41.5% (30810)	19.9% (17140)	8.9% (7225)	3.8% (10540)

(1) Expenditures for food, clothing, and shelter exceeds the average level for the region of residence by at least 20%

(2) Calculated by ranking values and establishing class boundaries to provide 25% of the municipalities in each of 4 classes

(3) Proportion of persons who attended university in the total population 15 or older

(4) Mean rate per 100 persons within each quartile

Source: 1981 Census [Stats Canada E-574,1983]

Table A7.8 1981 New Brunswick Population by Incidence of Low-Income (1) Quartiles (2) and Urban/Rural Residence

Incidence of Low-Income Quartile (3)		Percent of Total Population 15 Years and Over in (persons)			
			Parishes, Towns or Villages		Cities
		All Municipalities	Less Than 2500	Greater Than 2500	
Total	(18.1)	100.0% (696225)	100.0% (365440)	100.0% (114265)	100.0% (216520)
Quartile 1	(8.9)	19 1% (132840)	23.7% (86670)	40.4% (46170)	0.0% (0)
Quartile 2	(15.0)	26 4% (183920)	29 6% (108310)	27.9% (31895)	20.2% (43715)
Quartile 3	(19 7)	41 5% (288660)	24 4% (89250)	23.3% (26605)	79 8% (172805)
Quartile 4	(28.8)	13 0% (90805)	22 2% (81210)	8.4% (9595)	0 0% (0)

(1) Expenditures for food, clothing, and shelter exceed the average level for the region of residence by at least 20%

(2) Calculated by ranking values and establishing class boundaries to provide 25% of the municipalities in each of 4 classes

(3) Mean rate per 100 persons within each quartile

Source 1981 Census [Stats Canada E-574,1983]

Table A7.9 1981 New Brunswick Population by Migration (1) Quartiles (2) and Urban/Rural Residence

Migration Quartile (3)	Percent of Total Population in (persons)			
	All Municipalities	Parishes, Towns or Villages Less Than 2500	Parishes, Towns or Villages Greater Than 2500	Cities
Total (15.4)	100.0% (696225)	100.0% (365440)	100.0% (114265)	100.0% (216520)
Quartile 1 (7.5)	16.2% (112800)	28.6% (104440)	7.3% (8360)	0.0% (0)
Quartile 2 (12.1)	30.2% (210450)	30.6% (111695)	5.4% (6705)	42.7% (92550)
Quartile 3 (16.6)	34.7% (241575)	20.7% (75620)	36.7% (41985)	57.3% (123970)
Quartile 4 (25.3)	18.9% (131400)	20.2% (73685)	50.5% (57715)	0.0% (0)

(1) persons living in a different dwelling in 1981 from the one they occupied in 1976

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the municipalities in each of 4 classes

(3) mean rate per 100 persons

Source: 1981 Census [Stats Canada E-574,1983]

Table A7.10 1981 New Brunswick Population by Migration (1) Quartiles (2) and Language (3)

Migration Quartiles (4)	All Municipalities	Population in Municipalities With Large Proportions of (persons) French	English
Total (15.4)	100.0% (696225)	100.0% (196910)	100.0% (499315)
Quartile 1 (7.5)	16.2% (112800)	30.4% (59825)	10.6% (52975)
Quartile 2 (12.1)	30.2% (210450)	40.0% (78695)	26.4% (131755)
Quartile 3 (16.6)	34.7% (241575)	20.9% (41120)	40.1% (200455)
Quartile 4 (25.3)	18.9% (131400)	8.8% (17270)	22.9% (114130)

(1) persons living in a different dwelling in 1981 from the one they occupied in 1976
(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the municipalities in each of 4 classes
(3) mother tongue French or English greater than 50% of municipal population
(4) mean rate per 100 persons

Source 1981 Census [Stats Canada E-574,1983]

Table A7.11 1981 New Brunswick Population 15 and Over and Number of Persons by Migration (1) Quartiles (2) and Educational Attainment (3) Quartiles (2)

Migration Quartiles (4)		Percent of Total Population 15 Years and Over Within Educational Attainment (persons)			
		Quartile 1	Quartile 2	Quartile 3	Quartile 4
Total	(15.4)	100.0% (74195)	100.0% (86130)	100.0% (81485)	100.0% (280960)
Quartile 1	(7.5)	51.8% (38455)	25.6% (22045)	22.0% (17925)	1.2% (3470)
Quartile 2	(12.1)	27.0% (20060)	34.7% (29915)	32.0% (26090)	29.7% (83485)
Quartile 3	(16.6)	11.0% (8125)	29.2% (25180)	17.8% (14470)	49.3% (138590)
Quartile 4	(25.3)	10.2% (7555)	10.4% (8990)	28.2% (23000)	19.7% (55315)

(1) persons living in a different dwelling in 1981 from the one they occupied in 1976
(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the total in each of 4 classes
(3) proportion of persons who attended university in the total population 15 or older
(4) mean rate per 100 persons

Source: 1981 Census [Stats Canada E-574,1983]

Table A7.12 1981 New Brunswick Population by Incidence of Low Income (1) Quartiles (2) and Migration (3) Quartiles (2)

Incidence of Low-Income Quartiles (4)		Percent of Total Population Within Migration (persons)			
		Quartile 1	Quartile 2	Quartile 3	Quartile 4
Total	(18.1)	100.0% (112800)	100.0% (210450)	100.0% (241575)	100.0% (131400)
Quartile 1	(8.9)	12.3% (13850)	10.7% (22440)	12.0% (29000)	51.4% (67550)
Quartile 2	(15 0)	16.6% (18735)	18.4% (38665)	39.4% (95070)	23.9% (31450)
Quartile 3	(19.7)	35.9% (40445)	55.9% (117595)	45.5% (109920)	15.8% (20700)
Quartile 4	(28 8)	35 3% (39770)	15.1% (31750)	3.1% (7585)	8.9% (11700)

(1) expenditures for food, clothing, and shelter exceeds the average level for the region of residence by at least 20%

(2) quartiles were calculated by ranking values and establishing class boundaries to provide about 25% of the total in each of 4 classes

(3) persons living in a different dwelling in 1981 from the one they occupied in 1976

(4) mean rate per 100 persons

Source. 1981 Census [Stats Canada E-574,1983]

Appendix VIII

Global Site Classification Categories Based Solely on Topographic Codes

Site Category	ICD-8/ICD-9	Count
Bladder, Kidney, and Other Urinary Organs	188-189	333
Breast	174-175	55?
Endocrine	193	46
	194	4
Eye	190	11
Female Genital (incl. uterus/unspecified)	179-181	360
	234	3
Gallbladder	156	33
Ill-Defined Cancer	158	4
	159	15
	195-199	142
Intestine (small and large)	152	9
	153	503
Larynx	161	53
Liver	155	23
Male Genital (incl. prostate)	185	442
	186	1
	187	5
Mouth and Pharynx	140	8?
	141	1?
	143-145	??
	146	1?
	148	7
	149	1
Nasal, Middle Ear, Sinuses, Nasopharynx	147	10
	160	11
Oesophagus	150	3?
Pancreas	157	16?

Site Category	ICD-8/ICD-9	Count
Rectum, RS Junction and Anus	154	259
Respiratory and Intrathoracic Organs	162-165	657
Salivary Glands	142	18
Skin (melanotic and other)	172	35
	173	1713
Stomach	151	267

References

Adelstein AM. Life-style in occupational cancer. In: Vainio H, Sarsa M, Hemminki K (eds.). Occupational cancer and carcinigenisis. New York: Chemosphere Publ. Co. 1980.

Alavanja MCR, Malker H, Hayes RB. Occupational cancer risk associated with the storage and bulk handling of agricultural foodstuff. Journal of Toxicol Environ Health 1987;22:247-254.

Allen EG, Marquis L, Boissonnault L, Stairs HF, Moffatt RW, Masse Marcel. Report of the Task Force on non-incorporated areas in New Brunswick. New Brunswick 1976.

Armenian HK, Lilienfeld AM. Incubation period of disease. Epidemiologic Reviews 1983.

Austin H, Delzell E, Grufferman S, Levine R, Morrison AS, Stolley PD, Cole P. Case-control study of hepatocellular carcinoma, occupation, and chemical exposures. JOM 1987;29:665-669.

Axelson O, Sundell, Andersson K, Edling C, Hogstedt C, Kling H. Herbicide exposure and tumour mortality; an updated epidemiological investigation on Swedish railroad workers. Scand J Work Environ Health 1980;6:73-79.

Bagnell PC, Crocker JFS, Ozere RL. Reye's syndrome in Canada's maritime provinces. Chemosphere 1978;7:565-571.

Barthel E. Increased risk of lung cancer in pesticide-exposed male agricultural workers. J Toxicol Environ Health 1981;8:1027-1040.

Blair A, Grauman MS, Lubin JH, Fraumeni JF. Lung cancer and other causes of death among licensed pesticide applicators. JNCI 1983;71:31-37.

Blair A, Thomas TL. Leukemia among Nebraska farmers: A death certificate study. Am J Epidemiol 1979;110:264-273.

Blair A, Watts D. Bladder cancer and dairy farming (Letter). JOM 1980;22:576-577.

Blot WJ, Fraumeni JF. Geographic epidemiology of cancer in the United States. In: Shottenfeld and Fraumeni (eds.). Epidemiology and prevention. Toronto: Saunders 1982.

Brain JD, Valberg PA. Models of lung retention based on ICRP Task Group report. Arch Environ Health 1974;28:1-11.

Breslow NE, Lubin J, Marek P. Multiplicative models and cohort analysis. JASA 1983;78:1-12.

Brinton LA, Blot WJ, Becker JA, Winn DM, Browder J, Farmer JC, Fraumeni JF. A case-control study of cancers of the nasal cavity and paranasal sinuses. Am J Epidemiol 1984;119:986-.

Brown CC, Green SB. Additional power computations for designing comparative Poisson trials. Am J Epidemiol 1982;115:752-758.

Brownson RC, Chang JC, Davis JR, Bagby JR. Occupational risk of prostate cancer: a cancer registry-based study. JOM 1988;30:523-526.

Burmeister LF, Everett GD, Van Lier SF, Isacson P. Selected cancer mortality and farm practices in Iowa. Am J Epidemiol 1983;18:72-77.

Burmeister LF, Morgan DP. Mortality in Iowa farm laborers, 1971-78. JOM 1982;24:898-900.

Canadian Permanent Committee on Geographical Names (CPCGN). Gazetteer of Canada: New Brunswick. Canadian Department of Energy, Mines, and Resources, 2nd edition 1972.

Cantor KP, Fraumeni JF. Distribution of non-Hodgkin's Lymphoma in the United States between 1950 and 1975. Cancer Res 1980;40:2645-2652.

Cantor KP. Farming and mortality from non-Hodgkin's lymphoma: a case-control study. Int J Cancer 1982;29:239-247.

Carson R. Silent spring. Boston: Houghton Mifflin, 1962.

Chatterjee S, Price B. Regression analysis by example. New York: John Wiley and Sons 1977.

College of American Pathologists (CAP). Systematized nomenclature of pathology (SNOP). Chicago Ill. 1965.

Crabbe RS, Krzymien M, Elias L, Davie S. New Brunswick forestry spray operations: measurement of atmospheric fenitrothion concentrations near the spray area. National Research Council of Canada (NRCC) 1980 (technical report no. LTR-UA-56).

Crabbe RS, Elias L, Davie. Field study of effect of atmospheric stability on target deposition and and effective swath widths for aerial forest sprays in New Brunswick Part II. National Research Council of Canada (NRCC) January 1983 (laboratory technical report no. LTR-UA-65).

Crabbe RS. Spray operations: Field study of the effect of atmospheric stability on long-range pesticide drift. National Research Council of Canada (NRCC) 1980 (National Aeronautical Establishment report no. LTR-UA-52).

Crocker JFS, Rozee KR, Ozere RL, Digout SC. Insecticide and viral interaction as a cause of fatty visceral changes and encephalopathy in the mouse. Lancet 1974;July 6:22-24.

Delzell E, Grufferman S. Mortality among white and non-white farmers in North Carolina, 1976-1978. Am J Epidemiol 1985;121:391-402.

Energy, Mines, and Resources. Personal communications 1981.

Eriksson M, Hardell L, Berg NO, Moller T, Axelson O. Soft-tissue sarcomas and exposure to chemical substances: a case-referent study. Brit J Indust Med 1981;38:27-33.

Fasal E, Jackson EW, Klauber MR. Leukemia and lymphoma mortality and farm residence. Am J Epidemiol 1968;87:267-274.

Fleiss JL. Statistical methods for rates and proportions. Toronto: John Wiley & Sons 1973.

Frome EL. Regression methods for binomial and Poisson distributed data. Presented at AAPM first mid-year topical symposium; Mobile, Alabama March 12-16, 1984.

Gallagher RP, Threlfall WJ, Spinelli JJ, Band PR. Occupational mortality patterns among British Columbia workers. JOM 1984;26:906-908.

Gold E, Gordis L, Tonascia J, Szklo M. Risk factors for brain tumours in children. Am J Epidemiol 1979;109:309-319.

Goldsmith JR, Guidotti TL. Environmental factors in the epidemiology of lymphosarcoma. Pathol Annu 1977;12:411-425.

Granville, GC. Personal communication 1982.

Hakama M, Hakulinen T, Pukkala E, Saxen L, Teppo L. Risk indicators of breast and cervical cancer on ecologic and individual levels. Amer J Epidemiol 1982;116:990-1000.

Hardell L, Sandstrom A. Case-control study: soft-tissue sarcomas and exposure to phenoxyacetic acid or chlorophenols. Brit J of Cancer 1979;39:711-717.

Hardell L. Relation of soft-tissue sarcoma, malignant lymphoma, and colon cancer to phenoxy acids, chlorophenols and other agents. Scand J Work Environ Health 1981;7:119-130.

Hatcher JD, White FMM. Final Report: Task force on chemicals in the environment and human reproductive problems in New Brunswick. New Brunswick Department of Health, March 1985.

Hatcher JD, White FMM. Second Report: Task force on chemicals in the environment and human reproductive problems in New Brunswick. New Brunswick Department of Health, January 1984.

Hatcher JD, White FMM. Interim Report: Task force on chemicals in the environment and human reproductive problems in New Brunswick. New Brunswick Department of Health, April 1983.

Hearn S, Ott G, Kolesar RC, Cook RR. Mortality experience of employees with occupational exposure to DBCP. Arch of Environ Health 1984;39:49-55.

Higginson J. Importance of environmental and occupational factors in cancer. In: Vainio H, Sarsa M, and Hemminki K (eds.). Occupational cancer and carcinogenesis. New York: Chemosphere Publ. Co. 1980.

Hoar SK, Blair A, Holmes F, Boysen C, Robel RJ, Hoover R, Fraumeni JF. Agricultural herbicide use and risk of lymphoma and soft-tissue sarcoma. JAMA 1986;256:1141-1147.

Jenkins CD. Social environment and cancer mortality in men. New Engl J Med 1983;308:395-398.

Klaassen CD, Amdur MO, Doull J (eds.). Casarett and Doull's toxicology. Toronto: Macmillan Publishing Co. 1986.

Lilienbaum DG, Kupper LL, Morgenstern H. Epidemiologic Research. Toronto: Lifetime Learning Publications 1982:78-80.

Levin M, Haenszel W, Carroll JE, Gerhardt PR, Handy VH, Ingraham SC. Cancer incidence in urban and rural areas of New York State. J Natl Cancer Inst 1960;24:1243-1257.

Linet MS, Stewart WF, Van Notta ML, Mccaffrey LD, Szklo M. Comparison of methods of determining occupational exposure in a case-control interview study of chronic lymphocytic leukemia. JOM 1987;29:136-141.

Mancuso TF, Sterling TD. Relation of place of birth and migration in cancer mortality in the US; a study of Ohio residents (1959-1967). J Chron Dis 1974;27:259-474.

Mclaughlin JK, Linet MS, Stone BJ, Blot WJ, Malker HSR, Weiner JA. Multiple myeloma and occupation in Sweden. Arch of Environ Health 1988;43:7-10.

Milham S. Leukemia and multiple myeloma in farmers. Am J Epidemiol 1971;94:307-310.

Morgan DP, Lin LI, Saikaly HH. Morbidity and mortality in workers occupationally exposed to pesticides. Arch Environ Contamin Toxicol 1980;9:349-382.

Musicco M, Filippini G, Bordo BM, Melotto A et al. Gliomas and occupational exposure to carcinogens: case-control study. Am J Epidemiol 1982;116:782-790.

Myers GC, Manton KG. The structure of urban mortality. A methodological study of Hannover, Germany. Part I. Int J Epidemiol 1977;3:203-212.

National Research Council of Canada (NRCC). Long-term toxicological effects of fenitrothion in mammals including carcinogenicity and mutagenicity. In: Fenitrothion: the long-term effects of its use in forest ecosystems. National Research Council of Canada (NRCC) 1977 (publication no. 16073).

National Research Council of Canada subcommittee on pesticide and industrial organic chemicals. Aminocarb: the effect of its use on the forest and the human environment. National Research Council of Canada (NRCC) 1979 (publication no. 18979).

Newfoundland Medical Association Committee (NMAC). Report of the NMAC formed to review the medical aspects of the spruce budworm epidemic and control program. May, 1979.

Notkola VJ, Husman KRH, Laukkanen VJ. Mortality among male farmers in Finland during 1979-1983. Scand J Work Environ Health 1987;13:124-128.

Olsen JH, Jensen OM. Occupation and risk of cancer in Denmark. Scand J Work Environ Health 1987;13:1-91.

Payne CD (ed.). The GLIM System; Release 3.77. Oxford: Numerical Algorithms Group Ltd. 1985.

Pearce NE, Sheppard RA, Howard JK, Fraser J, Lilly BM. Leukemia among New Zealand agricultural workers. Am J Epidemiol 1986;124:402-409.

Pearce NE, Smith AH, Fisher DO. Malignant lymphoma and multiple myeloma linked with agricultural occupations in New Zealand. Am J Epidemiol 1985;121:225-237.

Piantadosi S, Byar DF, Green SB. The ecological fallacy. Amer J Epidemiol 1988;127:893-905.

Polissar L. The effect of migration on comparison of disease rates in geographic studies in the United States. Am J Epidemiol 1980;111:175-182.

Priester WA, Mason TJ. Human cancer mortality in relation to poultry population by county in 10 southeastern states. J Natl Cancer Inst 1974;53:45-49.

Rothman KJ. Modern Epidemiology. Toronto: Little, Brown and Company 1988.

Sackett DL. Bias in analytic research. J Chron Dis 1979;32:51-63.

Saffiotti U. Review of pesticide carcinogenesis data and regulatory approaches. Air pollution and cancer in man. International Agency for Research on Cancer (IARC) 1977 (publication no. 16).

Schottenfeld D. Chronic disease in the workplace and environment. Arch Environ Health 1984;39:150-157.

Schumacher, MC. Farming occupations and mortality from non-Hodgkin's Lymphoma in Utah. JOM 1985;27:580-584.

Siemiatycki J, Wacholder S, Dewar R, Cardis E, Greenwood C, Richardson L.Degree of confounding bias related to smoking, ethnic group, and socioeconomic status in estimates of the associations between occupation and cancer.JOM 1988;30:617-625.

Smith TL, Zoph PE. Demography: Principles and methods. Washington: Alfred Publishing Co. Ltd. 1976.

Spiegelman, M. Introduction to demography. Cambridge Mass.: Harvard University Press 1968.

Spitzer WO, Archer M, Hill GB, Horwitz RI, et al. Final report of the New Brunswick task force on the environment and cancer. New Brunswick Department of Health March 16, 1984.

Spitzer WO, Brouzes R, Hattwick MA, Hurwitz E, Kramer M, Larke RPB, Shank R, Seliske P. Report of the New Brunswick task force on the environment and Reye's syndrome. Clinical and Investigative Medicine 1982;5(2/3):203-214.

Spitzer WO. Final report on the activities of the New Brunswick task force on cancer and the environment March 1985.

Statistics Canada. Standard Geographic Classification 1976. Minister of Supply and Service 1977 (Stats Canada catalogue no. 12556).

Statistics Canada. Place Name Reference List; Atlantic Provinces 1981. Minister of Supply and Services 1983 (Stats Canada catalogue no. 94-902).

Statistics Canada. Rebasing Low Income Cut-offs to 1978; Technical Reference Paper. Minister of Supply and Services 1983 (Stats Canada catalogue no. 8-3302-519).

Statistics Canada. Standard Geographic Classification; 1981. Minister of Supply and Services 1982 (Stats Canada catalogue no. 12-567).

Statistics Canada. Census divisions and subdivisions; Population, occupied private dwellings, private households, census families in private households; selected characteristics: New Brunswick. Minister of Supply and Services 1982 (Stats Canada catalogue no. E-562).

Statistics Canada. Census divisions subdivisions; Population, occupied private dwellings, private households, and census and economic families in private households; Selected social and economic characteristics. Minister of Supply and Services 1983 (Stats catalogue no. E-571).

Statistics Canada. Special Tabulation of Land under cultivation by crops; Agriculture Canada. Minister of Supply and Sevices 1983 (Stats Canada special tabulation, 1983).

Statistics Canada. Standard Geographic Classification Manual; Atlantic Provinces Interim Edition III. Minister of Supply and Services March 1972.

Stemhagen A, Slade J, Altman R, Bill J. Occupational risk factors and liver cancer. Am J Epidemiol 1983;117:443-454.

Susser, M. Causal thinking in the health sciences; concepts and strategies in epidemiology. Toronto: Oxford University Press 1973.

Teppo L. Cancer incidence by living area, social class and occupation. Scand J Work Environ Health 1984;10:361-366.

Thomas TL, Fontham ETH, Norman S, Stemhagen A, Hoover RN. Occupational risk factors for brain tumours. Scand J Work Environ Health 1986;12:121-127.

Wang HH, MacMahon B. Mortality of workers employed in the manufacture of chlordane and heptachlor. JOM 1979;21:745-748(b).

Wang HH, MacMahon B. Mortality of pesticide applicators. JOM 1979;21:741-744(a).

Wicklund KG, Daling JR, Allard J, Weiss NS. Respiratory cancer among orchardists in Washington State 1968 to 1980. JOM 1988;30:561-564.

Williams RR, Stegens NL, Goldsmith JR. Associations of cancer site and type with occupation and industry from the Third National Cancer Survey interviews. J Natl Cancer Inst 1977;59:1147-1185.

Wilson FD. Components of change in migration and destination-propensity rates for metropolitain and non-metropolitain areas 1935-1980. Demography 1988;25:129-139.

Wong O, Brocker W, Davis HV, Nagle GS. Mortality of workers potentially exposed to organic and inorganic bromate chemicals, DCB, TRIS, PBB, and DDT. Brit J Indust Med 1984;41:15-24.

World Health Organization (WHO). International Classification of Diseases; Eigth Revision. Geneva: World Health Organization 1968.

World Health Organization (WHO). International Classification of Diseases for Oncology (ICD-O). Geneva: World Health Organization 1976.

World Health Organization (WHO). DDT and its Dervatives. Geneva: World Health Organization (Environmental Health Criteria 9) 1979.

World Health Organization (WHO). International Classification of Diseases; Ninth Revision. Geneva: World Health Organization 1975.

Zagraniski RT, Kelsey JL, Walter SD. Occupational risk factors for laryngeal carcinoma: Connecticut, 1975-1980. Am J Epidemiol 1986;124:67-76.