Pesticide Contamination of Surface Waters Draining Agricultural Fields: Pesticide Contamination Classification and Abatement Measures

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1.0 RATIONAL/OBJECTIVE

Agricultural pesticides are effective tools for increasing crop yields and quality. However, their usage has resulted in non-point source contamination of surface waters in the Canadian Great Lakes Basin. In accordance with the terms of Annex 13 of the revised Great Lakes Water Quality Agreement of 1987 (International Joint Commission, 1987), Agriculture Canada has undertaken programs to reduce non-point source pollution arising from agricultural activities. This report deals primarily with the surface runoff component of agricultural drainage, since it is thought to be a significant non-point source of pesticides in surface waters.

In a previous study, Shelton et al. (1988) developed a classification system for assessing the contamination risk posed by pesticides to surface and groundwater systems. Their surface water classification system was based on soil properties and total pesticide usage (i.e. total mass of all active ingredients applied) at the township level. Individual pesticides and their environmental behaviour were not considered in the classification system.

Currently, there is need for a classification system for assessing the relative potential of specific pesticides to be transported from agricultural lands in surface runoff. Simple indices which consider pesticide properties have proven useful for assessing pesticide groundwater pollution potentials. (Gustafson, 1989; 1982; McRae, 1991). Application of a similar approach may prove useful for making preliminary assessments of pesticide losses in surface runoff and can also provide a rationale for the selection of pesticides posing a low risk to surface waters.

This report is intended to provide a background for assessments of the relative potential of pesticides to contaminate surface runoff and to outline practical abatement measures. Toward this goal the report will present the following information:

1) Data documenting the incidence of pesticides in surface waters of the Canadian Great Lakes Basin,
2) A guide to factors affecting the extent of pesticide losses in surface runoff,
3) Indices for assessing the relative potential of pesticides to contaminate surface runoff and,
4) A discussion of abatement strategies.

Pesticides in Surface Waters

Surface water monitoring data provide a valuable source of information for setting basin-wide water quality priorities and assessing the progress of remedial measures. However, river monitoring data can reflect a variety of point and non-point sources of pesticide contamination. Some of the non-point sources which have been documented include; atmospheric deposition, tile drainage, interflow and surface runoff (Bengston et al., 1990; Nutter et al., 1984). At the field-scale though, surface runoff is thought to be one of the most significant sources of pesticides in surface waters (Leonard, 1988; Wauchope, 1978).

The presence of specific pesticides in surface waters is not only a function of their susceptibility to loss in surface runoff but is also affected by pesticide usage volume and transport characteristics within surface water systems, and weather patterns (Frank and Logan, 1988; Frank et al., 1991; Willis et al. 1987;). Section 2 of the report outlines two procedures for assessing the relative susceptibility of specific pesticides to be transported from the site of application in surface runoff.

Watershed Monitoring Data

The PLUARG (Pollution from Land Use Activities Reference Group) studies of the 1970's (Frank et al., 1982) and the studies reported by Frank and Logan (1988) and Frank et al. (1991) provide the most comprehensive analysis of the occurrence of pesticides in agricultural drainage waters in the Canadian portion of the Great Lakes Basin.

Table 1.1 lists the pesticides detected, as well as their frequencies of detection, in the 3 studies (Frank et al., 1982; Frank and Logan, 1988; Frank et al. 1991) . It is clear from the table that the frequency of detection of most pesticides has decreased. Metolachlor is one notable exception to this trend. It's increased presence is probably a reflection of its increased usage. While there was no record of metolachlor use during the PLUARG study (Frank et al., 1982), it currently has the highest usage volume of any agricultural pesticide in Ontario (Moxley, 1989). Although the decreased incidence of some compounds may be linked to soil and water conservation practices (Frank et al., 1991), it is clear from Table 1.1 that deregistration and deleted uses have also been effective in reducing the incidence of specific pesticides. In particular, DDT and dieldrin have been banned and the major use of endosulfan in tobacco was deleted (Frank et al., 1982).

Table 1.1 Incidence of pesticides in PLUARG watersheds 1975-1977 and at the mouth of the Grand, Saugeen and Thames river 1981-1990, as reported by Frank et al. (1982), Frank and Logan (1988) and Frank et al. (1991) respectively.

Common name	Frequency of Detection PLUARG Watersheds		Frequency of Detection '81-'85			Frequency of Detection '86-'90		
	1975-1976	1976-1977	Grand R.	Saugeen R.	Thames R.	Grand R.	Saugeen R.	Thames R.
2,4,5-T	1	2.7	NA	NA	NA	NA	NA	NA
2,4-D	8.1	5.8	8.7	5.7	29.9	5	0.7	0
2,4-DB	0	0	0	0	1.5	0	0	1.4
alachlor	0.6	0	3.2	0.7	5.4	0.4	0	1.4
atrazine	80.4	80	90.5	62.2	99	77.3	43	98.6
carbofuran	NA	0.8	0	0	0	0	0	0
chlordane	0	3.1	0	0	0	0	0	0
chlorpyrifos	0.2	0.4	0	0	0	0	0	0
cyanazine	NA	NA	8.4	3.5	15.8	0.8	1.3	4.3
cyprazine	0.9	1.5	NA	NA	NA	NA	NA	NA
DDT	92.5	93.6	1	0.7	1.5	0.4	0	0
diazinon	5	13.3	0	0	0.5	0	0	0
dicamba	0.2	0	3.9	2.1	18.1	0.4	0	0
dichlorprop	0	0	1	0.7	7.8	NA	NA	NA
dieldrin	20.9	20.4	0	2.1	6.5	0	0	0
endosulfan	20	18.5	4.8	0	4.5	0	0	0
EPTC	NA	5.7	0	0.7	0	0	0	0
ethion	0.4	0	NA	NA	NA	0	0	0
heptachlor epoxide	3.8	8.1	15.2	3.6	16.4	0.4	0.7	0
malathion	0	0.8	0	0	0.5	0	0	0
MCPA	0.9	0.4	1	0	2	0	0	0
mecoprop	0	0	1.9	0.7	4.9	0.4	0.7	0
metolachlor	NA	NA	4.2	1.4	7.4	3.5	1.3	27.1
metribuzin	0.7	1.3	0	0	3	0.4	0	0
prometon	0.2	1.5	NA	NA	NA	NA	NA	NA
simazine	6.2	12.3	0	0.7	4	0	1.3	0

NA - not analyzed

* frequency of detection is expressed as a percentage of samples analyzed.

Factors Affecting Pesticide Runoff Losses

Pesticide losses occur in the dissolved and adsorbed phases of surface runoff. Normally, the magnitude of loss is less than 1 or 2% of the amount applied (Wauchope, 1978; Weber et al., 1980; Weber and Miller, 1989). However, under conditions where intense rainfall occurs shortly after pesticide application, losses can range from 2 to 19% of the amount of pesticide applied (Weber and Miller, 1989).

The extent of pesticide loss in surface runoff is determined by pesticide availability and the extent of surface runoff and soil erosion. However, there are a number of other factors and considerations which can have a major influence on these three main determinants. For instance, pesticide availability is influenced by persistence, formulation, soil adsorption and pesticide application rates and methods (Wauchope, 1978; Wauchope and Leonard, 1980; Leonard, 1988). In addition, surface runoff and soil erosion are influenced by weather patterns, vegetative cover, soil properties and topography (Wischmeier and Smith, 1978; Schwab et al., 1981). Table 1.2 summarizes these and other significant factors and interactions affecting the extent of pesticide runoff losses.

In principle, assessments should consider all of the pertinent factors given in Table 1.2. However, the number and variability of the factors and processes involved make such detailed assessments impractical except on a case by case basis. General methods of assessment which consider a number of the most important factors are available and are discussed in Section 2 of the report.

Table 1.2. **Factors Affecting Pesticide Losses to Surface Runoff (Adapted from Leonard, 1988)**

1) SOIL FACTORS

Depth of interaction	- a relatively thin surface layer of soil (1 to 2 cm in depth) interacting with rainfall/runoff - also known as the runoff zone, surface active zone or mixing zone.	Ahuja and Lehman, 1983
	- the depth of the runoff zone is dependant on cover, rainfall intensity, slope and the degree of soil aggregation.	Sharpley, 1985
	- pesticides in the surface active zone are available for transport (leaching, runoff or volatilization), degradation, plant uptake or may be retained within the runoff zone in soil water or adsorbed to soil.	Heathman et al., 1986
	- the upper layers of the runoff zone are more completely mixed with runoff, with the extent of interaction decreasing exponentially with depth.	
Infiltration rates	- a function of the permeability of the soil profile, soil moisture, vegetation and temperature.	Novotny and Chesters, 1981
	- fine textured soils with high proportions of silt and clay generally have low infiltration rates and thus have a high potential to generate surface runoff.	Schwab et al., 1981
	- deep coarse textured soils with high proportions of sand generally have high infiltration rates and thus have a low potential to generate surface runoff.	
	- weakly adsorbed pesticides are more readily leached into the soil profile in soils with high infiltration rates; thereby decreasing the quantities of pesticide available for runoff.	Leonard, 1988

Table 1.2.   **Factors Affecting Pesticide Losses to Surface Runoff (Adapted from Leonard, 1988)**

	-	on soils with relatively low infiltration rates weakly adsorbed pesticides are more susceptible to losses in surface runoff.	Leonard, 1988
	-	infiltration rates for the first few storms after application are important in determining the extent of pesticide losses in surface runoff.	Baker J. L., 1987
Soil structure	-	the arrangement and organization of soil particles into aggregates.	Hillel, 1980
	-	soil structure has a major influence on soil drainage characteristics which in turn influences runoff and erosion.	Onstad and Voorhees, 1987
	-	soils with high aggregate stability are less susceptible to decreases in infiltration associated with surface crusting.	
	-	a well structured soil can help reduce erosion by reducing soil detachment and transport potentials.	Lal, 1988
Surface crusting and compaction	-	surface crusting and compaction decrease infiltration rates and the time to the inception of runoff as well as increasing the initial concentrations of pesticide in runoff.	Baker and Laflen, 1979
Slope	-	increasing slope increases the depth of interaction between soil and rainfall/runoff	Sharpley, 1985
	-	rate of runoff and erosion increase with increasing slope	Wischmeier and Smith, 1978
Antecedent soil moisture	-	pesticides applied to a moist soil are more susceptible to losses in surface runoff than applications to a dry soil surface.	Baldwin et al., 1975a; 1975b;
	-	high soil moisture content increases pesticide losses by decreasing the time to the inception of runoff and reducing the quantities of pesticide leached from the runoff zone deeper into the soil profile.	Leonard, 1988

2)   RAINFALL

Intensity, duration and amount	-	affects total runoff volumes and the erosive potential of storms which in turn are determinants of a storm's capacity to transport pollutants.	Novotny and Chesters, 1981
	-	the largest single-event losses of pesticides in surface runoff are associated with runoff events shortly after application and are primarily the result of unusually large runoff events.	Wauchope, 1978
	-	increasing rainfall intensity increases both soil erosion and the depth of interaction between the soil and rainfall/runoff	Sharpley, 1985
	-	small soaking rains may decrease subsequent runoff losses by washing pesticides into the soil profile.	Wauchope, 1987a
Rainfall timing	-	rainfall/runoff events shortly after pesticide application can account for more than 90% of the total annual runoff load of pesticide from a field.	Leonard et al., 1979
	-	the highest concentrations of pesticides in surface runoff are usually associated with events shortly after application.	Wauchope and Leonard, 1980
	-	mean annual pesticide loads are highly correlated with mean runoff volume during the month of application	Haith, 1986; Li et al., 1990
Runoff timing	-	rainfall occurring before runoff commences can reduce the losses of pesticides (especially those which are weakly adsorbed) by leaching them from the surface active zone, deeper into the soil profile.	Wauchope et al., 1990a

3)   CHEMICAL FACTORS

Pesticide persistence	-	pesticides which persist in the soil surface have a higher probability of runoff.	Wauchope, 1978
	-	under field conditions volatilization, biochemical and photochemical degradation, plant uptake, leaching and surface runoff losses are responsible for pesticide dissipation from the surface active zone.	
	-	the dissipation of pesticides under field conditions is favoured by high soil moisture content and high soil temperatures.	Nash, 1989

Table 1.2.   **Factors Affecting Pesticide Losses to Surface Runoff (Adapted from Leonard, 1988)**

	- microbial metabolism is considered to be the major degradation pathway of many pesticides in sediment and soil	Novotny and Chesters, 1981
Pesticide adsorption	- the adsorption of non-ionic pesticides to soil particles is primarily correlated with organic matter content and to a lesser extent with the clay content. - anionic pesticides are generally weakly adsorbed to soils (examples are 2,4-D and dicamba). - cationic pesticides are strongly adsorbed to the clay fraction of soils (examples are paraquat and diquat)	Karickhoff, 1984; Novotny and Chesters, 1981
	- soil pH affects the charge on ionizable pesticides and influences the amounts of pesticide adsorbed to clay and organic matter.	Hance, 1988
	- weakly adsorbed pesticides are transported mainly in the water phase of runoff. - strongly adsorbed pesticides are transported mainly in the sediment phase of runoff. - the transport of pesticides with intermediate adsorption coefficients is dependant on the sediment concentrations in runoff with increasing sediment concentrations resulting in increasing proportions of the pesticide being transported on sediment.	Leonard, 1988; Rao and Davidson, 1980; Baker and Johnson, 1983; Buttle, 1990
	- increased adsorption of pesticides due to increases in organic matter can retard the leaching of pesticides into the soil profile and prolong their presence in the runoff zone, thereby increasing the opportunity for losses in surface runoff.	Wagenet, 1987
Formulation	- controlled release formulations designed to reduce groundwater loadings of pesticides may increase losses in surface runoff.	Leonard and Knisel, 1989; Kenimer et al., 1989
	- wettable powders are most susceptible to surface runoff losses - with normal losses being 5% or less per year; emulsions have the next highest potential for loss - 1% or less per year; pesticides applied as aqueous solutions show losses on the order of 0.5% per year with the exception of ionic compounds like paraquat which are strongly bound to soils and tend to have higher loss potentials.	Wauchope, 1978; Wauchope and Leonard, 1980

4) CROP PRODUCTION FACTORS

Tillage systems	- conservation tillage reduces surface runoff losses of adsorbed pesticides by reducing soil loss. - the effect of conservation tillage on soluble/weakly adsorbed pesticides is complex, with both reductions and increases in pesticide runoff losses being possible	Leonard, 1988; Wauchope, 1987a; Baker, J.L., 1987
Residue management	- plant residues intercept rain and shield the soil's surface from the impact of raindrops. - the shielding effect of residues can decrease runoff volumes by preventing decreases in infiltration rates associated with surface crusting.	Lal, 1988; Onstad and Voorhees, 1987
	- the shielding effect of the residues also decreases soil erosion by decreasing the energy of raindrops thereby decreasing the detachment of soil particles.	Hillel, 1980
	- the decay of crop residues increases soil organic matter and is essential for maintaining good soil structure.	Lal, 1988
Rate of application	- the runoff losses of pesticides are in proportion to the amounts applied.	Leonard, 1988
Incorporation into the soil	- incorporation reduces the concentration of pesticide in the runoff zone thus reducing runoff losses	Baker and Laflen, 1979
Application timing	- optimization of application timing with respect to the timing of large rainfall/runoff events may lead to significant reductions in runoff losses.	BEAK, 1990; Baker and Johnson, 1983

2.0 METHODOLOGY FOR ASSESSING PESTICIDE RUNOFF LOSSES

Introduction

One of the goals of this project was to classify pesticides used in the Canadian portion of the Great Lakes Basin on the basis of their ability to contaminate surface runoff.

A number of methods have been used to assess the magnitude of pesticide losses in surface runoff including; small plot, field and watershed scale monitoring, laboratory soil-water systems and mathematical models. Currently, economic and logistic considerations make it impractical to experimentally determine the fate of pesticides in the complete set of environmental conditions in which they are likely to be used. Mathematical models can provide a practical and economical means of assessing the behaviour of pesticides under environmental conditions not studied by experimentation (Wagenet, 1987).

Mathematical modelling can be approached at a number of levels of complexity, depending on i) the availability of resources and data and, ii) the objectives of the assessment. A number of authors have advocated a hierarchical approach, using 3 classes of models - screening models, management models and simulation models (Jury and Ghodrati, 1989; Marsalek, 1988).

Generally, screening level models are used in preliminary assessments where an overview or a first-approximation comparison is required. Typically, screening level models are used to break large groups of chemical compounds into smaller groups with similar characteristics and environmental behaviours (Jury and Masoud, 1989). These models do not provide a definitive assessment since they generally consider only a few of the most important factors affecting pesticide fate. However, they are useful and practical tools for developing generalizations.

Screening models have been used to derive general ratings of pesticide groundwater contamination potentials (Rao et al., 1985; Laskowski et al., 1982; Gustafson, 1989 and McRae, 1991). A number of simple methods are also available for assessing the extent of pesticide losses in surface runoff.

Screening Level Procedures

Two simple procedures which are designed for classifying pesticide loss potentials are available. These procedures are not replacements for simulation models or field studies, rather they are designed for use in preliminary studies where it may be impractical to use methods of assessment, which are more data and resource intensive (i.e. simulation modelling or field studies). Both procedures discussed have been designed with simplicity in mind and are

currently being used in the United States by producers and those involved in water quality planning. The following sections will present an overview of two systems:

1) Soil/Pesticide Interaction Screening Procedure (SPISP),
2) "Kitchen Table"

The potential for implementing these screening procedures in the Canadian Great Lakes Basin will also be discussed.

Note: Both of the assessment procedures (SPISP and "Kitchen Table") also include components for the assessment of groundwater contamination by pesticides. The following discussions focus mainly on the surface runoff loss components of the procedures.

3.0 FINDINGS

SPISP

SPISP (Soil/Pesticide Interaction Screening Procedure) (Goss, 1988; Goss, 1991; Goss and Wauchope, 1990) is currently used by the USDA's Co-operative Extension Service as an advisory tool in consultations with producers. The procedure has been implemented throughout the continental United States. SPISP includes components for assessing pesticide runoff losses and pesticide leaching losses. Accounts of its use in an abatement program have been published (Carlson et al., 1990; Lemme et al., 1990). The following discussions are limited to the surface runoff loss component of SPISP.

Although SPISP provides the basis for broad comparisons of pesticide loss potentials, it is very important to recognize that the procedure cannot provide a definitive assessment in some instances. Where uncertainties in the rating exist a more detailed analysis (ie a second-tier evaluation) of a particular pesticide/site combination may be required. Goss and Wauchope (1990) have suggested that a second-tier evaluation could be performed by running the GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) computer model using more detailed pesticide, soil, climate and cropping data from the site of interest. Currently however, methodology for second-tier evaluations is under development and is not yet operational.

The following sections of the report present:

1) an example application of SPISP and,
2) a discussion of how to interpret the potentials.

Example Application

The numeric ratings used in the procedure were developed by running a number of compounds and scenarios through a GLEAMS computer simulation process under climatic conditions likely to result in pesticide losses (Goss, 1988; Goss, 1991). Results of these simulations were summarized with a number of regression equations which define 3 levels of loss potential for each of the following;

1) the pesticide's susceptibility to dissolved phase losses,
2) the pesticide's susceptibility to adsorbed phase losses,
3) the soil's ability to generate dissolved phase losses, and
4) the soil's ability to generate adsorbed phase losses.

a) Pesticide Ratings

The pesticide's dissolved phase runoff loss potential and adsorbed phase runoff loss potential are determined from Tables 3.1 and 3.2, respectively. As an example, the pesticide loss potentials for atrazine would be determined by first looking up atrazine's solubility, half-life and soil adsorption coefficient (Koc) solubility from the appropriate columns in Table 3.3. The corresponding values for solubility, half-life and soil adsorption coefficient are 33 ug/ml, 60 days and 100 ml/g, respectively. Using these values, the algorithm in Table 3.1 indicates that atrazine is classified as having a large solution runoff loss potential, since its solubility is greater than 1 ug/ml and its half-life is greater than 35 days and its soil adsorption coefficient is < 100000 ml/g. Similarly, the adsorbed runoff potential algorithm (Table 3.2) indicates that atrazine does not satisfy the conditions outlined for placement in either the large potential category or the small potential category. Thus, the algorithm indicates that atrazine should be placed in the medium potential category for adsorbed phase losses.

The method outlined above has been used to summarize the adsorbed and dissolved phase loss potentials for 101 pesticides used in the Canadian Great Lakes Basin (Table 3.3). Table 3.3 also summarizes the solubilities, half-lives and soil adsorption coefficients used to derive the ratings from Tables 3.1 and 3.2.

Table 3.1   Pesticide dissolved/solution runoff potential algorithm (from Goss, 1991).

> **LARGE:** **IF** solubility >=1 ug/ml **AND** half-life > 35 days **AND** K_{oc} < 100000 ml/g **OR**
> **IF** solubility >=10 ug/ml **AND** solubility < 100 ug/ml **AND** K_{oc} <= 700 ml/g
>
> **SMALL:** **IF** K_{oc} >= 100000 ml/g **OR**
> **IF** K_{oc} >= 1000 ml/g **AND** half-life <= 1 day **OR**
> **IF** solubility < .5 ug/ml **AND** half-life < 35 days

Table 3.2   Pesticide adsorbed runoff potential algorithm (from Goss, 1991).

> **LARGE:** **IF** half-life >= 40 days **AND** K_{oc} >= 1000 ml/g **OR**,
> **IF** half-life >= 40 days **AND** K_{oc} >= 500 ml/g AND solubility <= 0.5 ug/ml
>
> **SMALL:** **IF** half-life <= 1 day **OR**,
> **IF** half-life <= 2 days **AND** K_{oc} <= 500 ml/g **OR**
> **IF** half-life <= 4 days **AND** K_{oc} <= 900 ml/g **AND** solubility >= 0.5 ug/ml **OR**

TABLE 3.3   Properties, loss potentials (Goss, 1991) and volume of usage (Moxley, 1989) of pesticides used in the Canadian Great Lakes Basin

| | PESTICIDE PROPERTIES | | | PESTICIDE LOSS RATING[1] | | USAGE[2] |
Common Name	SOLUBILITY (ug/ml)	HALF-LIFE (days)	SOIL K_{oc} (ml/g)	ADSORBED	SOLUTION	VOLUME (kg)
1,3-dichloropropene	2250	10	32	S	M	709,290
dichloropropanes	*	*	*	*	*	+
2,4-D acid	890	10	20	S	M	150,720
2,4-D dimethylamine salt	796000	10	20	S	M	+
2,4-D esters or oil soluble amines	100 E	10	100 E	S	M	+
2,4-DB butoxyethyl ester	8	7	500	S	M	59,150
2,4-DB dimethylamine salt	709000	10 E	20 E	S	M	+

Table 3.3 continued...

| Common Name | PESTICIDE PROPERTIES | | | PESTICIDE LOSS RATING[1] | | USAGE[2] |
	SOLUBILITY (ug/ml)	HALF-LIFE (days)	SOIL K_{oc} (ml/g)	ADSORBED	SOLUTION	VOLUME (kg)
acephate	818000	3	2	S	M	14,570
alachlor	240	15	170	S	M	2,180
aldicarb	6000	30	30	S	M	3,260
amitrole	360000	14	100	S	M	210
ammonium thiocyanate	*	*	*	*	*	+
anilazine	8	1	1000 E	S	S	30
atrazine	33	60	100	M	L	1,045,110
azinphos-methyl	29	10	1000	M	M	43,120
Bacillus thuringiensis	*	*	*	*	*	4,810
benomyl	2	240	1900	L	L	1,210
bentazon	2300000	20	34	S	M	167,550
bromoxynil octanoate ester	0.08	7	10000	M	S	27,530
bromoxynil pentanoate ester	*	*	*	*	*	+
butylate	44	13	400	S	L	106,440
captafol	*	*	*	*	*	13,240
captan	5.1	2.5	200	S	M	71,410
carbaryl	120	10	300	S	M	27,050
carbofuran	351	50	22	M	L	12,570
chinomethionat	*	*	*	*	*	1,460
chloramben salts	900000 E	14	15 E	S	M	42,880
chlorfenvinphos	*	*	*	*	*	1,270
chlorimuron ethyl	1200	40	110	S	L	10
chloropicrin	2270	1 E	62	S	M	34,790
chlorothal dimethyl (DCPA)	0.5	100	5000	L	M	600
chlorothalonil	0.6	30	1380	M	M	78,470
chloroxuron	*	*	*	*	*	570
chlorpropham	89	30	400 E	S	L	180
chlorpyrifos	0.4	30	6070	M	S	3,400
cyanazine	170	14	190	S	M	226,790
cyhexatin	*	*	*	*	*	660
cypermethrin	0.004	30 E	100000 E	M	S	1,040
demeton	*	*	*	*	*	410
diazinon	60	40	1000 E	L	L	5,430
dicamba salt	400000	14	2	S	M	135,960
dichlobenil	21.2	60	400 E	M	L	500
dichlone	*	*	*	*	*	1,780
diclofop-methyl	0.8	37	16000	M	M	250
dicofol	1 E	60 G	180000 E	L	S	5,960
difenzoquat methlysulfate	817000	100	54500	L	L	5,480
dimethoate	39800	7	20	S	M	3,170
dinocap	4	20 G	550 E	S	M	8,410
dinoseb phenol	50	20	500	S	L	90
dinoseb salts	2200	20	63	S	M	+
diphenamid	260	30	210	S	M	3,650
diquat dibromide salts	718000	1000	1000000	L	S	3,100
diuron	42	90	480	M	L	2,770
DNOC sodium salt	100000	20 G	20	S	M	360
dodine acetate	700	20 G	100000 E	M	S	5,430
endosulfan	0.32	50	12400	L	M	14,020
EPTC	344	6	200	S	M	248,360
ethalfluralin	0.3	60	4000	L	M	17,250
ethion	1.1	150	10000	L	L	300
fenoxaprop-ethyl	0.8	9	9490	M	M	710
fensulfothion	*	*	*	*	*	2,910
fenvalerate	0.002	35	5300	M	M	40
ferbam	120	17	300	S	M	6,970
fixed copper	*	*	*	*	*	4,270
fluaziflop-p-butyl	2	15	5700	M	M	20
folpet	*	*	*	*	*	10,080
fonofos	16.9	40	870	S	L	18,370
formentate hydrochloride	500000	100 G	100000 E	L	S	1,160

Table 3.3 continued...

| | PESTICIDE PROPERTIES | | | PESTICIDE LOSS RATING[1] | | USAGE[2] |
Common Name	SOLUBILITY (ug/ml)	HALF-LIFE (days)	SOIL K_{oc} (ml/g)	ADSORBED	SOLUTION	VOLUME (kg)
glyphosate amine salt	900000 E	47	24000 E	L	L	158,680
ioxynil	*	*	*	*	*	10
iprodione	13.9	14	700	S	L	2,120
linuron	75	60	400	M	L	193,190
malathion	130	1	1800	S	S	4,820
maleic hydrazide	400000	30	20 E	S	M	4,100
mancozeb	6	70	2000	L	L	200,100
maneb	6 E	70	2000 E	L	L	13,670
MCPA dimethylamine salt	866000	25	20 E	S	M	222,190
MCPA ester	5 E	25	1000 E	M	M	+
MCPB	200000 E	14	20 E	S	M	24,410
mecoprop amine salt	660000	21	20 E	S	M	7,170
metam sodium	963000	7	10 E	S	M	3,000
methamidophos	1000000 E	6	5	S	M	1,910
methidathion	220	7	400 E	S	M	2,320
methomyl	58000	30	72	S	M	1,220
methoxychlor	0.1	120	80000	L	M	50
methyl isothiocyanate	7600	10	10	S	M	52,380
metiram	0.1 E	20 G	500000 G	M	S	170,840
metobromuron	*	*	*	*	*	62,480
metolachlor	530	90	200	M	L	1,724,700
metribuzin	1220	40	60 E	S	L	258,060
mevinphos	600000	3	44	S	M	50
monolinuron	*	*	*	*	*	12,810
naled	2000	1	180	S	M	1,580
napropamide	74	70	400	M	L	2,350
naptalam sodium salt	231000	14	20 E	S	M	2,760
oxamyl	282000	4	25	S	M	10
oxydemeton-methyl	1000000	10	10	S	M	680
oxyflurofen	0.1	35	100000 E	M	S	100
paraquat dichloride salt	620000	1000 E	1000000 E	L	S	3,980
parathion (ethyl)	24	14	5000 E	M	M	14,810
pebulate	100	14	430	S	M	1,920
permethrin	0.006	30	100000	M	S	1,580
phorate	22	60 E	1000 E	L	L	4,040
phosalone	3	21	1800	M	M	8,830
phosmet	20	19	820	S	M	45,850
primicarb	*	*	*	*	*	1,110
prometryn	33	60	400	M	L	1,020
propanil	200	1	149	S	M	560
propargite	0.5	56	4000 E	L	M	7,360
sethoxydim	4390	5	100 E	S	M	16,200
simazine	6.2	60	130	M	L	7,860
streptomycin	*	*	*	*	*	70
sulfur	*	*	*	*	*	44,520
terbacil	710	120	55	M	L	1,250
terbufos	5	5	500	S	M	77,920
thiophanate-methyl	3.5	10 G	1830 E	M	M	770
thiram	30	15	670	S	L	400
triadimefon	71.5	26	300	S	L	90
triallate	4	82	2400	L	L	710
trichlorfon	120000	10	10	S	M	1,510
trifluralin	0.3	60	8000	L	M	138,810
triforine	30	21	540 E	S	L	160
zineb	*	*	*	*	*	810

1 - Pesticide ratings derived from Tables 3.1 and 3.2
2 - Pesticide usage volume in the Canadian Great Lakes Basin 1988 (Moxley, 1989)
S - Small
M - Medium
L - Large
E - denotes a best estimate. Wauchope et al. (1990b) suggest probable error of a factor of 3 for solubility and K_{oc} and a factor of 2 for half-life.
G - denotes a best guess. Wauchope et al. (1990b) suggest a probable error of a factor of 10 for solubility and K_{oc} and a factor of 5 for half-life.

It should be noted that some of the pesticide parameter data given in Table 3.3 represent best estimates or best guesses. These data have been flagged with a G for guess and an E for estimate. These flags are carried through the procedure and are an indication of uncertainty. The pesticide properties given in Table 3.3 are a subset of the USDA/SCS/CES Pesticide Properties Database (Wauchope et al., 1991). Additional comments concerning the uncertainty in these flagged data are presented in Wauchope et al. (1990b).

b) Soil Ratings

Soil dissolved loss potentials and soil adsorbed loss potentials are determined from Tables 3.4 and 3.5, respectively. As an example, the soil ratings for a Brookston clay soil will be considered. The soil erodibility (i.e. the Universal Soil Loss Equation (USLE) K factor of the Brookston clay could be determined using the data presented by Shelton et al., (1990). Based on these data the erodibility of a Brookston clay soil would be estimated at 0.029 $t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$. Next, the soils hydrologic grouping would be determined from the soil drainage classification of Ontario soils (Irwin, 1984). Brookston clay has been classified as a hydrologic group D soil.

Using these data, the soil dissolved phase runoff loss potential is determined from the algorithm given in Table 3.4. The algorithm indicates that the Brookston clay soil would be classified as having a high dissolved phase runoff loss potential since it is a hydrologic group D soil.

Table 3.4   Soil dissolved/solution runoff loss potential algorithm (from Goss, 1991).

HIGH: **IF** hydrologic group = C   **OR**   hydrologic group = D
LOW: **IF** hydrologic group = A
INTERMEDIATE: **IF** hydrologic group = B

The soil adsorbed phase runoff loss potential is determined in the algorithm given in Table 3.5. The algorithm indicates that the example Brookston clay soil would have a high adsorbed phase runoff loss potential since it is classified as a hydrologic group D soil and since its erodibility is greater than 0.013 $t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$.

Table 3.5 Soil adsorbed runoff loss potential algorithm (from Goss, 1991)

HIGH: **IF** hydrologic group = C **AND** soil K factor >= 0.028 OR
             IF hydrologic group = D **AND** soil K factor >= 0.013

LOW: **IF** hydrologic group = A **OR**
             IF hydrologic group = B **AND** soil K factor <= 0.013 **OR**

NOTE: The soil erodibility factors given in Goss (1991) are in English/U.S. customary units. A conversion factor of 0.1317 (Foster et al., 1981) was used to convert the soil erodibility values given by Goss (1991) to the SI metric units $t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$, given in Table 3.5.

c) Overall Rating of The Soil/Pesticide Interaction

After the soil and pesticide loss potential ratings are determined (as detailed above), they are combined in two matrices (Tables 3.6 and 3.7) to derive an overall pesticide and soil-specific loss rating for dissolved and adsorbed phase losses, respectively. For the use of atrazine on Brookston clay in this example, the overall dissolved phase loss potential rating from Table 3.6 is 1 and the overall adsorbed phase loss potential rating from Table 3.7 is 2.

Table 3.6   Potential pesticide dissolved loss to runoff screening matrix (from Goss, 1991).

Soil Dissolved-Phase Loss Potential	Pesticide Dissolved-Phase Loss Potential		
	LARGE	MEDIUM	SMALL
HIGH	1	1	2
INTERMEDIATE	1	2	3
LOW	2	3	3

Table 3.7   Potential pesticide adsorbed loss to runoff screening matrix (from Goss, 1991).

Soil Adsorbed-Phase Loss Potential	Pesticide Adsorbed-Phase Loss Potential		
	LARGE	MEDIUM	SMALL
HIGH	1	1	2
INTERMEDIATE	1	2	3
LOW	2	3	3

   Using the procedures outlined above, Table 3.8 of the report has been developed for the loss potential categories for 101 pesticides used in the Great Lakes Basin (Moxley, 1989). The loss potentials in Table 3.8 are given for a range of soil adsorbed and dissolved phase loss potentials. Further work is needed to relate these ratings to specific soils and communicate the ratings to producers, extension personal and those involved in water quality planning.

Table 3.8   Loss potential ratings for pesticides used in the Canadian Great Lakes Basin.

OVERALL PESTICIDE RUNOFF LOSS POTENTIALS[*]

Common name	ADSORBED LOSS POTENTIAL SOIL RATINGS			DISSOLVED LOSS POTENTIAL SOIL RATINGS			COMMENTS
	HIGH	MED[**]	LOW	HIGH	MED	LOW	
1,3-dichloropropene	2	3	3	1	2	3	
dichloropropanes	*	*	*	*	*	*	*
2,4-D acid	2	3	3	1	2	3	
2,4-D dimethylamine salt	2	3	3	1	2	3	
2,4-D esters or oil soluble amines	2	3	3	1	2	3	E
2,4-DB butoxyethyl ester	2	3	3	1	2	3	
2,4-DB dimethylamine salt	2	3	3	1	2	3	E
acephate	2	3	3	1	2	3	
alachlor	2	3	3	1	2	3	
aldicarb	2	3	3	1	2	3	
amitrole	2	3	3	1	2	3	
ammonium thiocyanate	*	*	*	*	*	*	*
anilazine	2	3	3	2	3	3	E
atrazine	1	2	3	1	1	2	
azinphos-methyl	1	2	3	1	2	3	
Bacillus thuringiensis	*	*	*	*	*	*	*
benomyl	1	1	2	1	1	2	
bentazon	2	3	3	1	2	3	
bromoxynil octanoate ester	1	2	3	2	3	3	
bromoxynil pentanoate ester	*	*	*	*	*	*	*
butylate	2	3	3	1	1	2	
captafol	*	*	*	*	*	*	*
captan	2	3	3	1	2	3	
carbaryl	2	3	3	1	2	3	
carbofuran	1	2	3	1	1	2	
chinomethionat	*	*	*	*	*	*	*
chloramben salts	2	3	3	1	2	3	E
chlorfenvinphos	*	*	*	*	*	*	*
chlorimuron ethyl	2	3	3	1	1	2	
chloropicrin	2	3	3	1	2	3	E
chlorothal dimethyl (DCPA)	1	1	2	1	2	3	
chlorothalonil	1	2	3	1	2	3	
chloroxuron	*	*	*	*	*	*	*
chlorpropham	2	3	3	1	1	2	E
chlorpyrifos	1	2	3	2	3	3	
cyanazine	2	3	3	1	2	3	
cyhexatin	*	*	*	*	*	*	*
cypermethrin	1	2	3	2	3	3	E
demeton	*	*	*	*	*	*	*
diazinon	1	1	2	1	1	2	E
dicamba salt	2	3	3	1	2	3	
dichlobenil	1	2	3	1	1	2	E
dichlone	*	*	*	*	*	*	*
diclofop-methyl	1	2	3	1	2	3	
dicofol	1	1	2	2	3	3	G
difenzoquat methlysulfate	1	1	2	1	1	2	
dimethoate	2	3	3	1	2	3	
dinocap	2	3	3	1	2	3	G
dinoseb phenol	2	3	3	1	1	2	
dinoseb salts	2	3	3	1	2	3	
diphenamid	2	3	3	1	2	3	
diquat dibromide salts	1	1	2	2	3	3	E
diuron	1	2	3	1	1	2	
DNOC sodium salt	2	3	3	1	2	3	G
dodine acetate	1	2	3	2	3	3	G

Table 3.8 continued...

OVERALL PESTICIDE RUNOFF LOSS POTENTIALS[+]

	ADSORBED LOSS POTENTIAL SOIL RATINGS			DISSOLVED LOSS POTENTIAL SOIL RATINGS			
Common name	HIGH	MED[++]	LOW	HIGH	MED	LOW	COMMENTS
endosulfan	1	1	2	1	2	3	
EPTC	2	3	3	1	2	3	
ethalfluralin	1	1	2	1	2	3	
ethion	1	1	2	1	1	2	
fenoxaprop-ethyl	1	2	3	1	2	3	
fensulfothion	*	*	*	*	*	*	*
fenvalerate	1	2	3	1	2	3	
ferbam	2	3	3	1	2	3	
fixed copper	*	*	*	*	*	*	*
fluaziflop-p-butyl	1	2	3	1	2	3	
folpet	*	*	*	*	*	*	*
fonofos	2	3	3	1	1	2	
formentate hydrochloride	1	1	2	2	3	3	G
glyphosate amine salt	1	1	2	1	1	2	E
ioxynil	*	*	*	*	*	*	*
iprodione	2	3	3	1	1	2	
linuron	1	2	3	1	1	2	
malathion	2	3	3	2	3	3	
maleic hydrazide	2	3	3	1	2	3	E
mancozeb	1	1	2	1	1	2	
maneb	1	1	2	1	1	2	E
MCPA dimethylamine salt	2	3	3	1	2	3	E
MCPA ester	1	2	3	1	2	3	E
MCPB	2	3	3	1	2	3	E
mecoprop amine salt	2	3	3	1	2	3	E
metam sodium	2	3	3	1	2	3	E
methamidophos	2	3	3	1	2	3	E
methidathion	2	3	3	1	2	3	E
methomyl	2	3	3	1	2	3	
methoxychlor	1	1	2	1	2	3	
methyl isothiocyanate	2	3	3	1	2	3	
metiram	1	2	3	2	3	3	G
metobromuron	*	*	*	*	*	*	*
metolachlor	1	2	3	1	1	2	
metribuzin	2	3	3	1	1	2	E
mevinphos	2	3	3	1	2	3	
monolinuron	*	*	*	*	*	*	*
naled	2	3	3	1	2	3	
napropamide	1	2	3	1	1	2	
naptalam sodium salt	2	3	3	1	2	3	E
oxamyl	2	3	3	1	2	3	
oxydemeton-methyl	2	3	3	1	2	3	
oxyflurofen	1	2	3	2	3	3	E
paraquat dichloride salt	1	1	2	2	3	3	E
parathion (ethyl)	1	2	3	1	2	3	E
pebulate	2	3	3	1	2	3	
permethrin	1	2	3	2	3	3	
phorate	1	1	2	1	1	2	E
phosalone	1	2	3	1	2	3	
phosmet	2	3	3	1	2	3	
primicarb	*	*	*	*	*	*	*
prometryn	1	2	3	1	1	2	
propanil	2	3	3	1	2	3	
propargite	1	1	2	1	2	3	E
sethoxydim	2	3	3	1	2	3	E
simazine	1	2	3	1	1	2	
streptomycin	*	*	*	*	*	*	*
sulfur	*	*	*	*	*	*	*
terbacil	1	2	3	1	1	2	
terbufos	2	3	3	1	2	3	

Table 3.8 continued...

	OVERALL PESTICIDE RUNOFF LOSS POTENTIALS						
	ADSORBED LOSS POTENTIAL SOIL RATINGS			DISSOLVED LOSS POTENTIAL SOIL RATINGS			
Common name	HIGH	MED	LOW	HIGH	MED	LOW	COMMENTS
thiophanate-methyl	1	2	3	1	2	3	G
thiram	2	3	3	1	1	2	
triadimefon	2	3	3	1	1	2	
triallate	1	1	2	1	1	2	
trichlorfon	2	3	3	1	2	3	
trifluralin	1	1	2	1	2	3	
triforine	2	3	3	1	1	2	E
zineb	*	*	*	*	*	*	*

+ - Derived from Tables 3.4 and 3.6 and the procedures outlined in the text.
** - the terminology "MED" is used in place of "Intermediate" in this table.
E - Based on a best estimate for one or more pesticide parameters.
G - Based on a best guess for one or more pesticide parameters.
* - Unrated
NOTE: See next section for interpretations of the overall loss potentials.

Interpreting the Potentials

Although assigning loss potentials to a pesticide/soil combination is fairly straight-forward, interpretation of the potentials is not. Generally, class 1 combinations of pesticide/site have the highest potential for loss, class 2 combinations have the next highest potential for loss and class 3 pesticides have the lowest potential for loss. However, it is extremely important to note that there is uncertainty or fuzziness in class 1 and 2 ratings.

The fuzziness in class 1 and 2 ratings results from the probability that some pesticide/site combinations placed in these categories may in fact have a lower loss potential on some soils. The overall ratings given in the matrices (Tables 3.6 and 3.7) were defined such that, the low loss potential category (class 3) does not contain any occurrences of high or medium losses and also so the medium loss potential category (class 2) does not contain any occurrences of high losses. However the high loss potential category (class 1) may contain occurrences of medium and low losses and the medium loss potential category (class 3) may contain occurrences of low loss potential.

Some guidelines for interpreting the potentials are outlined below (Goss and Wauchope, 1990);

Class 1.   High loss potential -
  a)   use an alternate compound of lower loss potential or
  b)   make a site-specific evaluation to more definitely establish the pesticide's potential
       for loss at that site.

Class 2. Intermediate loss potential-

       a) use alternate compound of lower loss potential or

       b) if the pesticide is foliar applied, incorporated or banded under the soil's surface - downgrade the pesticide loss potentials, calculated in Table 3.1 or 3.3, by 1 rank (i.e. large to medium) and use Tables 3.6 or 3.7 to re-establish the overall potential.

       c) can be downgraded to class 3 if there is a low probability of rainfall.

       d) make a site-specific evaluation to more definitely establish the pesticide's potential for loss at that site.

Class 3. Low loss potential-

       a) Low loss potential - the use of this compound in accordance with the label can be considered as having a low potential for loss.

"Kitchen Table"

"Kitchen Table" (Hornsby and Buttler, 1990) was developed for making assessments of pesticide runoff and leaching losses in order to support decisions regarding pesticide usage and water quality. "Kitchen Table" has been used to develop pesticide "grower guides" to facilitate pesticide selection for 55 crops grown in Florida. This procedure differs from SPISP in two respects: i) pesticide ratings are expressed as numeric indices as opposed to the 3 classes used in SPISP and, ii) toxicological criteria are included. One other consideration in the use of "Kitchen Table" is that the system does not consider the "fuzziness"/uncertainty expressed by SPISP. "Kitchen Table" was designed to be simple and operational. The intent of the procedure is to lead the producer away from the use of pesticides posing the greatest hazard to water quality.

Kitchen Table uses a three level classification for rating the runoff and leaching potentials of soils. The soil ratings are compatible with those outlined by Goss (1988). The algorithm used to calculate the relative runoff potential index (RRPI) and relative leaching potential index (RLPI) are given in Tables 3.9 and 3.10, respectively. The algorithms given in these tables were used in conjunction with pesticide parameter data from Table 3.7 to define the Relative Runoff Potential Index (RRPI) and Relative Leaching Potential Index (RLPI) for over 100 pesticides used in the Canadian Great Lakes Basin (Table 3.11). The RRPI and RLPI and human and aquatic toxicity data are used in conjunction with Table 3.12 to support decisions regarding pesticide selection.

Table 3.9   "Kitchen Table" algorithms for the calculation of Relative Runoff Potential Potential Index (RRPI) (Augustijn-Beckers, 1992).

a) If K_{oc} >= 1000 Then RRPI = 1,000,000 / (K_{oc} X Half-life)

b) If K_{oc} < 1000 Then RRPI = 10 / ((1 / K_{oc}) X Half-life))

Table 3.10   "Kitchen Table" formula for the calculation of Relative Leaching Potential Potential Index (RRPI) (Augustijn-Beckers, 1992).

RLPI = (Koc X 10) / (Half-life)

Table 3.11   "Kitchen Table" Ratings - the Relative Leaching Potential Index (RLPI) and
Relative Runoff Potential Index (RRPI) for pesticides used in the Canadian Great
Lakes Basin.

Common Name	RRPI[1]	RLPI[2]	Comments
1,3-dichloropropene	32	32	
dichloropropanes	*	*	*
2,4-D acid	20	20	
2,4-D dimethylamine salt	20	20	
2,4-D esters or oil soluble amines	100	100	E
2,4-DB butoxyethyl ester	286	714	
2,4-DB dimethylamine salt	20	20	E
acephate	7	7	
alachlor	113	113	
aldicarb	10	10	
amitrole	71	71	
ammonium thiocyanate	*	*	*
anilazine	1000	>2000	E
atrazine	17	17	
azinphos-methyl	100	1000	
Bacillus thuringiensis	*	*	*
benomyl	2	79	
bentazon	17	17	
bromoxynil octanoate ester	14	>2000	
bromoxynil pentanoate ester	*	*	*
butylate	192	308	
captafol	*	*	*
captan	800	800	
carbaryl	300	300	
carbofuran	4	4	
chinomethionat	*	*	*
chloramben salts	11	11	E
chlorfenvinphos	*	*	*
chlorimuron ethyl	28	28	
chloropicrin	620	620	E
chlorothal dimethyl (DCPA)	2	500	
chlorothalonil	24	460	
chloroxuron	*	*	*
chlorpropham	83	133	E
chlorpyrifos	5	>2000	
cyanazine	136	136	
cyhexatin	*	*	*
cypermethrin	1	>2000	E
demeton	*	*	*
diazinon	25	250	E
dicamba salt	1	1	
dichlobenil	42	67	E
dichlone	*	*	*
diclofop-methyl	2	>2000	
dicofol	1	>2000	
difenzoquat methlysulfate	1	>2000	
dimethoate	29	29	
dinocap	91	275	G
dinoseb phenol	100	250	
dinoseb salts	32	32	
diphenamid	70	70	
diquat dibromide salts	1	>2000	E
diuron	23	53	
DNOC sodium salt	10	10	G
dodine acetate	1	>2000	G
endosulfan	2	>2000	
EPTC	333	333	
ethalfluralin	4	667	
ethion	1	667	
fenoxaprop-ethyl	12	>2000	
fensulfothion	*	*	*
fenvalerate	5	1514	
ferbam	176	176	

Table 3.11 continued.....

Common Name	RRPI	RLPI	Comments
fixed copper	*	*	*
fluaziflop-p-butyl	12	>2000	
folpet	*	*	*
fonofos	29	218	
formentate hydrochloride	1	>2000	G
glyphosate amine salt	1	>2000	E
ioxynil	*	*	*
iprodione	102	500	
linuron	42	67	
malathion	556	>2000	
maleic hydrazide	7	7	E
mancozeb	7	286	
maneb	7	286	E
MCPA dimethylamine salt	8	8	E
MCPA ester	40	400	E
MCPB	14	14	E
mecoprop amine salt	10	10	E
metam sodium	14	14	E
methamidophos	8	8	E
methidathion	357	571	E
methomyl	24	24	
methoxychlor	1	>2000	
methyl isothiocyanate	10	10	
metiram	1	>2000	G
metobromuron	*	*	*
metolachlor	22	22	
metribuzin	15	15	E
mevinphos	147	147	
monolinuron	*	*	*
naled	1800	1800	
napropamide	36	57	
naptalam sodium salt	14	14	E
oxamyl	63	63	
oxydemeton-methyl	10	10	
oxyflurofen	1	>2000	E
paraquat dichloride salt	1	>2000	E
parathion (ethyl)	14	>2000	E
pebulate	166	307	
permethrin	1	>2000	
phorate	17	167	E
phosalone	26	857	
phosmet	64	432	
primicarb	*	*	*
prometryn	42	67	
propanil	1490	1490	
propargite	4	714	E
sethoxydim	200	200	E
simazine	22	22	
streptomycin	*	*	*
sulfur	*	*	*
terbacil	5	5	
terbufos	400	1000	
thiophanate-methyl	55	1830	G
thiram	100	447	
triadimefon	115	115	
triallate	5	293	
trichlorfon	10	10	
trifluralin	2	1333	
triforine	88	257	E
zineb	*	*	*

1 - Relative Runoff Potential Index calculated from Table 3.9
2 - Relative Leaching Potential Index calculated from Table 3.10
E - Based on a best estimates for 1 or more pesticide parameter.
G - Based on a best guess for 1 or more pesticide parameter.

Table 3.12   "Kitchen Table" pesticide selection criteria (Buttler et al., 1991)

```
IF SOIL RATINGS
ARE:
                                                    THEN
 RUNOFF      LEACH                        SELECT PESTICIDE WITH:

  LOW        HIGH      Larger RLPI value,          AND    Larger HALEQ value
  LOW        MEDIUM    Larger RLPI value,          AND    Larger HALEQ value
  LOW        LOW       Larger RLPI and RRPI values,  AND  Larger HALEQ and Aquatic Toxicity values
  MEDIUM     HIGH      Larger RLPI and RRPI values,  AND  Larger HALEQ and Aquatic Toxicity values
  MEDIUM     MEDIUM    Larger RLPI and RRPI values,  AND  Larger HALEQ and Aquatic Toxicity values
  MEDIUM     LOW       Larger RRPI value,          AND    Larger Aquatic Toxicity value.
  HIGH       HIGH      Larger RLPI and RRPI values,  AND  Larger HALEQ and Aquatic Toxicity values
  HIGH       MEDIUM    Larger RLPI and RRPI values,  AND  Larger HALEQ and Aquatic Toxicity values
  HIGH       LOW       Larger RRPI value,          AND    Larger Aquatic Toxicity value.

     RRPI - Relative Runoff Potential Index
     RLPI - Relative Leaching Potential Index
     HALEQ - Health Advisory Limit or Equivalent
```

4.0 IMPLICATIONS FOR GREAT LAKES ECOSYSTEM

Implementation

SPISP and Kitchen Table **were not** developed to be regulatory tools. Rather, they are tools intended for use in making preliminary assessments of pesticide contamination potentials and for providing criteria to producers for selecting pesticides with a low potential to contaminate water systems.

One major technical consideration in the implementation of the runoff components of SPISP and "Kitchen Table" in the Great Lakes Basin concerns the reliability of data required by the soil rating procedure. Data needed for the procedure are available from soil drainage classifications, however, McKeague and Topp (1986) and Chisholm (1992) have advised caution in using the Ontario soil drainage classifications (Chisholm et al., 1984; Irwin, 1984).

McKeague and Topp (1986) attempted to verify the classification with field measurements on a number of soil types in Ontario. They noted significant discrepancies between their soil drainage interpretations and those suggested by the drainage classification. They also commented that the drainage classification was not accurate in many cases since it was based mainly on considerations of soil texture. McKeague and Topp (1986) and Chisholm (1992) have suggested that the drainage classification of Ontario could be improved by considering the structural characteristics of the soils.

Clearly, inaccuracies in the soil drainage classification could have an adverse effect on the soil ratings used by SPISP and "Kitchen Table". It is imperative that this technical question be resolved.

Data requirements for the leaching components of SPISP and "Kitchen Table" were not evaluated.

Abatement

Increasing concerns over pesticide contamination of both surface and groundwater systems have lead to the development of a group of abatement methods termed Best Management Practices (BMP). BMPs are defined as practical methods, measures or practices which prevent or reduce the amount of pollution generated by nonpoint sources to levels compatible with water quality goals (Novotny and Chesters, 1981; Logan, 1990).

Logan (1990) outlined 4 general classes of BMPs for the control of agricultural non-point source pollution including; 1) structural controls, 2) land management practices, 3) source controls and, 4) pesticide and nutrient management practices. These 4 approaches represent 2 fundamentally different philosophies (Odum, 1987):

1) **Minimizing the Movement of Pesticides in Surface Runoff** - Structural controls and land management practices are primarily aimed at minimizing the movement of pesticides from fields to bodies of water.

2) **Reducing the Pesticide Usage** - Source controls and pesticide management practices are focused on reducing the usage of pesticides, thereby preempting the possibility of pesticide loss.

Trade-offs

While there are effective approaches for reducing the surface runoff losses of pesticides, the implementation of some practices or measures may involve trade-offs.

For instance, there are indications that practices resulting in increased infiltration rates (such as no-till or terracing) may result in higher pesticide loadings to groundwater (Donigian and Carsel, 1987; Logan, 1990). In addition, although conservation tillage can reduce the total loadings of pesticide in runoff, some studies have indicated that conservation tillage can result in increased pesticide concentrations in runoff (Fawcett, 1992). It has been suggested that concerns over these transient pesticide concentrations may be more relevant than concerns over total loadings (Haith, 1987).

Minimizing Pesticide Movement in Surface Runoff

There have been relatively few studies on the effectiveness of practices specifically designed to reduce non-point sources of pesticide contamination. Many of the approaches which have been proposed, borrow from a group of structural controls and land management practices which were originally associated with reducing the transport of sediment and nutrients into surface waters.

Baker and Johnson (1983) proposed a 3 point approach for the reduction of chemical runoff losses using a number of BMPs:

1) The first point in their approach involves <u>reducing the volume of runoff and sediment</u> through the use of conservation tillage, contouring or tile drainage.

2) The second approach involves <u>reducing the delivery of pesticides from field to stream</u> through the use of structural measures such as terraces, buffer strips and grassed waterways.

3) The third approach for <u>reducing pesticide losses involves reducing the concentrations of chemicals in runoff</u> through chemical incorporation, optimization of pesticide application with respect to environmental conditions which increase the risks of runoff losses, the use of chemicals and formulations less susceptible to runoff losses and reduced rates.

Reducing the Volumes of Runoff and Sediment

a) Tillage

Considerable interest and research has been focused on differences in pesticide losses between soil tillage systems. In particular, it has generally been assumed that conservation tillage systems, which have been widely promoted as practices for reducing runoff volumes, soil erosion and nutrient losses, would also reduce pesticide losses.

In an extensive review of tillage effects on pesticide losses Fawcett et al. (1992) concluded that conservation tillage practices generally result in reduced pesticide losses, except in cases where infiltration is limited by soil type, internal drainage or problems such as compaction. Under these conditions pesticide losses from conservation tillage may exceed or be comparable to losses from conventional tillage systems.

b) Contouring

Contouring is a soil conservation practice applicable to sloping lands. With contouring, tillage and planting operations are carried out perpendicular to the slope of the land as opposed to up-and-down the slope.

c) Tile Drainage

Tile drainage is normally regarded as a crop production tool rather than a measure for improving water quality. However, studies have shown that tile drainage also has the potential to decrease runoff losses of pesticides. Tile drainage lowers surface moisture levels allowing more

storm water to infiltrate, thereby resulting in lower surface runoff volumes. To some extent, reductions in surface runoff losses may be compensated by increased losses of pesticide in tile drainage. The extent to which this occurs is dependant on i) pesticide travel times from the soil's surface to tile drainage and ii) pesticide transformation rates in the soil (Baker and Johnson, 1983).

Reducing the Delivery of Pesticides From Field to Stream

a) Terraces

Terracing involves the construction of a ridge or embankment across a slope to control erosion. Terraces reduce slope lengths and divert or store surface runoff. Excess water is removed by grassed outlets, subsurface drains or by infiltration.

b) Grassed Waterways

Grassed waterways are used to conduct excess surface water from croplands. They are defined as broad and shallow waterways covered in erosion resistant grasses. Grassed waterways improve water quality by retarding the transport of sediment and water from field to stream.

Clearly, grassed waterways are effective measures for reducing the movement of both water and sediment associated pesticides. However, Fawcett et al. (1992) pointed out that the capacity of grassed waterways must also be considered.

c) Buffer Strips

Buffer strips are untreated areas bordering fields or bodies of water. These areas may or may not consist of permanent vegetation or may be planted in densely grown crops such as a forage or small grain.

Reducing the Concentrations of Pesticide in Runoff

a) Incorporation

Incorporation or subsurface application of pesticides reduces chemical concentrations and loadings in surface runoff by decreasing the amounts of chemical initially present in the soil's surface active zone.

b) Optimization

A variety of environmental considerations can increase the magnitude of pesticide loss in runoff including; i) a high antecedent soil moisture at the time of application, ii) a high probability of rainfall/runoff occurring shortly after application and iii) a high seasonal risk of rainfall/runoff following application. Optimization involves making adjustments in application timing such that one or more of these conditions are avoided.

c) Product Selection

Baker and Johnson (1983) suggested that pesticides and formulations less susceptible to losses in surface runoff could be substituted for those with a high potential for loss.

Reducing the Usage of Pesticides

a) Integrated Pest Management (IPM)

Precise definitions of IPM are still vague and a number of interpretations are possible (Higham, 1990). In their simplest form IPM programs are targeted at eliminating unnecessary pesticide usage. This approach is an alternative to prophylactic or calendar-based pesticide applications.

The most advanced forms of IPM use combinations of chemical, mechanical, biological, cultural and varietal controls to manage pest populations.

b) Crop Rotation

Crop rotation is an effective technique for managing some pest problems - it can also reduce the risks of surface water contamination. Fawcett et al. (1992) commented that the greater diversity of crops grown in watersheds managed under crop rotation will result in a greater diversity in the timing and types of pesticides applied.

c) Reducing Recommended Rates

Lowering the recommended application rates of pesticides has the potential to lower the quantities of pesticides applied, thereby decreasing the quantities of pesticide available for transport in runoff.

Currently, recommended rates are based on 80% or better pest control across a broad geographic area, under widely varying climatic conditions and reasonably high infestation levels. Although excellent control has been achieved with lower rates under ideal circumstances, current legislation prohibits recommendations for the use of a pesticide below the labelled rates. Until liability and legal concerns can be resolved relative to this issue, one of the most direct measures for reducing chemical inputs will go unimplemented.

d) Source Controls

Source controls include legislative actions to ban or restrict the use of specific pesticides. Although these measures represent a highly effective means of eliminating the threat of pesticide contamination to both surface and ground waters, it is clear that water quality objectives must be balanced against economic realities. In order to maintain productivity, suitable alternatives must be available to producers. Such alternatives may include substitute compounds and/or non-chemical pest control options.

5.0 GAPS/NEEDS FOR FUTURE RESEARCH

a) Classification

1. Either SPISP or "Kitchen Table" should be implemented to facilitate the assessment of pesticide runoff losses and pesticide selection.

2. Implementation of either classification scheme should include both the leaching and the surface runoff components.

3. Possible inaccuracies in the Ontario soil drainage classification may adversely affect the accuracy of the soil rating schemes used in the pesticide assessment procedures. This potential problem deserves further study. Resolution of this problem would facilitate application of the screening procedures and would also benefit those involved in planning subsurface drainage projects.

4. Further work is needed to implement SPISP:
    i) Human and aquatic-life toxicity data should somehow be incorporated into the screening procedure.
    ii) Provisions should be made for second-tier analysis in order to clarify the ratings of Class 1 and 2 pesticides.

b) Pesticide Movement Abatement

1. Provide producers with criteria for the selection of pesticides with low toxicity and low potential for the contamination of water systems.

2. Increase the level of commitment to integrated pest management programs in order to provide producers with more reduced and non-chemical pest control options.

3. Develop third party or no party liability for pesticide recommendations below current label restrictions.

4. Develop a producer manual outlining standards and specifications for pesticide management and abatement measures.

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