

# An Assessment System for Potential Groundwater Contamination from Agricultural Pesticide Use in North Dakota — Technical Guideline

**Extension Report No. 18**, March 1994  
Bruce Seelig, Water Quality Specialist

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## Introduction

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A groundwater assessment system is proposed to help develop and implement best management practices (BMP) to protect groundwater from pesticide contamination. This system will help producers organize natural resource information into groundwater sensitivity categories. BMP recommendations will be adapted for each groundwater sensitivity category. To determine the groundwater sensitivity of a given area, a guided path, or stepwise algorithm, (Figure 1) is used.

**Figure 1. Stepwise algorithm for determination of ground water sensitivity to pesticides (first order of priority).** (12KB b&w image)

A variety of systems have been developed to determine groundwater vulnerability and/or sensitivity. **Vulnerability** assessment requires physical information about materials that overlie and protect aquifers from contamination (Pettyjohn et. al., 1991). **Sensitivity** assessment includes a measure of human activity above an aquifer in addition to the hydrogeologic factors.

Unfortunately all assessment systems have weaknesses and none of them adequately address the complexity of the natural system. Perhaps the greatest weakness is that assessment schemes are often based on computer simulations and have not been verified for actual field conditions (Wagenet and Rao, 1990). If the user is aware of the basic assumptions and consequent weaknesses in each computer simulation, they can be useful for groundwater assessment. However, extrapolation beyond the boundaries of those assumptions can lead to nonsensical conclusions.

Aspects of several different assessment systems have been utilized to create a system that best fits conditions in North Dakota. It should be noted that the assessment system for North Dakota does not rely on artificial values and weights. Considering our limited understanding of the complexity of natural systems, rating systems often build the illusion of relative importance when in fact there is none. However, some general trends common to most groundwater assessment systems have been incorporated into the North Dakota system. Key factors that determine vulnerability or sensitivity will be assessed to assign each site to a specific category. The categories will emphasize similarities in factors and will represent a rating system only in the broadest sense. Hopefully this will avoid the usual criticisms leveled at the inconsistencies of a rating system, and the credibility problems that follow. Instead, the focus will be on placement in categories that allow logical development of an effective system of management practices that protect groundwater.

## **STEP 1. Aquifers versus groundwater**

The first step requires the user to determine if an aquifer with a useable supply of water exists. We recognize that because there is linkage between all forms of groundwater, protection of all groundwater is desirable. However, in the real world of limited funds, priorities must be set. As identified in the position paper developed by the North Dakota Technical Advisory Committee for the Pesticide/Groundwater Protection Management Plan, water resources that serve human needs are of the highest priority. Emphasis must be placed on protection of readily accessible groundwater or shallow aquifers with useable water.

In North Dakota, aquifers located in glacially derived materials are of greatest value due to their generally good water quality, high yields, and shallow depths. The water must be of such quality that it is useable for human needs. Useable water quality is considered to be Class I groundwater or water having less than 10,000 ppm total dissolved solids, according to the North Dakota State Department of Health. The term shallow has been used to describe vulnerable aquifers with less than 50 feet of material overlaying them, similar to a combination of Pettyjohn et al.'s (1991) Class I and Class II aquifers. Many glacial and alluvial aquifers in North Dakota meet this definition; however, many are deeper than 50 feet. All glacial and alluvial aquifers will be considered as worthy of protection, particularly those shallower than 50 feet.

Those aquifers that supply useable water to a significant number of people must also take on a higher level of importance than those that don't. Glacial or alluvial aquifers with useable water that are extensive enough to be used by significant numbers of people are identified in the groundwater studies report (North Dakota Geological Survey and State Water Commission), for each county in North Dakota.

In general, aquifers located in bedrock in North Dakota have poor quality water, are deep, and have variable yields. Some of these aquifers even exceed the standard of 10,000 ppm. As a whole, these aquifers are not worthy of the same level of protection as glacial aquifers or alluvial aquifers. However, in some parts of the state, particularly the unglaciated southwest, bedrock aquifers are the only source of groundwater. Even though bedrock aquifers underlay extensive areas, water quality and yield is unpredictable. Areas of useable water within each bedrock aquifer are not as readily identifiable compared to glacial and alluvial aquifers. Within the county groundwater studies report, information about bedrock aquifers is quite general and difficult to apply to a specific area. This makes the sensitivity assessment more difficult, because important information about the aquifer is not as easily extracted from the report.

The first step in the assessment process requires the user to locate the extent of the appropriate aquifers. The first order of priority is the determination of glacial or alluvial aquifers under the area of interest. Only in areas of southwestern North Dakota, where bedrock aquifers are the sole source of groundwater, should the assessment be extended to include these aquifers as second order of priority.

## **STEP 2. Pesticide use**

Distribution of land use has been recognized as an important factor in protecting groundwater from agricultural chemicals (Thomas, 1992a). Different types of land use will require different levels of agricultural inputs. Land use is a general indicator of the amount and type of pesticide applied above an aquifer. Pesticide use will be combined with land use in the following land use – pesticide categories: 1) cropland with pesticides; 2) hayland, pastureland, forestland, and rangeland with pesticides; and 3) no pesticides.

For regional assessments, the land use – pesticide category can be determined from a combination of ASCS records and maps, Pesticide Use on Major Crops in North Dakota, North Dakota Agricultural Statistics, and the USDA Agricultural Census. For farm assessments, land use – pesticide categories may be determined from personal knowledge.

## **STEP 3. Filtration potential**

After the location of vulnerable aquifers and pesticide usage over them is assessed, the site properties that affect pesticide movement must be determined. In simple terms, the soil and geologic materials act as a filter to protect aquifers from contamination. That filtering process is often referred to as pesticide "**attenuation**" in scientific parlance. Attenuation can be defined as lessening the amount, force, or value of something. In this case, the amount of pesticide is lessened as it is filtered-out on soil and geologic materials. An estimate of the potential for materials to attenuate or filter-out pesticides will be presented as the "**filtration potential**" for this sensitivity assessment system.

In reality, pesticide attenuation is a complex process that depends not only on the physical and chemical characteristics of the overlaying materials, but also on the physical and chemical characteristics of the pesticide. Analysis of contamination potential of groundwater requires solutions to complex formulas for water and solute transport. It also requires large amounts of many different types of data. Manipulation of large amounts of data within complex formulas has only become possible in recent years due to computers. A growing number of computer programs are now available to help assess contaminant movement within a set of assumed conditions. These programs have been utilized to help predict contamination under various conditions, thereby identifying groundwater sensitivity. Unfortunately, these programs are generally accurate within narrow conditions, and the user must be aware of the basic assumptions used to develop the program before realistic interpretations can be made from the results.

Because monitoring and interpreting data from actual field sites is expensive and time consuming, computer simulations will continue to be used as a tool for assessing vulnerability and sensitivity. Computer simulations must be used with caution, particularly where little field validation has been demonstrated (Thomas, 1992b). Computer simulation studies have identified several factors that are commonly recognized to affect groundwater contamination. These factors will be used in this assessment system to identify categories of groundwater sensitivity; however, computer simulations will not be used in the categorization process.

Depth to the aquifer and vadose zone texture have been recognized as important factors in several groundwater assessment systems (Cates and Madison, 1991; Pettyjohn et al., 1991; Trojan and Perry, 1988; Aller et al. 1985). Goss (1992) determined soil organic matter to be the most important soil characteristic influencing pesticide movement through soils. Brown et al. (1991) recognized permeability and the presence or absence of organic layers as the most important soil factors affecting pesticide leaching in Florida soils. Groundwater vulnerability maps in North Dakota use soil permeability, soil organic matter content, and depth to water table as the most important factors in groundwater vulnerability determination. Cates and Madison (1991) incorporated soil texture and organic matter content into their system for site evaluations for potential groundwater contamination in Wisconsin.

Pesticide properties must also be accounted for when determining groundwater sensitivity. Pesticide half-life ( $T_{1/2}$ ) and organic carbon adsorption coefficient ( $K_{oc}$ ) have been used to rate pesticide potential to leach (Goss, 1992; Hornsby, 1992;).

The assessment of filtration potential of materials overlaying an aquifer will include the following:

1. depth to the saturated aquifer combined with predominant waterflow direction;
2. soil and geologic strata permeability;
3. soil organic matter content;
4. pesticide  $K_{oc}$  and  $T_{1/2}$ .

**Aquifer depth - water flow direction.** Depth to the saturated aquifer can be determined from the county groundwater studies report. Depths less than 50 feet are considered to be shallow. Soils are an excellent indicator of long term water flow direction (Bigler and Richardson, 1984; Arndt and Richardson, 1989; Knuteson et al., 1989; Seelig and Richardson, 1993). Water flow through a soil to the groundwater can be categorized as **recharge** (downward through the soil to groundwater) and **discharge** (upward through the soil from the groundwater). **Flowthrough** is the term used to described lateral movement of groundwater through the soil.

The presence and depth of calcium carbonate (lime) and a water table will be used to assess the long-term hydrologic environment. As the depth of calcium carbonate increases, so does the groundwater recharge potential. For this assessment system, soils of **recharge areas** lack calcium carbonate in the upper 30 inches of the soil profile. Soils of **discharge and flowthrough areas** have calcium carbonate in the surface horizon (usually throughout the soil profile) and will have a water table within 6 feet of the surface. Soils of an **intermediate** hydrologic environment that may be inactive or have a relatively even balance between recharge and discharge will be characterized by a combination of calcium carbonate and water table depths that do not fall in either of the two categories described above. Depth to calcium

carbonate and water table can be determined from a county soil survey report (USDA, Soil Conservation Service). Presence of calcium carbonate in each soil horizon is indicated by effervescence when dilute hydrochloric acid is applied to the soil. This information is available in the soil series descriptions.

Irrigation increases the potential for groundwater recharge. Many factors such as timing of water application, tile drainage, soil texture, and pumping of wells influence groundwater recharge under irrigated fields. Despite these extenuating factors, the hydrologic environment for **irrigated soils** will be considered **recharge**.

A groundwater recharge area overlaying a shallow aquifer constitutes **low potential** for filtration of contaminants from percolating water. All other combinations of groundwater flow and aquifer depth have **high filtration potential**.

**Soil and geologic material permeability.** Soil permeability is closely related to soil texture. Soils in the sandy and sandy skeletal textural families that overlie sand and gravel geologic materials have **low potential** for filtration. Soils in the fine textural family that overlie geologic material finer than sand and gravel have **high potential** for filtration. All other textures or combination of textures will have **intermediate potential** for filtration. Family textural classification of soils can be determined from a county soil survey. Texture of geologic material overlaying the aquifer can be determined from a county groundwater studies report or sometimes from the county soil survey report.

**Organic matter content.** Soil organic matter (o.m.) content has the largest influence on pesticide attenuation compared to the other soil factors. Organic matter content of < 2% in the A horizon (very low to moderately low) will have **low potential** to filter pesticides from percolating water. As o.m. content increases, filtration potential also increases. Soils with > 2% o.m. (moderate to very high) in the A horizon have a **high potential** to filter pesticides from percolating water. Soil organic matter classes are given in the map unit descriptions in most county soil survey reports (Table 1). If this information is not in the county soil survey report, the local SCS office should be contacted.

**Table 1. Soil organic matter content (percent) conversion from soil mapping unit description.**

| organic matter descriptor | organic matter content by weight |
|---------------------------|----------------------------------|
|                           | ( % )                            |
| Very Low                  | < 0.5                            |
| Low                       | 0.5 - 1.0                        |
| Moderately Low            | 1.0 - 2.0                        |
| Moderate                  | 2.0 - 4.0                        |
| High                      | 4.0 - 8.0                        |
| Very High                 | > 8.0                            |

**Pesticide chemistry.** The tendency for a pesticide to move with water through soils is also influenced by its chemistry. This is referred to as leaching potential. It is just the opposite of filtration potential or pesticide tendency to be removed from the water and trapped or filtered by the soil. Hornsby's index for pesticide leaching potential (Table 2) will be utilized because it is a combination of the  $K_{oc}$  and  $T_{1/2}$ . The ratio of  $K_{oc}$  and  $T_{1/2}$  is multiplied by 10 to give a leaching index for each pesticide. The smaller the index, the more likely the pesticide will not be filtered but will leach to the groundwater. A pesticide with an index of 10 or less or  $K_{oc}$  of 100 or less (Hornsby, 1992) would have a **low filtration potential** and high leaching potential. If the index is 2000 or greater (Hornsby, 1992) the pesticide would have a **high filtration potential** and low leaching potential. Pesticides that do not meet these criteria are considered to have both **intermediate filtration potential** and leaching potential. Their Hornsby index is a relative indication of how close they may be to pesticides that are considered leachable.

**Table 2. Pesticide properties and leaching potential (After Wauchope, et. al., 1992)**

| Half-life | Soil Sorption | Hornsby | Leaching |
|-----------|---------------|---------|----------|
|-----------|---------------|---------|----------|

| Pesticide                       | (T1/2) days | (Koc)   | Index  | Potential    |
|---------------------------------|-------------|---------|--------|--------------|
| 1,3-Dichloropropene             | 10          | 32      | 32     | High         |
| 1-Naphthaleneacetamide          | 10          | 100     | 100    | High         |
| 2,4,5-T amine salts             | 24          | 80      | 33     | High         |
| 2,4-D acid                      | 10          | 20      | 20     | High         |
| 2,4-D dimethylamine salt        | 10          | 20      | 20     | High         |
| 2,4-D esters or oil-sol. amines | 10          | 100     | 100    | High         |
| 2,4-DB butoxyethyl ester        | 7           | 500     | 714    | Intermediate |
| 2,4-DB dimethylamine salt       | 10          | 20      | 20     | High         |
| 3-CPA sodium salt               | 10          | 20      | 20     | High         |
| Acephate                        | 3           | 2       | 7      | High         |
| Acifluorfen sodium salt         | 14          | 113     | 81     | Intermediate |
| Alachlor                        | 15          | 170     | 113    | Intermediate |
| Aldicarb                        | 30          | 30      | 10     | High         |
| Aldoxycarb (aldicarb sulfone)   | 20          | 10      | 5      | High         |
| Ametryn                         | 60          | 300     | 50     | Intermediate |
| Amitraz                         | 2           | 1,000   | >2,000 | Low          |
| Amitrole (aminotriazole)        | 14          | 100     | 71     | High         |
| Ancymidol                       | 120         | 120     | 10     | High         |
| Anilazine                       | 1           | 1,000   | >2,000 | Low          |
| Arsenic Acid                    | 10,000      | 100,000 | 100    | Intermediate |
| Asulam sodium salt              | 7           | 40      | 57     | High         |
| Atrazine                        | 60          | 100     | 17     | High         |
| Azinphos-methyl                 | 10          | 1,000   | 1,000  | Intermediate |
| Bendiocarb                      | 5           | 570     | 1,140  | Intermediate |
| Benefin (benfluralin)           | 40          | 9,000   | >2,000 | Low          |
| Benomyl                         | 67          | 1,900   | 283    | Intermediate |
| Bensulfuron methyl              | 5           | 370     | 740    | Intermediate |
| Bensulide                       | 120         | 1,000   | 83     | Intermediate |
| Bentazon sodium salt            | 20          | 34      | 17     | High         |
| Bifenox                         | 7           | 10,000  | >2,000 | Low          |
| Bienthrin                       | 26          | 240,000 | >2,000 | Low          |
| Bromacil acid                   | 60          | 32      | 5      | High         |
| Bromacil lithium salt           | 60          | 32      | 5      | High         |
| Bromoxynil butyrate ester       | 7           | 1,079   | 1,541  | Intermediate |
| Bromoxynil octanoate ester      | 7           | 10,000  | >2,000 | Low          |
| Butylate                        | 13          | 400     | 308    | Intermediate |
| Captan                          | 2.5         | 200     | 800    | Intermediate |
| Carbaryl                        | 10          | 300     | 300    | Intermediate |
| Carbofuran                      | 50          | 22      | 4      | High         |
| Carboxin                        | 3           | 260     | 867    | Intermediate |
| Chloramben salts                | 14          | 15      | 11     | High         |
| Chlordimeform hydrochloride     | 60          | 100,000 | >2,000 | Low          |
| Chlorimuron ethyl               | 40          | 110     | 28     | Intermediate |
| Chlorobenzilate                 | 20          | 2,000   | 1,000  | Intermediate |
| Chlorね neb                      | 130         | 1,650   | 127    | Intermediate |
| Chloropicrin                    | 1           | 62      | 620    | Intermediate |
| Chlorothalonil                  | 30          | 1,380   | 460    | Intermediate |
| Chloroxuron                     | 60          | 3,000   | 500    | Intermediate |
| Chlorpropham (CIPC)             | 30          | 400     | 133    | Intermediate |
| Chlorpyrifos                    | 30          | 6,070   | 202    | Intermediate |
| Chlorsulfuron                   | 40          | 40      | 10     | High         |
| Clomazone (dimethazone)         | 24          | 300     | 125    | Intermediate |
| Clopyralid amine salt           | 40          | 6       | 2      | High         |
| Cyanazine                       | 14          | 190     | 136    | Intermediate |
| Cycloate                        | 30          | 430     | 143    | Intermediate |

|                                   |       |           |        |              |
|-----------------------------------|-------|-----------|--------|--------------|
| Cyfluthrin                        | 30    | 100,000   | >2,000 | Low          |
| Cypermethrin                      | 30    | 100,000   | >2,000 | Low          |
| Cyromazine                        | 150   | 200       | 13     | Intermediate |
| Dalapon sodium salt               | 30    | 1         | <1     | High         |
| DBCP                              | 180   | 70        | 4      | High         |
| -----                             |       |           |        |              |
| DCNA (dicloran)                   | 60    | 1,000     | 167    | Intermediate |
| DPCA<br>(chlorthal-dimethyl)      | 100   | 5,000     | 500    | Intermediate |
| Desmedipham                       | 30    | 1,500     | 500    | Intermediate |
| Diazinon                          | 40    | 1,000     | 250    | Intermediate |
| Dicamba salt                      | 14    | 2         | 1      | High         |
| -----                             |       |           |        |              |
| Dichlobenil                       | 60    | 400       | 67     | Intermediate |
| Dichlorprop (2,4-DP)<br>ester     | 10    | 1,000     | 1,000  | Intermediate |
| Diclofop-methyl                   | 30    | 16,000    | >2,000 | Low          |
| Dicofol                           | 45    | 5,000     | 1,110  | Intermediate |
| Dicofol                           | 45    | 5,000     | 1,110  | Intermediate |
| Dicrotofos                        | 20    | 75        | 38     | High         |
| -----                             |       |           |        |              |
| Diethyltethyl                     | 30    | 1,400     | 467    | Intermediate |
| Difenoquat<br>methylsulfate salt  | 100   | 54,500    | >2,000 | Low          |
| Diflubenzuron                     | 10    | 10,000    | >2,000 | Low          |
| Dimethipin                        | 120   | 10        | 1      | High         |
| Dimethoate                        | 7     | 20        | 29     | High         |
| -----                             |       |           |        |              |
| Dinocap                           | 5     | 550       | 1,100  | Intermediate |
| Dinoseb phenol                    | 20    | 500       | 250    | Intermediate |
| Dinoseb salts                     | 20    | 63        | 32     | High         |
| Diphenamid                        | 30    | 210       | 70     | Intermediate |
| Dipropetryn                       | 100   | 900       | 90     | Intermediate |
| -----                             |       |           |        |              |
| Diquat dibromide salt             | 1,000 | 1,000,000 | >2,000 | Low          |
| Disulfoton                        | 30    | 600       | 200    | Intermediate |
| Diuron                            | 90    | 480       | 53     | Intermediate |
| DNOC sodium salt                  | 20    | 20        | 10     | High         |
| Dodine acetate                    | 20    | 100,000   | >2,000 | Low          |
| -----                             |       |           |        |              |
| Endosulfan                        | 50    | 12,400    | >2,000 | Low          |
| Endothall (endothal)<br>salt      | 7     | 20        | 29     | High         |
| EPTC                              | 6     | 200       | 333    | Intermediate |
| Esfenvalerate                     | 35    | 5,300     | 1,510  | Intermediate |
| Ethalfluralin                     | 60    | 4,000     | 667    | Intermediate |
| -----                             |       |           |        |              |
| Ethephon                          | 10    | 100,000   | >2,000 | Low          |
| Ethion                            | 150   | 10,000    | 667    | Intermediate |
| Ethofumesate                      | 30    | 340       | 113    | Intermediate |
| Ethoprop (ethoprophos)            | 25    | 70        | 28     | High         |
| Etridiazole                       | 103   | 1,000     | 97     | Intermediate |
| -----                             |       |           |        |              |
| Fenac (chlorfenac) salt           | 180   | 20        | 90     | High         |
| Fenamiphos                        | 50    | 100       | 20     | High         |
| Fenarimol                         | 360   | 600       | 17     | Intermediate |
| Fenbutatin oxide                  | 90    | 2,300     | 256    | Intermediate |
| Fenoxyprop-ethyl                  | 9     | 9,490     | >2,000 | Low          |
| -----                             |       |           |        |              |
| Fenoxy carb                       | 1     | 1,000     | >2,000 | Low          |
| Fenthion                          | 34    | 1,500     | 441    | Intermediate |
| Fenvalerate                       | 35    | 5,300     | 1,510  | Intermediate |
| Ferbam                            | 17    | 300       | 176    | Intermediate |
| Fluazifop-p-butyl                 | 15    | 5,700     | >2,000 | Low          |
| -----                             |       |           |        |              |
| Flucythrinate                     | 21    | 100,000   | >2,000 | Low          |
| Flumetralin                       | 20    | 10,000    | >2,000 | Low          |
| Fluometuron                       | 85    | 100       | 12     | High         |
| Fluridone                         | 21    | 1,000     | 476    | Intermediate |
| Fluvalinate                       | 7     | 1,000,000 | >2,000 | Low          |
| -----                             |       |           |        |              |
| Fomesafen sodium salt             | 100   | 60        | 6      | High         |
| Fonofos                           | 40    | 870       | 218    | Intermediate |
| Formetanate<br>hydrochloride salt | 100   | 1,000,000 | >2,000 | Low          |

|                                       |       |           |        |              |
|---------------------------------------|-------|-----------|--------|--------------|
| Fosamine ammonium<br>salt             | 8     | 150       | 188    | Intermediate |
| Fosetyl-aluminum                      | 0.1   | 20        | 2,000  | Low          |
| <hr/>                                 |       |           |        |              |
| Glufosinate ammonium<br>salt          | 7     | 100       | 143    | High         |
| Glyphosate<br>isopropylamine salt     | 47    | 24,000    | >2,000 | Low          |
| Hexazinone                            | 90    | 54        | 6      | High         |
| Hexythiazox                           | 30    | 6,200     | >2,000 | Low          |
| Hydramethylnon<br>(amdro)             | 10    | 730,000   | >2,000 | Low          |
| <hr/>                                 |       |           |        |              |
| Imazamethabenz-<br>methyl (m-isomer)  | 45    | 66        | 15     | High         |
| Imazamethabenz-<br>methyl (p-isomer)  | 45    | 35        | 8      | High         |
| Imazapyr acid                         | 90    | 100       | 11     | High         |
| Imazapyr<br>isopropylamine salt       | 90    | 100       | 11     | High         |
| Imazaquin ammonium<br>salt            | 60    | 20        | 33     | High         |
| <hr/>                                 |       |           |        |              |
| Imazethapyr                           | 90    | 10        | 1      | High         |
| Iprodione                             | 14    | 700       | 50     | Intermediate |
| Isazofos                              | 34    | 100       | 29     | High         |
| Isofenphos                            | 150   | 600       | 40     | Intermediate |
| Isopropalin                           | 100   | 10,000    | 1,000  | Intermediate |
| <hr/>                                 |       |           |        |              |
| Lactofen                              | 3     | 10,000    | >2,000 | Low          |
| Lambda-cyhalothrin                    | 30    | 180,000   | >2,000 | Low          |
| Lindane                               | 400   | 1,100     | 28     | Intermediate |
| Linuron                               | 60    | 400       | 67     | Intermediate |
| Malathion                             | 1     | 1,800     | >2,000 | Low          |
| <hr/>                                 |       |           |        |              |
| Maleic hydrazide<br>potassium salt    | 30    | 20        | 15     | High         |
| Mancozeb                              | 70    | >2,000    | >286   | Intermediate |
| Maneb                                 | 70    | >2,000    | >286   | Intermediate |
| MCPA dimethylamine<br>salt            | 25    | 20        | 8      | High         |
| MCPA ester                            | 25    | 1,000     | 400    | Intermediate |
| <hr/>                                 |       |           |        |              |
| MCPB sodium salt                      | 14    | 20        | 7      | High         |
| Mecoprop (MCPP)<br>dimethylamine salt | 21    | 20        | 9      | High         |
| Mepiquat chloride salt                | 1,000 | 1,000,000 | >2,000 | Low          |
| Metalaxyll                            | 70    | 50        | 7      | High         |
| Metaldehyde                           | 10    | 240       | 240    | Intermediate |
| <hr/>                                 |       |           |        |              |
| Metham (metam)<br>sodium salt         | 7     | 10        | 14     | High         |
| Methamidophos                         | 6     | 5         | 12     | High         |
| Methanearsonic acid<br>sodium salt    | 1,000 | 100,000   | 1,000  | Intermediate |
| Methazole                             | 14    | 3,000     | >2,000 | Low          |
| Methidathion                          | 7     | 400       | 570    | Intermediate |
| <hr/>                                 |       |           |        |              |
| Methicarb<br>(mercaptodimethur)       | 30    | 300       | 100    | Intermediate |
| Methomyl                              | 30    | 72        | 24     | High         |
| Methoxychlor                          | 120   | 80,000    | >2,000 | Low          |
| Methyl bromide                        | 55    | 22        | 4      | High         |
| Methyl isothiocyanate                 | 7     | 6         | 9      | High         |
| <hr/>                                 |       |           |        |              |
| Methyl parathion                      | 5     | 5,100     | >2,000 | Low          |
| Metiram                               | 20    | 500,000   | >2,000 | Low          |
| Metolachlor                           | 90    | 200       | 22     | Intermediate |
| Metribuzin                            | 40    | 60        | 15     | High         |
| Metsulfuron-methyl                    | 30    | 35        | 12     | High         |
| <hr/>                                 |       |           |        |              |
| Mevinphos                             | 3     | 44        | 15     | High         |
| Molinate                              | 21    | 190       | 90     | Intermediate |
| Monocrotophos                         | 30    | 1         | <1     | High         |
| NAA ethyl ester                       | 10    | 300       | 300    | Intermediate |

| NAA sodium salt                    | 10    | 20        | 20     | High         |
|------------------------------------|-------|-----------|--------|--------------|
| Naled                              | 1     | 180       | 1,800  | Intermediate |
| Napropamide                        | 70    | 700       | 100    | Intermediate |
| Naptalam sodium salt               | 14    | 20        | 14     | High         |
| Nitrapyrin                         | 10    | 570       | 570    | Intermediate |
| Norflurazon                        | 30    | 700       | 233    | Intermediate |
| Oryzalin                           | 20    | 600       | 300    | Intermediate |
| Oxadiazon                          | 60    | 3,200     | 1,600  | Intermediate |
| Oxamyl                             | 4     | 25        | 62     | High         |
| Oxycarboxin                        | 20    | 95        | 48     | High         |
| Oxydemeton-methyl                  | 10    | 10        | 10     | High         |
| Oxyfluorfen                        | 35    | 100,000   | >2,000 | Low          |
| Oxythioquinox<br>(quinomethionate) | 30    | 2,300     | 767    | Intermediate |
| Paraquat dichloride<br>salt        | 1,000 | 1,000,000 | >2,000 | Low          |
| Parathion<br>(ethyl parathion)     | 14    | 5,000     | >2,000 | Low          |
| PCNB                               | 21    | 5,000     | >2,000 | Low          |
| Pebulate                           | 14    | 430       | 307    | Intermediate |
| Pendimethalin                      | 90    | 5,000     | 556    | Intermediate |
| Permethrin                         | 30    | 100,000   | >2,000 | Low          |
| Petroleum oil                      | 10    | 1,000     | 1,000  | Intermediate |
| Phenmedipham                       | 30    | 2,400     | 800    | Intermediate |
| Phorate                            | 60    | 1,000     | 167    | Intermediate |
| Phosalone                          | 21    | 1,800     | 857    | Intermediate |
| Phosmet                            | 19    | 820       | 432    | Intermediate |
| Phosphamidon                       | 17    | 7         | 4      | High         |
| Picloram salt                      | 90    | 16        | 2      | High         |
| Piperalin                          | 30    | 5,000     | 167    | Intermediate |
| Pirimiphos-methyl                  | 10    | 1,000     | 1,000  | Intermediate |
| Prochloraz                         | 120   | 500       | 42     | Intermediate |
| Profenofos                         | 8     | 2,000     | >2,000 | Low          |
| Prometon                           | 500   | 150       | 3      | High         |
| Prometryn                          | 60    | 400       | 67     | Intermediate |
| Pronamide<br>(propyzamide)         | 60    | 800       | 133    | Intermediate |
| Propachlor                         | 6.3   | 80        | 127    | Intermediate |
| Propamocarb                        | 30    | 1,000,000 | >2,000 | Low          |
| Propanil                           | 1     | 149       | 1,490  | Intermediate |
| Propargite                         | 56    | 4,000     | 714    | Intermediate |
| Propazine                          | 135   | 154       | 11     | Intermediate |
| Propham (IPC)                      | 10    | 200       | 200    | Intermediate |
| Propiconazole                      | 110   | 650       | 59     | Intermediate |
| Propoxur                           | 30    | 30        | 10     | High         |
| Pyrazon (chloridazon)              | 21    | 120       | 57     | Intermediate |
| Quizalofop-ethyl                   | 60    | 510       | 85     | Intermediate |
| Sethoxydim                         | 5     | 100       | 200    | Intermediate |
| Siduron                            | 90    | 420       | 47     | Intermediate |
| Simazine                           | 60    | 130       | 22     | Intermediate |
| Sulfometuron-methyl                | 20    | 78        | 39     | High         |
| Sulprofos                          | 140   | 12,000    | 857    | Intermediate |
| Tebuthiuron                        | 360   | 80        | 2      | High         |
| Temephos                           | 30    | 100,000   | >2,000 | Low          |
| Terbacil                           | 120   | 55        | 5      | High         |
| Terbufos                           | 5     | 500       | 1,000  | Intermediate |
| Terbutryn                          | 42    | 2,000     | 476    | Intermediate |
| Thiabendazole                      | 403   | 2,500     | 62     | Intermediate |
| Thidiazuron                        | 10    | 110       | 110    | Intermediate |
| Thifensulfuron-methyl              | 12    | 45        | 38     | High         |
| Thiobencarb                        | 21    | 900       | 429    | Intermediate |
| Thiodicarb                         | 7     | 350       | 500    | Intermediate |
| Thiophanate-methyl                 | 10    | 1,830     | 1,830  | Intermediate |

|                        |    |         |        |              |
|------------------------|----|---------|--------|--------------|
| Thiram                 | 15 | 670     | 447    | Intermediate |
| Toxaphene              | 9  | 100,000 | >2,000 | Low          |
| Tralomethrin           | 27 | 100,000 | >2,000 | Low          |
| Triadimefon            | 26 | 300     | 115    | Intermediate |
| Triallate              | 82 | 2,400   | 293    | Intermediate |
| Tribufos               | 10 | 5,000   | >2,000 | Low          |
| Trichlorfon            | 10 | 10      | 10     | High         |
| Triclopyr amine salt   | 46 | 20      | 4      | High         |
| Triclopyr ester        | 46 | 780     | 170    | Intermediate |
| Tridiphane             | 28 | 5,600   | 2,000  | Low          |
| Trifluralin            | 60 | 8,000   | 1,330  | Intermediate |
| Triforine              | 21 | 200     | 95     | Intermediate |
| Trimethacarb           | 20 | 400     | 200    | Intermediate |
| Triphenyltin hydroxide | 75 | 23,000  | >2,000 | Low          |
| Vernolate              | 12 | 260     | 217    | Intermediate |

\* These values are based on results of field and laboratory measurements found in the literature. References for T1/2 and Koc values and footnotes regarding factors that influence interpretation of these values is presented in Wauchope et.al. (1992). The complex interaction of site factors such as soil water content, temperature, pH, and application procedures make precise extrapolation of results beyond each study site impossible. Nevertheless, T1/2 and Koc have been demonstrated to directly affect the environmental fate of most pesticides. The values expressed in this table should be interpreted only in a broad and relative sense.

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North Dakota State University Agriculture and University Extension  
NDSU Dept. 7070, P.O. Box 6050, Fargo, ND 58108-6050