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Aquatic Vegetation Management and Control

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There is an ever increasing demand upon water resources for recreational, agricultural, industrial, and numerous other purposes.

Water areas, like land areas, support plant life. The kinds and amounts of plants vary within the different aquatic environments of streams, rivers, lakes, ponds, marshes, and other wetlands. Aquatic plants can be the dominant visible feature of some water areas. In other cases, they may occupy only the water margin, grow out of sight beneath the water surface, or grow as minute organisms suspended in the water. Aquatic plants belong to two groups—vascular plants and algae.

The planned uses for a body of water determine, to a large extent, the need for management or control of aquatic plants. A given body of water may be used for irrigation, fishing, boating, swimming, water skiing, or water fowl hunting. Plant control may be required to meet the objectives of domestic, industrial, recreational, or agricultural consumption of water.

Many of the plants may be pests in some situations and desirable in others. The category into which they are placed depends upon:

- Their abundance
- The use of the waters which they inhabit
- Personal values of people using or living near the water

The information in this publication applies to control of plants in:

- Recreational waters used for fishing, boating, and aquatic sports
- Agricultural reservoirs and water distribution channels used for stock watering, irrigation, and drainage
- Ornamental ponds
- Coastal bays, estuaries, and channels
- Drinking water reservoirs
- Ditchbanks

CATEGORIES OF AQUATIC WEEDS

The first step toward prevention or control of aquatic weeds is to correctly identify them. Most control methods are aimed at specific plants or groups of plants with similar growth habits. Usually aquatic weeds are separated into four broad categories based on their life form. These are algae and emersed, submersed, and floating vascular plants.

Algae

Algae are the simplest plants in structure and organization as well as the most primitive. They are the most common and most uniformly distributed of all aquatic plants. The waters of the United States contain many species. Algae are simple aggregates of cells capable of carrying out all life processes without specialized tissue such as leaves, roots, or stems. They vary from microscopic forms to long, stringy mats. Under conditions of high nitrogen and phosphorus levels and during hot, calm, sunny weather, algae multiply rapidly and may accumulate in large masses. Algae reproduce by spores, cell division, and/or fragmentation. They are divided into two groups.

Filamentous algae consist of long, stringy hair-like filaments that form mats or "pond scums" during summer which can be seen without the aid of a microscope. Others may form a green, fur-like coating on stones and other bottom objects. In early spring they grow on the bottom and rise to the surface during hot, calm, sunny weather. Stonewart algae or muskgrass, because of their size, growth, and attachment to the pond bottom, may be mistaken for vascular plants. Examples are chara and nitella. Chara has a strong, musty odor, and is sometimes encrusted with calcium deposits which give it a rough, gritty texture.

These plants consist of an erect central main stem from which clusters of branches arise at various intervals. They generally grow as tall as 2 or 3 feet, and can completely cover a pond or lake bottom.

Plankton algae are commonly single cell or small colonial groups, free-floating, and either green, blue-green, or brown. In large numbers, plankton algae may color the water brown, yellow, pea soup green, or even red during the warm seasons. When this occurs, the lake or pond is said to be "blooming." These blooms may indirectly provide the food for fish, but they may also make water undesirable for swimming or fishing, or for use as a domestic water supply. Each ounce of water in this condition contains millions of microscopic algae cells. Upon death, they may release foul odors and tastes to the water and, in some species, toxins capable of poisoning livestock. Complete chemical treatment for "water blooms" is not normally desirable or feasible. Treatment would be expensive and would only be effective for a few days. Serious oxygen depletion from sudden death of the "bloom" could cause extensive kills of fish.

Vascular Plants

Vascular plants are more complex in structure and organization with specialized tissues such as roots, leaves, stems, and flowers. There are annuals and perennials; many flower and produce seed; others propagate asexually (tubers, winter buds, turions, and fragments).

Emersed plants are rooted or anchored in the substratum with most of the leaf-stem tissue above the water surface and not lowering or rising with changes in the water level. Most plants are perennial with creeping rootstocks. The foliage is aerial. Examples are cattails, tules, and yellow waterlilies.

Submersed plants are adapted to grow with all or most of their vegetative tissue below the water surface. They are usually rooted in the bottom soils. Examples of submersed plants are pondweeds, coontail, elodea, and milfoil.

Floating plants are either free floating or anchored to the bottom and produce most of their leaf-stem tissue or thalli at or above the water surface. Leaves or thalli of floating plants rise or lower with the water level. Examples of floating plants are the duckweeds, azolla, white waterlily, and water hyacinth.

The following basics must be considered in evaluating control methods. Floating and submersed plants can interfere with swimming or boating. In fact, dense plant growth can make swimming hazardous. Rooted emergent shoreline plants may make it difficult to launch boats and may limit the usefulness of beach areas. Good examples are reed canarygrass and cattails. Dense vegetation also interferes with fish propagation, hatchery operations, and fishery management. Aquatic plants may give water an off-flavor or fishy odor and make it unfit for drinking without treatment.

Free-floating aquatic vegetation and fragments of submersed plants often clog irrigation pipes and nozzles. In irrigation systems, aquatic plants reduce water-flow rates, increase evaporation and seepage rates, and increase the danger of breaks in canals because the water level is increased to maintain the water flow. Some aquatic plants may restrict industrial and agricultural withdrawals of water.

On the other hand, aquatic plants may be desirable for special purposes. Certain plants and their seeds are useful as cover and food to attract waterfowl for fall hunting. If fishing is a major interest, a limited number of aquatic plants, both floating and submerged, may be desirable. They provide fish with cover, food, and a spawning site. But when plants are over-abundant, they interfere with fish life and fishing.

It becomes apparent that the desirability of aquatic plants depends on the point of view of the water user. Reservoir managers and swimmers want clean, clear water that is free of vascular plants, algae, and other organisms. Waterfowl hunters want an abundance of aquatic plants that attract ducks and geese. Anglers prefer to see lily pads, plant beds, and plankton that nurture fish and the organisms they feed upon but only if they do not become widespread and spoil the fishing. Conservationists strive for suitable plant cover on watersheds and banks of streams, lakes, and ponds to control erosion and to protect water quality. Irrigators want clean, free-flowing water. It is clear that the owner or manager of a body of water should be knowledgeable about aquatic plants so the individual can choose procedures to meet management objectives. The application of science to management of water areas and aquatic environments offers the best solution to meeting the diverse interests of all water users.

CONTRIBUTION OF PLANTS TO THE AQUATIC ENVIRONMENT

Energy

Aquatic plants, like all other green plants, use energy from the sun to manufacture carbohydrates. Part of the energy obtained is essential for plant growth. Excess energy is stored as carbohydrates, oil, and other products. This stored energy supports most other organisms in aquatic environments. Submerged aquatic plants and algae contribute to the water environment by taking in carbon dioxide and releasing oxygen during photosynthesis.

Food Chain

Algae and flowering plants form the base of the food pyramid, or the first link in the food chain. These plants, called producers, support the aquatic animal population, termed the consumers. Organisms that feed directly on these plants are called primary consumers. Part of the energy transferred to the consumer through food is used in the growth of the consumer, and the excess is stored. The primary consumer is eaten in turn by a secondary consumer, and so forth as the cycle of energy utilization and storage is repeated up the food pyramid. As the food pyramid becomes taller, or the food chain longer, fewer individual organisms can be supported.

The stems and leaves of submersed parts of vascular plants serve as host for a whole community of microscopic organisms, all of which contribute to the food chain in a pond or lake. Bacteria, fungi, algae, diatoms, protozoans, insect larvae, thread worms, bristle worms, rotifers, and small crustaceans are the principal members of the community of organisms that live on and around the larger plants. The population of this community is spread over all leaf and stem surfaces. Increasing in numbers until the end of the summer, this microscopic community provides support for the larger organisms, including fish.

Animal Habitat

The underwater plants contribute in another way to the ecological structure of the total pond or lake community. Many of the free swimming creatures, such as fish and amphibians, use plant beds as places to deposit eggs. The young of many fish use these beds for shelter from predators, or they seek the plants as a feeding area since a rich supply of food organisms is usually available there.

The game fish that fishermen seek are at the top of the food pyramid and, thus, the presence of green plants, especially plankton algae, are important to the success of this sport.

Pondweeds, arrowhead, bulrushes, and reeds are important foods for wildlife. The snapping turtle's diet consists of 90% vegetable matter; plants make up two-thirds of the food for the smaller painted turtle. Muskrats eat the rootstocks, tubers, and stems of emergent plants, including cattails, arrowheads, bulrushes, and waterlilies. They also use aquatic plants for building their houses and lining their dens. Aquatic plants are important food sources for waterfowl, upland game birds, and shore birds.

Eutrophication

In the course of extended time, a pond or a lake will fill with decayed plant matter, etc., and beome dry land. The deeper the lake the longer the time required to fill. This filling process is aided by the growth of aquatic plants in many ways. The continued cycle of plant growth and decomposition creates a slow buildup of organic matter in the basin. Plants also retard the flow of water and thereby cause suspended material to settle to the bottom. As the filling progresses, plants of the shallower zones become established in the former deeper zones. Most bogs and swamps are lakes that are being filled by these processes.

Water Pollution

Pollution associated with aquatic plant growth may be of two types—pollutants that *inhibit* growth and those that *stimulate* growth. Although both forms can be serious, this discussion is centered around the growth-stimulating pollutants.

Chemicals that stimulate growth are primarily nitrogen and phosphorus compounds that discharge from sewage plant effluents, home waste disposal systems, food producing plants, and well-fertilized agricultural watersheds. These nutrient materials stimulate profuse growth of both algae and vascular aquatic plants.

Depending on conditions, a polluted pond or lake may be either excessively turbid and scum-coated or clear and choked with plants. Either condition indicates water of relatively high fertility and optimum conditions for plant growth. Sewage treatment or disposal systems that meet governmental requirements may not circumvent the problem of increased fertility; nitrates and phosphates remaining in treated sewage stimulate plant growth in receiving waters.

Fish Kills

Dense aquatic plant growth may deplete oxygen and subsequently kill fish. Warm, calm, and cloudy weather in summer and thick, opaque, or snow-covered ice in winter contribute to this hazard. Under these conditions, plants do not photosynthesize and produce oxygen. Instead, they consume oxygen through respiration, and some die and decompose. Toxic substances may be released into the water during decomposition of algae, especially the blue-green algae.

Organic decomposition occurring throughout the year makes continuous demand upon available oxygen. If oxygen is not continuously added to the water through wave action, inflowing water, or photosynthesis, oxygen levels may be reduced to the extent that they are inadequate for survival of fish and many of their food organisms.

Also, in deep lakes the water below the photic zone may have a very low level of oxygen. When the lake turns over or breathes (moving of the bottom water and mixing with the water in the upper layers over a short time period in response to seasonal temperature changes), fish may be distressed or killed because of the subsequent low oxygen levels in the upper layers.

MANAGEMENT AND CONTROL

Wise management of water is necessary if control of aquatic vegetation is to be more than temporary. Management must begin with an evaluation of all uses of a given body of water. Chemical, biological, and physical factors should be manipulated as much as possible to obtain the maximum utilization of the water for benefit of the greatest number of people.

Management: Construction of Ponds, Reservoirs, Ditches, etc.

Proper design and construction of ponds and ditches are important factors in preventative control of aquatic plants. Shallow water at the margins of ponds and ditches provides an ideal habitat for emersed plants, such as cattail. Submersed plants can easily become established there and then spread into deeper waters. Steep banks with a 1:1 to 1:1.5 slope until water depth is at least 3 feet will help to prevent establishment of many emergent and bank weeds. However, steep sides may create other problems. If small children frequent a pond, steep sides would definitely be a safety hazard. Remove fertile topsoil from the pond or reservoir basin before filling. If a beach area for swimming and other recreational purposes is desired, remove the fertile topsoil and replace with sand. If possible, prevent waters heavily laden with silt and nutrients from entering an impoundment.

Construction of ponds, lakes, canals, and ditches so they can be drained is an effective means of controlling aquatic plants. The water levels in some large lakes and reservoirs may be lowered enough to expose plants in the shallow areas. Freezing or drying periods of several months may be necessary to control plants in some ponds and lakes. In most canals, it is not practical to interrupt water flow during the summer months when aquatic plants make their most rapid growth. The species of plants and the seasonal growing period will generally determine whether this method is practical or not. An overriding factor on lowering reservoirs or drying up ponds will be the presence of a fish population along with their spawning habitats.

If grass is planted on ditchbanks, 2,4-D can be applied to keep out most undesirable broadleaf plants. East of the Cascade Mountains, redtop or other low-growing, adapted grasses should be seeded at the waterline and crested wheatgrass on the shoulders and top of the ditchbank. Provide roadways on both ditchbanks for weed control and other operations.

Mechanical Control

Physical removal is effective for small quantities of plants near shorelines. The techniques consist of cutting, mowing, raking, digging, or pulling. In small ponds or lakes, emergent plants such as sedges, cattails, and rushes can be mowed, pulled by hand, or dug with a hoe.

Chaining may be practical in some instances, particularly in canals. Draglines are useful for deepening and cleaning canals and margins of lakes and ponds. Underwater mowers are used in both lakes and canals for cutting plants.

Certain problems are associated with the above methods. Pulling or cutting usually must be repeated several times to eliminate new growth as it appears. Single cutting treatments usually are not effective because most submersed and emergent vegtation is perennial and the underground portion of the plants is unharmed by such a treatment. Attempts to remove submerged plants by cutting or dragging a chain or cable over the bottom are not effective. Actually, this practice may spread the infestation because the plants can regenerate from plant fragments. Also, plant fragments and other debris dislodged by such devices plug irrigation sprinklers, pumps, etc. Mechanical control may be slower and more costly than other methods of control.

Burning ditchbank weeds may increase the flow of water in a ditch and help prevent seed from infesting new land. Sear green vegetation the first time and then thoroughly burn 7 to 10 days later. Control by burning is also only temporary.

Biological Control

Biological control employs plant or animal agents to eliminate or reduce growth of vegetation or to alter the habitat to favorably change the type of plant growth. Insects, mites, snails, pathogenic microorganisms, fish, ducks, geese, manatees, and competitive plants have been tried for biological control of aquatic weeds. Biological control is not new, but practical and safe means of controlling aquatic plants by these methods are extremely limited.

Muskrats may cut considerable quantities of plants, but in doing so they leave fragments that may act as sources for plant propagation. Domestic waterfowl may feed on certain floating and submerged plants; however, the fertility resulting from their excrement may create excessive algae blooms that may be more undesirable than the original problem. Some exotic species of fish, such as the white amur, are being promoted to control aquatic vegetation. Since the impact of these organisms on the aquatic ecosystems is not fully known, their release is prohibited in many states. No biological-control agents for aquatic weeds are available in the Pacific Northwest.

Control with Herbicides

Unlike terrestrial herbicides, which are applied to a stationary, two-dimensional area, aquatic herbicides are applied to an area having a third dimension, depth, and usually having some degree of motion.

Responsible use of aquatic herbicides requires careful consideration of many factors. The most important consideration is the safety of the people using the treated water. Contamination of domestic water supplies, or failure to observe the proper precautions in water-use restrictions, may result in health hazards. Most waters are managed on a multiple-use concept. Game fish, waterfowl, and aquatic mammals share water usage with swimmers and boaters. Irrigation and domestic requirements also may be met by withdrawals from a lake, canal, or river.

Pesticides are often blamed for a phenomenon called swimmers' itch. Swimmers' itch, in fact, is caused by a parasite which is associated with snails and water birds. A brief summary of swimmers' itch is as follows:

> Birds, through their feces, deposit a blood fluke in the water. This fluke will deposit eggs in the water. When hatched, the small organisms, called miracidia, must find a snail for an intermediate host for a short time or they will die. In the snail, the

miracidia develop into cercaria, which leave the snail as free-swimming organisms that can penetrate the skin of man. After penetration, the cercaria cause an itching, burning sensation and small red spots that appear at the point of entry into the skin. These symptoms are noticed soon after the bather leaves the water.

Environmental Consideration and Restrictions

Incorrect application of herbicides to water may involve serious hazards to man, wildlife, fish, and desirable plant life. Consequently, you must analyze the biological, water-use, and physical aspects.

- Biological aspects
  - Identify the problem species.
  - Identify other species present.
  - Determine density, stand, or scope of problem and stage of weed growth.
- Water-use aspects
  - Irrigation, potable, recreational, fish production, livestock, wildlife.
  - Length of time water can be quarantined from each use.
  - Amount of and destination of outflow. Can outflow be regulated? If so, for how long?
- Physical aspects
  - Size of channel or pond to be treated.
  - Water depth and movement or velocity.
  - Water turbidity.
  - Water temperature.
  - Water quality.

After all these factors are carefully analyzed, choose the herbicide labeled for that use, considering safety, effectiveness and selectivity, residues, and cost. Obtain permission, if necessary, from appropriate state and/or federal agencies.

The control of aquatic vegetation presents special problems because:

- The water often has multiple uses.
- Herbicides do not always remain where they are placed.

Consider all the uses of the water to be treated, including those far downstream. Read the label to determine that the herbicide you choose is compatible with these uses.

Types of water uses to consider before applying herbicides include:

- Human use, such as drinking, cooking, and swimming. Few tolerances have been established for herbicide residues in such water. Copper sulfate has been used for control of algae in drinking water for many years and is permitted in raw drinking water. However, you should avoid contamination of any drinking water with any level of herbicide which is not registered for that use.
- Livestock and wild animal use.
- Irrigation.
- Industrial uses.
- Fish production—most aquatic herbicides are not toxic to fish or other animal life at the concentrations recommended for plant control. Notable exceptions are Grade B xylene, acrolein, and some solvents and emulsifiers in certain formulations of normally nontoxic herbicides. These should not be used in fisheries or where the water treated with these herbicides could enter fishery waters.

Trout are especially susceptible to copper sulfate. Do not treat trout waters with copper sulfate without consulting fish biologists.

Application Rates

Correct application of herbicides to aquatic situations involves equipment calibration and calculation of appropriate water volumes or areas. Environmental hazard can result from the incorrect application rate.

Excessive application can cause:

- Damage to fish, either from direct toxicity or from lack of oxygen caused by excessively rapid kill of plants. Bacterial contamination resulting from decay of killed fish might further contaminate downstream water supplies.
- The need for exclusion of livestock from use of the water for a longer time than necessary.
- Water unfit for irrigation use.

State and Federal Regulations

Many states have regulations that govern the use of pesticides in water. Check with the appropriate agency when in doubt. There also are stringent federal and state regulations controlling the importation of exotic fish and plants.

Treatment Techniques

Lower lakes and ponds that have a high rate of inflow prior to treatment to insure adequate contact time for the herbicide. Close the spillway and retain the treated water for at least the minimum period specified on the label before overflow. The amount of draw down will vary according to the situation. Avoid excessive exposure of bottom areas.

Most herbicides should be applied to submersed aquatic plants in late spring or early summer when the plants are young and growing. Treatment at this time usually gives the best control with a minimum of chemical. Applications in late summer or early fall require more chemical and usually give slow, erratic control. Furthermore, access to normally dense aquatic vegetation is best in the spring or early summer before the plants reach the surface.

Points to Remember

The applicator should:
- Be certain of the identity of the vegetation to be treated and the capability of the chemical to control it.
- Obtain a permit (if necessary) to treat any lake or pond—whether for plant control, cleaning, or other purposes.
- Never use more chemical than suggested on the label. Fish and other valuable aquatic life may be killed.
- Use treated water only as suggested on the label.

Environmental Changes Caused by Aquatic Plant Control

The sudden elimination of a dense growth of vegetation from an aquatic environment often causes side effects that can produce significant changes in the biological and physical makeup of a lake, pond, or stream.

Following the death of large quantities of vascular plants in a pond or lake, a greenish or yellowish-brown turbid condition may be noticed. This condition is due to the presence of billions of microscopic algal cells which have used the nutrients released from the decaying vascular plants for their growth and reproduction. The green or blue-green algae are often responsible for a pea soup appearance, whereas, other algae and various one-celled organisms cause the yellowish-brown colors in water.

When conditions are optimal for development of algae, a dense bloom can quickly develop. These dense blooms of plankton algae cut down light penetration and, thereby, inhibit the regrowth of those species defoliated by the treatment, but the algae may turn out to be more objectionable than the original plant infestation.

Chemical Formulations

Aquatic herbicides are available in several formulations.

Sprayable formulations. Most herbicides are formulated to be mixed with water and sprayed.

Kinds available are:
- Water-soluble powders or crystals that form true solutions in water.
- Wettable powders that can be dispersed in water.
- Water-soluble liquid concentrates that form true solutions in water.
- Emulsifiable liquid concentrates that form ordinary "oil-in-water" emulsions in water.
- Special liquid concentrates that form "water-in-oil" emulsions (called invert emulsions) when mixed with water and oil in the spray tank or when applied through special mixing nozzles.

Granular formulations. Many aquatic herbicides are used as dry granules of various sizes. Kinds available are:
- Granulated pure chemical, such as crystalline copper sulfate.
- Granules or larger pellets of clay and other materials impregnated with the parent herbicide.
- Slow release granules or pellets designed to release the chemical into the water over an extended period.

Application Techniques

Four zones of a body of water may be treated:
- Water surface
- Total water volume
- Bottom 1- to 3-foot layer of water
- Bottom substrate surface

Surface Treatment

Generally, only one-fourth to one-third of the surface area of the water should be treated at a time. This helps protect fish from a possible shortage of oxygen from vegetative decomposition. Surface acreage of a rectangular body of water equals length in feet times width in feet divided by 43,560.

Total Water Volume Treatment

The whole body of water (from surface to the bottom) is treated; more frequently, one-fourth or one-third of the total water volume is treated at a time. Calculate the volume of the body of water and add chemicals to obtain the required dilution in the water.

The concentration of chemical needed to kill aquatic plants is often very small and is stated in "parts per million" (ppm).

If the toxicity level of a certain chemical for a particular aquatic plant is 2 ppm of active ingredient (ai), for example, the chemical should be applied at a rate of 2 parts of "ai" to 1 million parts of water in the area to be treated.

First, calculate the acre-feet of the body of water to be treated. Multiply surface acres by the average depth in feet. An acre-foot of water weighs 2.7 million pounds. If one dissolves 2.7 pounds of any material in 1 acre-foot of water, there will be a concentration of 1 ppm by weight (ppmw). Use the following formula to determine the material needed to obtain a desired ppm concentration:

$2.7 \times$ ppm wanted $\times$ acre-feet = pounds required

Assume one wants to treat a pond containing 10 acre-feet. The concentration of active ingredient required is 0.5 ppm. Use this formula:

$2.7 \times 0.5 \times 10 = 13.5$ pounds of active ingredient

Bottom Layer Treatment

Treating the deepest 1 to 3 feet of water is especially useful in deep lakes where it is impractical and too costly to treat the entire volume of water. Such treatments are generally made by attaching several flexible hoses at 3- to 5-foot intervals on a rigid boom. Each hose is usually equipped with some type of nozzle at the end. They may be weighted to reach the depth desired. The length of hose and speed of the boat carrying the application equipment also affect the depth of application. Successful bottom treatments apply the herbicide as a "blanket" in the lower 1 to 3 feet of water.

Bottom Soil Treatment

Herbicide applications may be made to the bottom soil of a drained pond, lake, or channel to control certain submersed and emersed species. The interval between treatment and reintroducing water varies up to 3 weeks, depending on the herbicide used.

VEGETATION MANAGEMENT IN STATIC WATER

Floating and Emersed Weeds

Sprayable formulations are almost always preferred for floating and emersed plants. These plants are killed by direct foliage applications of the spray mixture:

- By aircraft.
- By ground equipment—operated from the bank of small ponds or if plants occur only around the margin.
- From a boat, using various types of booms or spray guns.

Submersed Plants

The herbicide formulations for the control of submerged plants and algae in static water may be in the form of sprays or granules.

Sprayable formulations are most often applied as water-surface treatments, particularly in shallow water. The herbicide is dispersed throughout the water by diffusion, thermal currents, and wave action. Sprayable herbicides can be applied under the surface by:

- Injection through a hose pulled along behind a boat.
- Injection into the water by booms.

Sprayable herbicides sometimes are used for bottom soil treatments. Some sprays may be applied from aircraft at low volumes, e.g., 5 to 10 gallons per acre. Both surface and injection treatments made by boat or ground equipment are more effective and are easier when large volumes of liquid carrier are used. A handy sprayer for making applications by boat uses a special pumping system that draws water from the lake or pond as the boat moves along. Concentrated herbicide is metered into the pumped water to achieve the concentration required. This avoids both frequent interruptions to prepare spray solutions and the need to carry water on board.

Granular formulations are most often used for control of algae or submersed plants, although some are effective on certain emersed plants. Because granules sink to the substrate, they perform about the same way as herbicides applied as bottom soil treatments. Application rates for granular herbicides may be based on:

- Amount of herbicide per unit of surface area.
- The concentration (ppm) that would be achieved if the same amount of herbicide were dissolved and totally dispersed in the water (total water volume treatment).

Granular herbicides perform best when distributed evenly over the water surface. They may be broadcast by hand or manual spreader over small areas. Special granule spreaders mounted on aircraft or boats are used for large-scale applications. Advantages of granular herbicides are:

- Treatment is usually confined to the bottom where the submersed plants are.
- They can be made to provide a long contact time with plants (slow release granules).
- The herbicide concentration can be held to a low level.
- They make it possible to use chemicals that in other formulations would be toxic to fish.

Plant Control in Large Impoundments

Herbicide applications that are successful in smaller bodies of water often perform poorly in large impoundments. These impoundments often have much water movement caused by thermal currents or the wind. Plant control may sometimes be improved in these sites by:

- Using the maximum recommended application rates.
- Treating relatively large water areas at one time.
- Applying herbicides only during periods of minimum wind.
- Using bottom treatment in deep water.
- Using granular formulations when possible.
- Selecting herbicides that are absorbed quickly by the plants.

VEGETATION MANAGEMENT IN FLOWING WATER

Aquatic plants in flowing water are the most difficult to control. Because the water is moving from one location to another, the possible hazards of herbicide use are greater.

Herbicides are sometimes used to control plants in natural streams. Control of aquatic plants in man-made water distribution and drainage systems is more common. Most of these carry irrigation water. Do not irrigate crops with treated water unless permitted by the pesticide label. Some systems also carry domestic, industrial, and recreational water. As the number of water uses increases, more restrictions and precautions are required.

Floating and Emersed Plants

When floating and emersed plants are found in flowing water and control of these plants becomes necessary, the procedure when using herbicides will be the same as when applied in static waters. Precautions for flowing waters are important. What are the flowing waters used for? Do they support fish life, are they used for recreation, etc.? Much concern for the environment is in order when applying pesticides to flowing water.

Submersed Plants and Algae

These plants can be effectively controlled in flowing water only by continuously applying enough herbicide at a given spot to maintain the needed concentration and contact time.

The greater the cross-sectional area and the depth of the stream and the greater the speed of flow, the larger the volume of water that must be treated.

The large volume of water that must be treated makes the use of herbicides in flowing water costly, particularly when:

- The plant infestation covers only a small area.
- The herbicides are effective for only a short distance downstream.

Few herbicides are available for control of submersed plants in flowing water. The more common ones are:

- Copper sulfate, used for control of algae. It is toxic to trout at recommended treatment rates, but only moderately toxic to most other fish species. The toxicity of copper to fish increases with decreased total alkalinity of the water.
- Grade B xylene and acrolein, are highly toxic to fish and many other forms of aquatic life. They are used primarily in water delivery systems that contain no fish, or where the water delivery is far more important than the value of the few fish that might be present. These products are usually injected below the flowing water surface, to enhance distribution in the water, to reduce volatilization, and to increase the stability of Grade B xylene emulsions.

Be certain that the residues in the treated water and runoff water are at or below the levels permitted for all subsequent uses.

PLANT CONTROL IN LIMITED FLOW WATERWAYS

Flood drainage canals, sloughs, and drains are good examples of limited flow waterways. Plant control methods in these systems of little water movement are very similar to those used in static water. Consider the possible contamination of water used for other purposes when you plan the use of herbicides in limited flow water. In some areas, drainage water may flow directly onto cropland and be used for irrigation or it may enter a fishery or drinking water supply.

VEGETATION MANAGEMENT ON DITCHBANKS

Weeds on ditchbanks are a major obstacle in irrigation of crops and subsequent drainage. They reduce the flow of water and thus cause flooding, seepage, breaks in ditchbanks, increased evaporation and transpiration loss, decreased water delivery, and decreased drainage of water. They obstruct inspection and maintenance operations of the irrigation systems and cause silt deposits in the irrigation channels. Also, seeds and other propagules produced by weeds on ditchbanks can infest cropland.

Ditchbanks provide a variable plant habitat. A major reason for this is that soil moisture varies greatly within a short distance on an irrigation ditchbank. Emergent aquatic species are often found at the waterline. Within a few feet of this area, up over the top of the bank, the soil may be very dry with drought-tolerant species predominant.

Plant control methods will depend on which plants are to be controlled in relation to the water level, intended water use, and the subsequent use of the water "downstream."

When spraying ditchbanks, the sprayer should travel upstream to avoid the possiblility of concentrating any herbicide which may get into the water.

SELECTED HERBICIDES USED IN AQUATIC SITES

The following is a brief description of herbicides used to control weeds growing in aquatic situations. Specific recommendations for control of aquatic and ditchbank weeds are not included. Current recommendations can be obtained within your state from Cooperative Extension and by consulting appropriate product labels for specific rates, timing, and registered uses.

Acrolein (Magnacide-H)

Acrolein is a contact herbicide used to control submersed and floating weeds and algae in irrigation canals, ditches, drains, and ponds. It is not toxic to common field crops irrigated with treated water when used as directed by the product label. Acrolein is volatile, flammable, and very toxic to mammals, birds, fish, and many other aquatic organisms.

Apply acrolein before weed growth is 4 to 6 inches tall. Specialized equipment is required for application. Acrolein is injected directly into the water using oxygen-free nitrogen as a propellant.

Repeat treatment every 3 to 4 weeks during the remainder of the season. There is no potable (drinking) water tolerance for acrolein, and it must not be applied in potable waters. Do not permit treated water to return to water courses containing desirable fish, vegetation, or other organisms until the herbicide has completely dissipated from the water.

Copper sulfate (Various Trade Names)

Copper sulfate can be used to control most algae in most waters, except in streams and rivers. It is an inorganic herbicide formulated as various-sized crystals. Dissolution rates in the water vary according to crystal size, water quality, flow rate, and other factors. The effectiveness of the product is influenced by water hardness, organic matter content, and algal density. Make the first treatment before a severe algae problem develops; repeat treatments at 2- to 3-week intervals may be required for continued control. The herbicide can be applied by:

- Suspending the crystals in porous bags beneath the water surface or dragging the bags through the water.
- Pouring directly into water of irrigation channels if the irrigation channel is concrete lined.
- Apply over the water surface of impoundments.
- Using a specially-designed continuous feeder.

When applying to fish-containing waters, note label cautions for application and rates due to different fish sensitivities. Potable water has a tolerance of 1 ppm of copper.

Copper sulfate will not eliminate established growths of submersed vascular weeds. However, continuously maintained concentrations, begun in early spring for control of algae in municipal-water canals and reservoirs, inhibit the growth of rooted submersed plants.

Dalapon (Dowpon M)

Dalapon is a translocated, foliage-applied herbicide used to control emersed, marginal, and bank grasses along the inside of irrigation canals and drainage ditches. Best results occur when a suitable nonionic surfactant is used in the spray solution. Fishing and grazing are restricted after using dalapon. Minimize contact of the spray solution with the water surface.

Water-use restrictions occur following use of dalapon, particularly when used in situations other than described above. Thus, observe all label directions and restrictions.

Dichlobenil (Casoron G-10)

Only the granular formulation of dichlobenil, which is labeled for aquatic use, should be used. Dichlobenil will control submersed weeds in lakes and ponds when applied before or immediately after weed growth emerges from the hydrosoil. Apply the granules in early spring to the exposed lake or pond bottom or over the water surface.

Dichlobenil should be used only on lakes and ponds with little or no outflows. Do not use treated water for irrigation or drinking. Do not use fish from treated water for food or feed within 90 days after treatment. Observe all other labeled water-use restrictions listed on the label.

Diquat (Diquat Water Weed Killer)

Diquat is a contact herbicide. It will control the top growth of most species of submersed weeds in clear-water ponds and lakes when injected below the water surface. Apply before submersed weeds reach the water surface.

Diquat is readily adsorbed by silt or other suspended material in water, and its effectiveness is greatly reduced when mixed with such water. It is also an effective herbicide for control of free-floating species such as duckweed. On floating weeds, apply diquat as a foliage spray with surface equipment. When this type of application is made, use a suitable nonionic surfactant recommended by the manufacturer in the spray solution. The effectiveness of diquat on free-floating aquatic weeds is due to the rapid desiccation of the above-water leaves and stems and rapid absorption of the chemical from the water by roots and stems. Diquat only temporarily affects floating-leaf or emersed species rooted in the hydrosoil. It is not effective on chara or attached algae.

Do not use treated water for animal consumption, swimming, spraying or irrigation nor for drinking until 10 days after treatment. Observe all other label restrictions.

Endothall (Hydrothol, Aquathol)

Endothall is a contact herbicide and, depending on formulation, is used to control algae and submersed weeds. For algae control in irrigation systems, lakes, ponds, and reservoirs, the dimethylamine salt (Hydrothol) formulations are sprayed on the water or injected below the water surface when growth appears.

Submersed weeds in lakes and ponds can be controlled with either the dipotassium salt or dimethylamine salt of endothall (Aquathol and Hydrothol, respectively). Apply either material by spraying on the water or injecting below the water surface after growth has developed in the late spring or early summer. The dipotassium salt formulation works best when water temperatures reach a consistent 62° to 65°F.

Endothall is not effective on chara or elodea. There are several restrictions on the use of water following treatment with endothall, depending on product used and rates applied. The Hydrothol formulations may be toxic to fish at the concentrations required for control of submersed weeds. Consult and observe the restrictions on the appropriate label.

Glyphosate (Roundup)

Glyphosate is a nonselective, translocated, foliage-applied herbicide used for control of a variety of emersed, marginal, and bank weeds along irrigation and drainage ditches. Apply glyphosate to the inside of dewatered ditches only. Best weed control is obtained when the herbicide is applied to vigorously growing weeds at the labeled growth stage. It is especially effective against perennial grasses such as reed canarygrass and johnsongrass. The herbicide rate and timing depends on the target weed species.

Since glyphosate is not selective, occasionally all the vegetation may be killed, allowing erosion of the canal banks. When this occurs, make provisions to establish a desirable low-growing grass, such as redtop or creeping red fescue east of the Cascade Mountains.

Consult the label for any restrictions that apply following treatment with glyphosate.

Xylene

Xylene is a nonselective, contact herbicide used to control submersed weeds in flowing canals. Apply this product after weed growth is well established, but before it becomes matted at the surface or causes channeling of the water. When applying xylene, mix with an emulsifier and inject under pressure near the bottom of the channel, preferably in turbulent water. The emulsifier will help the xylene form a stable emulsion with the water. Without the emulsifier, xylene will float on the water surface and evaporate.

Xylene is flammable, volatile, and very toxic to fish and many other aquatic organisms. There is no potable water tolerance for xylene, and it must not be applied to potable waters. Do not allow the treated water to return to water containing desirable fish, vegetation, or other organisms until the herbicide has completely dissipated from the water.

Repeat treatments as required during the remainder of the season. Do not allow man or animal to drink the treated water nor flood irrigate seedling crop plants with treated water. Xylene can be used only in programs of the Bureau of Reclamation and cooperating user organizations.

Simazine (Aquazine)

Simazine is a nonselective herbicide used to control algae and submersed weeds in lakes and ponds with little or no outflow. Apply simazine in the spring while the submersed plants are actively growing and before they reach the water surface. Make treatments for algae control when 5% to 10% of the water surface is covered with scum.

Trees on the shoreline may be injured or killed by simazine applied to the water. Do not use water from treated ponds for irrigation, livestock water, or human consumption until 12 months following treatment. Fishing and swimming are permitted any time after application.

2,4-D (Various Trade Names)

2,4-D is a selective, foliage-applied herbicide used to control broadleaf weeds. When selecting a formulation of 2,4-D for a particular situation, be sure it is registered for that use. At this time, Weedar 64 is the only formulation of 2,4-D registered for use in controlling broadleaved weeds on the inside perimeter of irrigation channels in the western United States. The use of other products for this purpose is an illegal application.

Some granular formulations of 2,4-D are registered to control Eurasian watermilfoil and other weeds in lakes and ponds. Other formulations of 2,4-D are available for control of floating, emersed, marginal, and bank weeds of ponds and lakes.

Restrictions apply to livestock grazing and the use of water treated with 2,4-D. Consult and observe all other water-use restrictions on the herbicide label. These restrictions will vary with the particular use and site of application. Some formulations of 2,4-D are more toxic to fish than others. Avoid drift to nearby 2,4-D susceptible crops.

This publication was compiled from these study guides and our own sources to provide what we feel is the minimum of information required for aquatic herbicide application.

1. The Aquatic Plant Manual by E.P.A., which was developed by California State Polytechnic University (contract 68-01-2918);
2. Pesticide Training Manual on Aquatic Pest Control, Maryland Department of Agriculture, prepared by the College of Agriculture, Pennsylvania State University;
3. Aquatic Plant Control Training Manual, prepared by the staff of the Florida Department of Natural Resources, Division of Resources Management, Bureau of Aquatic Plant Research and Control;
4. The Pesticide Applicator Training Manual on Aquatic Pest Control, prepared by the College of Agriculture and Life Science, Cornell University.
5. Pacific Northwest Pest Control Handbook, prepared by state agencies in the Pacific Northwest.

EQUIVALENTS AND EQUATIONS

Liquid Measurements

1 gallon	=	4 quarts
1 gallon	=	8 pints
1 pint	=	16 ounces
1 cup	=	8 ounces
1/2 cup	=	4 ounces
1/4 cup	=	2 ounces
1 tablespoon	=	1/2 ounce
8 tablespoons	=	4 ounces
16 tablespoons	=	8 ounces

0.1 gallon	=	12.8 ounces
0.2 gallon	=	25.6 ounces
0.25 gallon	=	32.0 ounces (1 qt)
0.3 gallon	=	38.4 ounces
0.4 gallon	=	51.2 ounces
0.5 gallon	=	64.0 ounces
0.6 gallon	=	76.8 ounces
0.7 gallon	=	89.6 ounces
0.8 gallon	=	102.4 ounces
0.9 gallon	=	115.2 ounces
1.0 gallon	=	128.0 ounces

Solid Measurements

0.1 pound	=	1.6 ounces
0.2 pound	=	3.2 ounces
0.3 pound	=	4.8 ounces
0.4 pound	=	6.4 ounces
0.5 pound	=	8.0 ounces
0.6 pound	=	9.6 ounces
0.7 pound	=	11.2 ounces
0.8 pound	=	12.8 ounces
0.9 pound	=	14.4 ounces
1.0 pound	=	16.0 ounces

Units and Conversion Equivalents

1 ac = 43,560 sq ft

1 ac ft (ac ft) = 43,560 cu ft = 325,762 gal = 2,720,000 lb of water

1 cu ft/second (cfs) = 450 gal/minute (gpm)

1 cu ft = 7.48 gal = 62.4 lb of water

1 gal = 128 fl oz = 8.33 lb of water

1 ppm by volume (ppmv) = 1 gal/million gal of water

1 ppm by weight (ppmw) = 8.33 lb of chemical/million gal of water

1 ppmw = 2.72 lb of chemical/ac ft of water

$$\text{gal of liquid formulation required} = \frac{\text{lb ai required}}{\text{lb ai/gal of concentrate}}$$

$$\text{lb of dry formulation required} = \frac{\text{lb ai required} \times 100}{\text{\% ai in formulation by weight}}$$

(ai = active ingredient)

Formulas for Herbicide Application to Ponds or Lakes

Volume of pond in cu ft = surface area in sq ft × average depth in ft

Volume of pond in ac ft = surface area in ac × average depth in ft

$$\text{Volume of pond in ac ft} = \frac{\text{volume of pond in cu ft}}{43{,}560}$$

$$\text{ppmv} = \frac{\text{gal of 100\% ai}}{\text{volume in ac ft} \times 0.33}$$

Total gal of chem required = ac ft × ppmv × 0.33

$$\text{ppmw} = \frac{\text{lb ai of chem applied}}{\text{volume in ac ft} \times 2.72}$$

Total lb ai required = ac ft × 1.72 × ppmw desired

$$\text{Total gal of liquid formulation required} = \frac{\text{ac ft} \times 2.72 \times \text{ppmw desired}}{\text{lb ai/gal of concentrate}}$$

Formulas for Herbicide Application to Channels

cfs = cross section area in sq ft × average velocity in ft/second (fps)

cross section area of rectangular channel in sq ft = average width in ft × the average depth in ft

$$\text{ppmv} = \frac{\text{gal of chemical} \times 1{,}000{,}000}{\text{cfs} \times 450 \times \text{minutes applied}}$$

$$\text{gal of chemical/cfs} = \frac{\text{ppmv} \times 450 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{total gal of chemical required} = \frac{\text{ppmv} \times 450 \times \text{cfs} \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{ppmw} = \frac{\text{lb of chemical} \times 1{,}000{,}000}{\text{cfs} \times 3{,}744 \times \text{minutes applied}}$$

$$\text{ppmw} = \frac{\text{gal of formulation} \times \text{lb ai/gal} \times 1{,}000{,}000}{\text{cfs} \times 3{,}744 \times \text{minutes applied}}$$

$$\text{lb of chemical/cfs} = \frac{\text{ppmw} \times 3{,}744 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{gal of formulation/cfs} = \frac{\text{ppmw} \times 3{,}744 \times \text{minutes applied}}{\text{lb ai/gal} \times 1{,}000{,}000}$$

DEFINITION OF TERMS USED IN WEED CONTROL

Abscission—The formation of a layer of cells which cause the fruit, leaf, or stem to fall off the plant.

Absorption—Penetration of a substance from the surface to below the surface.

Acid Equivalent (ae)—The theoretical yield of parent acid from an active ingredient content of a formulation.

Activator—Materials used in a pesticide formulation to increase the effectiveness of the toxic materials towards the target pest.

Active Ingredient (ai)—The chemical(s) in a formulated product that is/are principally responsible for the herbicidal effects and that is/are shown as active ingredient(s) on herbicide labels.

Acute Oral LD_{50}—The dosage required to kill 50% of the test animals when given in a single oral dose in toxicity studies.

Acute Toxicity—The amount of a substance, as a single dose, to cause poisoning in a test animal.

Adhesive—A substance that will cause a spray material to stick to the sprayed surface, often referred to as a sticking agent.

Adjuvant—Any substance in a herbicide formulation which enhances the effectiveness of the herbicide.

Adsorption—Adherence of a substance to a surface.

Aerobic—Living in the air; opposite to anaerobic.

Aesthetic—Producing a pleasant or satisfying feeling to an exposure; enjoy seeing a beautiful flower or handsome animal.

Agitate—Keeping a mixture stirred up.

Algae—Nonvascular chlorophyll-containing plants, usually aquatic.

Alkalinity—Containing sodium and potassium carbonate salts. (Calcareous: Containing an excess of calcium usually in the form of the compound calcium carbonate-Limy.)

Anaerobic—Living in the absence of air; opposite to aerobic.

Anionic Surfactant—A surface-active additive to a herbicide having a negative charge.

Annual Plant—A plant that completes its life cycle in one year.

Antagonism—Opposing action of different chemicals such that the action of one is impaired, or the total effect is less than that of one component used separately.

Antidote—A practical immediate treatment, including first aid, in case of poisoning.

Aquatic Plants—A plant that grows in water. There are three types: submergent, grow beneath the surface; emergent, root below the surface but foliage above the water; and floating.

At Emergence—Treatment applied during the visible emerging phase of the specified crop or weed.

Band or Row Application—An application to a continuous restricted area, such as in or along a crop row, rather than over the entire field area.

Basal Treatment—A treatment applied to the stems of woody plants at and just above the ground.

Bed-Up—To build up beds or ridges with a tillage implement.

Berm—Narrow shelf typically along the water's edge of canals formed by deposited silt.

Biennial—A plant that completes its life cycle in two years. The first year the seed germinates and the plant produces leaves, roots, and stores food. The second year it flowers and produces fruits and seeds.

Bioassay—The qualitative or quantitative determination of a substance by response measurements of treated living organisms as compared to measurement on nontreated, check, or standard living organisms.

Biological Control or Biocontrol—Controlling a pest by its natural enemies, including competitive plants; these may already occur in the area or be introduced.

Broadleaf Plants—Basically classified as dicotyledons. Plants have two cotyledon leaves in the seedling stage; true leaves are broad and have netlike or reticulate veins.

Brush Control—Control of woody plants.

Carcinogen—A substance capable of producing cancer.

Carrier—A gas, liquid, or solid substance used to dilute, propel, or suspend a herbicide during its application.

cfs—Cubic feet per second.

Chlorosis—Loss of green color in foliage followed by yellowing of the tissue.

Chronic Toxicity—Results produced in test animals exposed for long periods to chemicals.

Combustible—Will burn when near an open flame or spark.

Compatible—Mixable in the formulation or in the spray tank for application together in the same carrier without undesirably altering the separate effects of components.

Concentration—The amount of active ingredient or herbicide in a quantity of diluent expressed as percent, lb/gal, etc.

Contact Herbicide—A herbicide that is phytotoxic by contact with plant tissue rather than as a result of translocation.

Contaminate—To alter or render a material unfit for a specified use by allowing the pesticide to come into contact with it.

Control—May not mean eradication, but reduction of the weed problem to a point where it does not cause economic damage.

Crown—The point where the stem and root join in a seed plant.

Cuticle—Waxy, fatty material that covers plant surfaces such as leaves.

Cut-Surface Application—Treatments applied to frills or girdles that have been made through the bark into the wood of a tree.

Deciduous Plants—Those plants which are perennial in habit but lose their leaves during winter.

Deflocculating Agent—A material added to suspension to prevent particles from clumping together and settling out of spray tanks.

Defoliant or Defoliator—Any substance or mixture of substances for which the primary use is to cause the leaves or foliage to drop from a plant.

Degradation—The process by which a chemical is decomposed or broken down into less complex compounds or elements.

Deoxygenation—Depletion of oxygen.

Dermal Toxicity—Measures the amount of a pesticide or poisonous material that can be absorbed through the skin of animals to produce toxic symptoms.

Desiccant—Any substance or mixture of substances used to accelerate the drying of plant tissue.

Detergent—Primarly used as a cleaning agent. It is often used as a wetting agent to reduce surface tension of spray droplets.

Dewatered Ditch—A drained ditch.

Dicot (Dicotyledon)—A plant that has two seed leaves or cotyledons; broadleaf plants.

Diluent—Any gas, liquid or solid material used to reduce the concentration of an active ingredient in a formulation.

Directed Application—Precise application to a specific area or plant organ such as to a row or bed or to the lower leaves and stems of plants.

Dispersing Agent—A material that reduces the cohesive forces between similar particles.

Dissolve—Refers to getting solids into solutions.

Dormancy—State of inhibited germination of seeds or growth of plant organs. A state of suspended development.

Dose (Rate)—The terms are the same; however, rate is preferred. Refers to the amount of active ingredient applied to a unit area regardless of percentage of chemical in the carrier.

Drift—The movement of airborne particles by air motion or wind away from the intended target area.

Early Postemergence—Applied after emergence during the cotyledonary growth phase of crop or weed seedlings.

Efficacy—Capacity for serving to produce effects; effectiveness.

Emergence—The act by germinating seedlings of breaking through the soil surface.

Emersed Plant—A rooted or anchored aquatic plant adapted to grow with most of its leafstem tissue above the water surface and not lowering or rising with the water level.

Emetic—A material used to cause vomiting to rid stomach of poisonous compounds.

Emulsifiable Concentrate (ec)—A concentrated herbicide formulation containing organic solvents and adjuvants to facilitate emulsification with water.

Emulsifier—A surface active substance which promotes the suspension of one liquid in another.

Emulsion—The suspension of one liquid as a minute globule in another liquid (for example, oil dispersed in water).

Epidermis—The outer cellular tissue of an animal or plant.

Epinasty—More rapid growth on the upper surface of a plant organ or part (especially leaves) causing it to bend downward.

Erosion—Wear away by wind or water.

Ester—A compound formed by reaction of an acid and an alcohol accompanied by the loss of water formed during the reaction.

Filler—A diluent in the powdered form.

Flag Stage—Stage of growth of cereals and other grasses at which the sheath and leaf have been produced from which the head will emerge.

Floating Plant—A free-floating or anchored aquatic plant adapted to growth with most of its vegetative tissue at or above the water surface and lowering or rising with the water level.

Foliar Application—Application of a herbicide to the leaves or foliage of plants.

Formulation—A mixture containing the active pesticide, the carrier, diluents, and other additives required to make the material ready for application.

Freeboard—Distance above water level.

gpa—Gallons per acre.

Gradient—Steps or progress in the rate of growth (plant) or development (seed).

Granule or Granular—A dry formulation of herbicide in which the active ingredient is impregnated on small particles of carrier such as clay or ground-up corncobs.

Grass—Botanically, any plant of the *Gramineae* family. Grasses are characterized by narrow leaves with parallel veins; by leaves composed of blade, sheath, and ligule; by jointed stems and fibrous roots; and by inconspicuous flowers usually arranged in spikelets.

Growth Regulator—A substance used for controlling or modifying plant growth processes without appreciable phytotoxic effect at the dosage applied.

Habitat—Environment (place) where plant grows naturally.

Hard Water—Generally defined as water containing 332 ppm of calcium carbonate. Water that contains certain minerals, usually calcium and magnesium sulfates, chlorides, or carbonates, in solution in sufficient amounts to cause a curd or precipitate instead of a lather when soap is added. Very hard water may cause precipitates in some herbicide sprays.

Hazard—The probability that injury or detrimental effects will result if a substance is not used properly.

Hazard Ratio—The relationship of the degree of risk.

Herbaceous Plant—A vascular plant that does not develop persistent woody tissue above ground.

Herbicide—A chemical used for killing plants or severely interrupting their normal growth processes.

High Volume Sprays—Spray applications of more than 60 gallons per acre volume.

Hormone—A naturally occurring substance in plants that controls growth or other physiological processes. It is used with reference to certain man-made chemicals that regulate or affect growth activity.

Hydrosoil—Soil at bottom of the body of water. Soil-water interface at the bottom of the body of water.

Incorporate Into Soil—The mixing of a herbicide into the soil, generally by mechanical means.

Inert Ingredient—That part of compound without toxic or killing properties, sometimes called the carrier.

Inhibit—To hold in check or stop.

Integrated Control—Utilizes multiple approaches for pest control, giving consideration to minimum pesticide usage.

Invert Emulsion—The suspension of minute water droplets in a continuous oil phase.

Ionic Surfactant—One that ionizes or dissociates in water.

Jointing Stage—When the internodes of grass stems are elongating.

Label—All written, printed, or graphic matter on or attached to pesticide containers as required by law.

Lactation—To secrete milk.

Late Postemergence—Applied after the specified crop or weeds are well established.

Lateral Movement—Chemical movement in a plant or in a soil to the side or horizontal movement in the roots or soil layer.

Layby Application—Applied with or after the last cultivation of a crop.

LC_{50}—Means of expressing the lethal concentrations of a compound. It is a statistical estimate of the dosage necessary to kill 50% of a test animal population, usually expressed in ppm.

LD_{50}—Means of expressing the dosage necessary to kill 50% of a test animal population. It is expressed in weight of the chemical (mg) per unit of body weight (kg).

Leaching—The downward movement of a substance in solution through the soil.

Leaf Blade—The flat portion of a leaf.

Low-Volatile Ester—An ester compound with a high molecular weight and a low vapor pressure such as butoxy-ethanol, iso-octyl, or propylene glycol butyl ether ester.

Low-volume Spray—A spray application of 5 to 20 gallons per acre.

Marginal Plants—Those plants growing near shoreline.

Marl—A calcium carbonate deposit on algae.

Miscible Liquids—Two or more liquids capable of being mixed, which will remain mixed under normal conditions.

Moncot—A seed plant having a single cotyledon (monocotyledon) or leaf; includes grasses, corn, and lilies.

Mutagen—A compound having the property to induce mutations.

Necrosis—Localized death of living tissue (as, for example, following desiccation, browning, and loss of function).

Node—Region of plant stem where leaf or leaves are attached.

Non-ionic Surfactant—Chemically inert.

Nonselective Herbicide—A chemical that is generally toxic to plants without regard to species (may be a function of dosage, method of application, etc.).

Noxious Weed—A weed specified by law as being especially undesirable, troublesome, and difficult to control. Definition will vary according to legal interpretations.

Oral Toxicity—Toxicity of a compound when it is ingested.

Overall Treatment—Uniform application over the entire area.

Overtop Application—Uniform over the top of transplanted or growing plants such as by airplane or raised spray boom of ground rigs. A broadcast application above the plant canopy.

Pellet—A dry formulation of herbicide and other components in discrete particles usually larger than 10 cubic millimeters.

Penetrant—Wetting agents that enhance the ability of a liquid to enter into the pores of a substrate.

Perennial—A plant that lives for more than two years.

Persistent Herbicide—A herbicide which, when applied at the recommended rate, will harm susceptible crops planted in normal rotation after harvesting the treated crop, or which interferes with regrowth of native vegetation in noncrop sites.

Pesticide—Any substance or mixtures of substances used to control or kill insects, rodents, weeds, fungi, and other pests.

Pesticide Tolerance—The amount of pesticide residue which may legally remain in or on a food crop.

Photic Zone—Zone where light is sufficient for plant growth.

Photosynthesis—The manufacture of simple sugars by green plants utilizing light as the energy source.

Phylogenetic—Origin and evolutionary developments of plants.

Phytoplankton—Microscopic plant life living suspended in water.

Phytotoxic—Injurious or toxic to plants.

Postemergence (poe)—After emergence of the specified weed or planted crop.

Postharvest—Application of a pesticide to the soil or plant after crops have been harvested.

Potable Water—Drinkable water.

Preemergence (pre)—Prior to the emergence of the specified weed or planted crop.

Preemergence Incorporated—Applied after seeding and incorporated in the soil above the seed.

Preplanting Application—Applied on the soil surface before seeding or transplanting.

Preplanting Soil Incorporated (ppi)—Applied and tilled into the soil before seeding or transplanting.

psi—Pounds per square inch.

Pubescent—In reference to hair on plants.

Quiescent—Quiet, still, inactive.

Rate—The amount of active ingredient or acid equivalent applied per unit area or other treatment unit.

Registered—Pesticides that have been approved for use by the Environmental Protection Agency.

Residual—To have continued killing effect over a period of time.

Residue—The amount of pesticide that is on or in the crop at the time an analysis is made.

Residue Tolerance—The amount of pesticide residue which may legally remain in or on a food crop.

Resistance—The ability of an organism to suppress or retard the injurious effects of a pesticide.

Rhizome—Underground root-like stem that produces roots and leafy shoots.

Seed—The part of a flowering plant that typically contains the embryo with its protective coat and stored food and will develop into a new plant if sown.

Seedling Stage—Early stage of plant growth, within a few days to a few weeks after seed germination and emergence.

Selective Herbicide—A chemical that is more toxic to some plant species than to others (may be a function of dosage or mode of application).

Silty Water—Water clouded with very small particles of clay, silt, and sand.

Soil Application—Applied primarily to the soil surface rather than to vegetation.

Soil Injection—Placement of the herbicide beneath the soil surface with a minimum mixing or stirring of the soil as with an injection blade, knife, or tine.

Soil Layered—Placement of the herbicide in a discrete horizontal zone under a lifted or tilled layer of soil.

Soil Persistence—Refers to the length of time that a herbicide application on or in the soil remains effective.

Soil Residual—A herbicide that prevents the growth of plants when present in the soil. Soil residual effects may be temporary or relatively permanent.

Soil Sterilant—See Soil Residual.

Solubility—The amount of a substance which will dissolve in a given amount of liquid at a specific temperature.

Soluble Solid—A dry herbicide formulation that is soluble in the carrier liquid.

Solvent—A liquid such as water or oil used to dissolve other material such as herbicides.

Spore—A reproductive body of bacteria; algae, mosses, and ferns.

Spot Treatment—The application of a herbicide to a selected individual area; usually defined as less than 10% of a field or given area.

Spray Drift—The movement of airborne spray particles from the intended area of application.

Spreading Agent—A substance to improve the wetting, spreading, or possibly the adhesive properties of a spray.

Static Water—Pond, lake, or reservoir water that has little or no inflow or outflow.

Stolon—The above-ground runners or slender stems that develop roots and shoots and new plants at the tips or nodes.

Stunting—In reference to plant, the retarding effect of growth and development.

Subacute Toxicity—Results produced in test animals by long-term exposure to repeated doses or concentrations of a substance.

Submersed Plant—An aquatic plant adapted to grow with most all of its vegetative tissue below the water surface.

Surface Tension—A property of liquids related to surface molecular forces, a drop of liquid tends to form an apparent membrane that causes it to ball up rather than spread as a film.

Surfactant—A material which favors or improves the emulsifying, dispersing, spreading, wetting, or other surface modifying properties of liquids.

Surveillance—To keep watch on change in activity, growth, or performance.

Susceptibility—Lack of capacity to tolerate herbicide treatment.

Suspension—Finely divided solid particles dispersed in a solid, liquid, or gas.

Synergism—Complimentary action of different chemicals such that the total effect is greater than the sum of the independent effects.

Systemic—A compound which moves freely within a plant such that application to one area will result in movement to all areas of the plant to exert its effect.

Taxonomy—Science of classification—arrangement according to characteristics.

Teratogen—A compound having the property of causing congenital malformations in the fetus (birth defects).

Terrestrial Plant—A land plant.

Thallus—A nonvascular plant body with distinguishable roots, stems, or leaves.

Tolerance—Capacity to withstand herbicide treatment without marked deviation from normal growth or function.

Topical Application—Treatment of a localized surface site such as a single leaf blade, petiole, or growing point.

Transient—Not permanent; lasting for a short time.

Translocated Herbicide—A herbicide that is moved within the plant. Translocated herbicide may be either phloem mobile or xylem mobile, but the term is frequently used in a more restrictive sense to refer to herbicides that are moved in the phloem.

Translocation—Transfer of food or other materials such as 2,4-D from one part to another in plants (see Systemic).

Tuber—An underground plant storage stem of reserve food; may also be a reproductive organ.

Turbidity—Suspended material in water preventing light penetration.

Turion—A scaly, often thick and fleshy, detached winter bud, by means of which many water plants survive winter.

Vapor Drift—The movement of chemical vapors from the area of application.

Vascular plant—Plants which have specialized food and water conducting cells.

Vigilance—Staying watchful and alert.

Volatile—A compound is volatile when it evaporates or vaporizes (changes from liquid to a gas) at ordinary temperatures on exposure to the air.

Water Dispersible Slurry—A two-phase concentrate that contains solid herbicide suspended in liquid which is capable of suspension in water.

Water Soluble Powder—A finely ground herbicide powder which will dissolve in water.

Weed—A plant growing where it is not desired. Any plant that is a nuisance, hazard, or causes injury to man, animal, or the desired crop.

Weed Control—The process of limiting weed infestations or killing weeds for aesthetic, economic, public health, or other reasons.

Weed Eradication—The elimination of all live plant parts and seeds of a weed from a site.

Wettable Powder (wp)—A finely-divided, dry herbicide formulation that can be suspended readily in water.

Wetting Agent—Substance which serves to reduce interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces.

Zooplankton—Microscopic animal life living suspended in water.

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