ENVIRONMENTAL FATE OF HEXAZINONE

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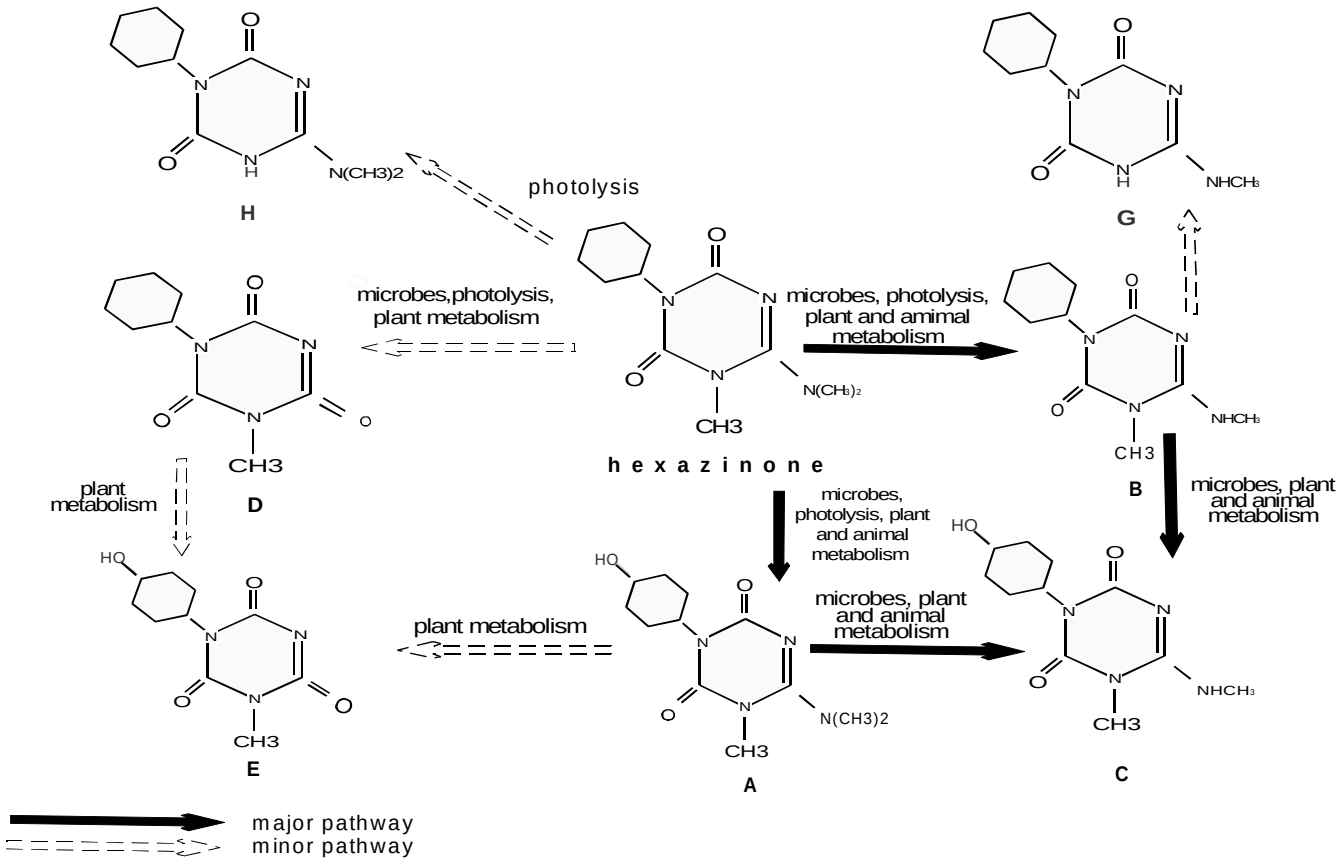
This reviewed all routes of environmental fate of hexazinone with an emphasis on plant uptake and plant metabolism under forest conditions. Hexazinone: 3-cyclohexyl-6-dimethylamino-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione. Chemical Family: Triazine

Hexazinone Degradation



Molecular weight	252.32g
Water solubility	29,800 ppm (water at 25°C)
Vapor pressure	$1.90x10^{-07}$ mmhg (at 25°C)
Henry's constant *	2.1×10^{-12} atmospheres-m^3/mole
Hydrolysis half-life (average over several pH levels at 15°C)	greater than 56 days
Organic carbon adsorption coefficient (Koc) (average values from eight tests with three soil types)	610 cm^3/gm
Octanol-water coefficient (Kow)	15.0
Anerobic half-life	232 days
Aerobic half-life (average values from three tests in sandy loam	222 days
Field dissipation half-life (average from two soil types)	139 days

*from datapackage-AMR-595-86 (1988), other data from Kollman and Segawa (1995).

Physical Chemical Properties

Hexazinone is very soluble in water (29,800 ppm at 25°C), and has a low average organic carbon adsorption coefficient (Koc=610) and a low octanol/water coefficient (Kow=15.0). These numbers suggest that hexazinone is mobile in the environment and partitions into water more than to soil, or biota. In Linders et al. (1994) hexazinone is classified as moderately mobile in soil. Bouchard and Lavy (1985a) found that hexazinone is weakly adsorbed by soil, in fact, less adsorbed by soil and more mobile than atrazine. Also, hexazinone is the most water-soluble triazine herbicide. Compared to more basic triazines, protonation and adsorption-desorption by cation exchange would occur less readily for hexazinone due to its weak basicity. Therefore little charged hexazinone would exist in soil and is adsorbed by soil through non-polar mechanisms (Bouchard and Lavy, 1985a). With the moderate to long half-life and moderate mobility, hexazinone can potentially move off-site with water in run-off and in baseflow.

Mode of Action

Hexazinone is a contact and residual herbicide, readily absorbed by the leaves and roots. Since hexazinone is tolerated by conifers, it is a very effective herbicide for reducing competition from broad leaf trees and bushes, as well as annual and perennial weeds. The granular hexazinone formulation works as rain or snowmelt breaks down pellets, thus releasing the active ingredient, which can then move downward in the soil in concentrated columns (Ghassemi et al., 1981). Release of the herbicide from Pronone 10 G granules is very effective since it takes about a half

cm of rain to release the herbicide from the granules (Feng et al., 1988) The hexazinone is absorbed from the soil/hexazinone solution by plant roots and is translocated upward in the conductive tissue to the leaves where it blocks photosynthesis within the chloroplasts. In woody plants, first yellowing then defoliation occurs. Sometimes plants may refoliate and then defoliate again during the growing season, eventually dying (Ghassemi et al., 1981; Sidhu and Feng, 1993). When applied as a foliar spray, some uptake occurs by absorption through leaves (Ghassemi et al., 1981). According to the label, it may take up to 6 to 8 weeks after rainfall for the symptoms appear in the plants (Pronone 10G and Velpar L labels). Applications made prior to snowfall would take longer.

Environmental Fate of Hexazinone

Air: Hexazinone has a low vapor pressure and thus volatilization occurs only to a minor extent. A low Henry's Law Constant indicates hexazinone has little escaping tendency from a dilute aqueous solution (E.I. Du Pont de Nemours & Company 1988). Aerial drift is not expected to cause a problem for non-target plant species if granular hexazinone is applied by ground (Ghassemi et al., 1981). Pronone 10G has a protective coating that reduces dust formation and loss of hexazinone during application (Feng and Sidhu, 1989) and due to its non-volatilility, large granule size and weight, treatment with Pronone 10 G may result in “negligible” off-site drift (Feng et al., 1988).

Water: Photodegradation and biological decomposition are the major routes of hexazinone degradation (Ghassemi et al., 1981). Hexazinone is generally stable in water and shows little tendency to hydrolyze over a period of up to two months. In aqueous solution under light, hexazinone is slowly degraded to metabolite A, by hydroxylation, and to metabolites B and H by demethylation (Rhodes, 1986). In natural stream water hexazinone did not dissipate noticeably in 260 days (Bouchard et al., 1985). A hydrolysis half-life has been reported to be greater than 56 days by Kollman and Segawa (1995) and Linders et al. (1994).

Soil: The major routes of hexazinone dissipation in soil are photodegradation, biodegradation and leaching (Ghassemi et al., 1981). Hexazinone degrades microbially more readily than by photodegradation (Neary et al., 1983). Rhodes (1980) found that degradation in soil is primarily by demethylation and hydroxylation of the cyclohexyl ring. Metabolite C is the predominant metabolite for three soil types. The other metabolites detected in significant amounts were A, B, and G. Microbial degradation studies with hexazinone treated field-soil and sterile-soil indicate that the triazine ring is broken to release CO_2 (Rhodes 1980, Rhodes 1987). A lab photodegradation study with soil showed that hexazinone degrades to primarily metabolite B by demethylation, and some A and D after six weeks under artificial light (Rhodes 1987). Soil

studies have determined half-lives of 10 to 275 days (Bouchard et al., 1985a; Neary et al.,1983; Michael 1990). Kollman and Segawa (1995) reported field dissipation half-lives of 123 and 154 days from 2 different soil types. Linders et al. (1994) classified hexazinone as "slightly degradable" with a half-life of 62 days.

Biota: Studies conducted on tolerent and non-tolerent plant species indicate that ability to metabolize hexazinone, restrict movement to the foliage or limit uptake contribute to tolerance (McNeil et al., 1984; Baron and Monaco 1986; Jensen and Kimball 1990; Sidhu and Feng, 1993). Metabolites detected in plant studies vary from study to study; however, metabolites A, B, C, D and E have been detected in at least one or more of the studies. Michael (1990) determined that metabolic half-lives were 4 to 15 days in five species when hexazinone was applied at a rate of 1.5 lbs ai/ac. In a much higher application rate study (6.01 lbs/ac), he found half-lives from 19 to 59 days in bracken fern, blueberry, dogwood and grasses. Michael also determined the half-life to be 55 days in leaf litter during the same study. He noted that rapid translocation to underground plant parts may contribute to observed short half-life for other herbicides, but not hexazinone.

The U.S. EPA has set a drinking water Health Advisory (HA) for hexazinone. The lifetime HA for an adult is 200 ppb for effects other than cancer risk. Hexazinone is listed in EPA's group D for cancer risk, which means there is not enough evidence and not enough data to demonstrate that it is a cancer risk (U.S. EPA 1988). Hexazinone is classified by Linders et al. 1994 as "slightly accumulating" with a bioconcentration factor (BCF) of 5 to 7. A U.S.D.A. Forest Service report (1984) found that hexazinone and its metabolites have low toxicity to animals. The rodent studies showed that hexazinone is noncarcinogenic, nonteratogenic and has little or no effect on fertility, reproduction or development. Human exposure estimates from consumption of fish, deer and rabbits hunted from treatment areas were estimated. They indicated that the exposure to hexazinone from consumption of these animals would be low. Rapisarda (1980a) found that when goats were fed 1 and 5 ppm of ^{14}C-labeled hexazinone for five days, most of the ^{14}C was eliminated in the urine and some in the feces. The goats had 10 ppb of total ^{14}C residue in the meat and fat tissues and the liver and kidney had 90 and 40 ppb. Half of the hexazinone in the liver was the parent compound. Only a small fraction of the parent compound was intact in the kidney and urine.

In an off-site movement study, Neary et al. (1983) found that hexazinone did not accumulate in aquatic invertebrates and macrophytes and no changes in species composition or in diversity were noticed. In 24-hour long exposure trials, Schneider et al**.** (1995) found that short-term exposures of stream biota to hexazinone may have only a temporary effect. However, the study

showed that concentrations as low as 3.6 ppb can impact productivity of periphyton communities temporarily. Thus long-term exposures may potentially affect biota. These longer exposures may occur due to hexazinone's persistence and mobility, and capacity to move into surface water in repeated doses. Kreutzweizer et al.(1995) found that contamination from hexazinone runoff into streams from forest applications would be "episodic and brief", therefore lessening possible direct effects on periphyton and secondary effects on macroinvertebrates. The study found no significant adverse effects on macroinvertebrates from a test concentration of 2.7 ppm in water for 12 hours.

Studies Conducted in Forest Environment

The outcome of studies on hexazinone movement in the forest environment vary due to the multitude of variables involved in each study. The variation of residues observed in forest soils may be due to factors such as the differences in soil composition (USDA 1985; Neary et al., 1983; Feng et al., 1992), differences in root uptake and foliar deflection of granules due to unique plant species in treatment areas, and diverse routes of environmental degradation (Feng et al., 1992). Study results also vary depending on the amount and the timing of precipitation, application method, herbicide formulation, treatment rate and for surface water studies, proximity to a stream or river draining a watershed.

The following are seven selected studies of the environmental fate of hexazinone. The first two studies focus on leaching and runoff from forest watersheds. Some studies concentrate on determining hexazinone uptake into plants, residues in soil and organic matter, deposition in leaf litter and studies of residues in crops and animals.

Carlson J. and H. Fiore, 1993. Of the three herbicides used in the Eldorado National Forest (ENF) (hexazinone, triclopyr and glyphosate), due to its long persistence and higher mobility, hexazinone has the greatest risk of off-site movement into surface or groundwater. Hexazinone is generally applied (2 to 3 lbs ai of Pronone 10G) in the fall or winter so that rain or snowmelt carries the herbicide into the root zone. Due to the timing of the application, the likelihood for off-site movement due to precipitation is greatest. Hexazinone can move off-site from runoff from storms or in spring snowmelt. The ENF environmental impact statement for the herbicide application required a study of hexazinone residues in water and sediment from rain or snowmelt flowing off of treated areas. During the 1991-92 study, hexazinone was detected at the level of 1.8 ppb in 1 out of 33 rain runoff samples taken during a storm that occurred three days after the October 1991 application. Samples collected during the next storms had no detectable residues . Samples of runoff from snowmelt were collected in March, April and May of 1992. Of the 36 samples collected, six had hexazinone levels from 1.3 to 2.8 ppb. Fourteen of these sites were

resampled following the first storm of the season a year after application in 1992; no hexazinone was detected. There were no detections in any sediment samples.

H. Fiore, 1995. In the 1992-93 study, no hexazinone was detected in 12 samples collected during the first storm runoff event after the fall 1992 applications. However, hexazinone was detected at 8 out of 25 spring snowmelt water sampling sites in 1993. The levels ranged from 1.3 to 19 ppb. There were additional detections at five of these eight sites one year later at 1.1 to 15 ppb. Up to 24 months after application hexazinone continued to be detected at low concentrations in samples from three locations that were frequently monitored. ENF staff suspected that hexazinone moved into ground water at concentrations high enough to supply baseflow to streams for up to 24 months. There were no detections in the sediment samples.

Sidhu and Feng, 1993. In August 1986, 1.8 and 3.6 lbs ai/ac (2 and 4 kg ai/ha) were aerially applied in a Canadian boreal forest to determine concentrations of hexazinone and metabolites A and B in vegetation for two years after treatment. The study focused on several woody and herbaceous species, leaf litter, and a grass species. For broadleaf herb and woody species, the leaves were separated from the stems and analyzed separately. The detection limit for hexazinone was 7 ppb. The numbers reported were from the 3.6 lbs ai/ac application. Concentrations detected in samples from the 1.8 lbs ai/ac treatment were 30 to 50% less. Prior to winter, at two months after treatment, residues in terminal stems of trembling aspen, Saskatoon berry and willow ranged from 20 to 50 ppb dry weight. Degradation, movement and absorption of hexazinone after the application, occurred in the spring after the snow melted. Concentrations in the vegetation of woody and herbaceous species were highest during May and July following the application. The highest average concentrations from May through September were 1.58 ppm for aspen, 2.86 ppm for the herb showy aster, and 7.32 ppm marsh reed grass. The residues decreased significantly by the end of the first growing season and were non-detectable or near the detection limit the end of the second growing season. The concentration of residues in the leaves was greater than in the stems for all woody species sampled. The maximum stem concentration was less than 2% of the concentration in the leaves. The concentration in herbaceous plant stems ranged from nine to 18% of the concentration detected in the leaves, in the three species sampled. A maximum concentration of 4.09 ppm was detected in leaf litter was detected 10 months after application.

Detections of metabolites A and B varied greatly. Although it was not the objective of the study, the authors noted the various patterns of uptake, degradation, and translocation, as well as how they were related to tolerance and levels of metabolites A and B. Highly sensitive species, such as the marsh reed grass and Saskatoon berry, tended to accumulate a greater amounts of

hexazinone and metabolite B and less metabolite A. These two species may not be able to limit absorption and translocation as more tolerant species, and tend to metabolize hexazinone to the phytotoxic metabolite B. Plants demontrating medium or low sensitivity tended to accumulate higher concentrations of metabolite A and moderate concentrations of hexazinone and metabolite B. In plants showing the least sensitivity, the accumulation of hexazinone and metabolite B were low or not detected. These plants restricted movement to the foliage.

The final portion of this study estimated exposure of wildlife to hexazinone in plant material based on the highest concentrations detected. At maximum intakes of 3 and 16 mg of hexazinone per kg of dry matter for an application of 3.6 lbs/ac or less, the consumption of the herbicide was estimated below acute toxicity LD50 and No Observable Effect Levels (NOEL) reported for several organisms.

J. L. Michael, (1990) studied the fate of a hexazinone application to a pine planting site in Alabama. Plant samples of bracken fern, blueberry, dogwood and grasses were collected from a site treated with Velpar L (liquid formulation) and a site treated with Velpar ULW (granule formulation). At both sites 6.01 lbs ai/ ac (6.75 kg/ha) were applied with a helicopter to 180 acre plots (75 ha), which included buffer zones around the streams that ran through them. Equivalent proportions of live and dead plants were collected as in the study areas. The highest residues detected in the collected plant tissue were from the liquid hexazinone treated area. The concentrations detected ranged from 196 to 951 ppm at the liquid formulation site and from 60 ppb to 34 ppm at the granule site. The report states that these concentrations were similar to detections in other plants of approximately 100 ppm per lb ai/ac applied. Metabolites detected in plant samples vary by species and were detected at much lower levels than the parent compound. Metabolites B and D seemed to be the highest detected in all the species. Metabolites A and E were also detected almost as frequently but generally at much lower concentrations. Half-lives of residues in plants collected at the granule site were longer (26-59 days) than those at the liquid site (19-36 days). Both formulations of hexazinone were not detected in most plant species at 180 days after treatment.

The half-life calculated for both the liquid formulation and the granule formulation in leaf litter was about 55 days. At one year after application, about 99% of the hexazinone had dissipated. Metabolites B and D were detected most often in litter. Soil samples were collected from below the litter layer and in areas of bare soil. Hexazinone was detected in almost all samples collected at the 0-15 cm and 15-30 cm depths at both sites. There was less movement of hexazinone through the soil profile at the liquid application site than at the granule application. The liquid formulation may be adsorbed by vegetation and litter more than granules. For bare soil, half-

lives ranged from 18-77 days. However, the half-life calculated for soil under litter was 275 days at the liquid treated site.

Maximum concentrations of 422 ppb in stream water near the granular treated site and 473 ppb near the liquid treated site were observed. Hexazinone was detected in the stream for up to six months after treatment. Metabolites detected in water occurred at much lower concentrations than the parent compound. Metabolite B was most frequently detected (highest concentration of 23 ppb). Metabolite B was also detected in samples collected at the control site. Levels detected in the sediment were lower than the amount detected in the water. Initial concentrations of hexazinone detected in sediment were less than 200 ppb, and were reduced to a minimum in 180 days. The levels increased at about 238 days coinciding with a change in sediment composition from a loam soil to a sand-like friable rock. Levels detected in sediment later in the study were higher than levels detected in soil at the same time period.

T.L. Lavy et al., 1989. Lavy et al. reported that hexazinone retained in the litter layer can be retaken up by vegetation (recycled), or be microbially degraded or leach into soil layers under the litter layer. Velpar L (liquid) was ground applied at 1.21 lbs. ai/ac (1.36 kg ai/ha) to a forest watershed in West Virginia during May 1984. The trees were taller than 7-year-old pines. At 70 days after treatment, leaves remaining on the trees showing symptoms of herbicide exposure were determined to have a mean detectable residue level of 0.84 ppm. At about 85 days after treatment, 0.96 ppm was detected, and a month later 0.49 ppm was found. Leaves on the ground sampled six months after application had a detection of 0.09 ppm. Based on the data collected it was concluded that less than 0.15% of the hexazinone applied was taken into the leaves.

After application, the forest litter was able to adsorb much of the liquid hexazinone applied, and almost all of the hexazinone applied had dissipated from the litter layer during the first month. The soil depth study indicated that hexazinone was highly adsorbed onto the litter layer, moderately adsorbed onto the top 8 cm of mineral soil, and only sightly adsorbed at the lower soil depths. The litter layer interfered with hexazinone movement on steep slopes by delaying and preventing movement to surface water.

In the stream portion of the study it was found that hexazinone concentrations increased as discharge increased. Up to 68 days after application, hexazinone was detected at levels less than 1 ppb on the average. The levels were low because there was little rain. At 68 days after application, a heavy storm increased the runoff and discharge. 16 ppb was measured. It was believed that the increased rainfall dissolved hexazinone from the litter layer. The dissolved hexazinone in water percolated through the soil profile until it reached an impervious layer like

hardpan or bedrock. The dissolved hexazinone then flowed down the slope just above this layer to the stream. It was found that the highest monthly concentration of hexazinone in the stream occurred six months after application. Another elevated concentration was detected 17 months after application. Hexazinone concentrations decreased with time, however, up to 36 months after application 1 to 2 ppb of hexazinone was still detected. The rainfall occurring in this forest during the summer was the same as rainfall in the fall and winter. However, runoff was greater in the winter and spring. More hexazinone was found in the fall, winter and spring months because of less transpiration and evaporation and colder temperatures slowing down degradation. Once the hexazinone begins to kill the forest hardwoods, less transpiration and evaporation occur. Hexazinone remains bioavailable for longer than 18 months. 1.8 % of the total hexazinone applied was detected in water during the first year, and about 1.2% was found during the second year. No hexazinone was detected in sediment.

D.C. Bouchard et al., 1985b. Velpar L was applied to a forest watershed in Arkansas in mid to late April 1982 at 1.78 lbs. ai/ac (2.0 kg ai/ha) using spot-gun sprayers for a grid-spot application. Oak foliage was sampled June 1 through June 29, 1982, at three intervals following the application and almost a year later, on May 31, 1983. The residues detected on the first sampling date in June ranged from 0.0 to 1200 ppb, from 160 to 660 ppb on the second sampling date and from 120 to 310 ppb on the third sampling date. The May 31, 1983 samples contained from 0.0-100 ppb. Leaf litter that fell from treated trees onto the forest floor was also sampled. At 7, 10, and 13 months after application, less than 60 ppb of hexazinone was detected in the samples collected. In this study it was determined that less than 0.10 % of the hexazinone was returned to the forest floor in leaf litter.

At 42 days post application the hexazinone residues in the top 10 cm of soil had decreased to about 10% of the original concentration. After the initial rapid degradation, the rate slowed during the fall and winter due to colder temperatures, additional hexazinone being added from leaf litter, and to residues being bound to the soil and unavailable for leaching and microbial degradation. The half-life in soil ranged from 28 to 180 days.

Water samples were collected at 1 to 2 hour intervals with automatic samplers and by hand. The highest level of hexazinone detected was 14 ppb during a 1 hour period approximately a few weeks after application. Hexazinone was detected in stream water during periods of higher discharge through the end of the 1.3 year study. Some samples were separated into sediment and water samples. The levels detected in both was similar, thus indicating that hexazinone was not transported on sediment. Approximately 2-3% of the hexazinone applied to the watershed was transported off the watershed in the stream discharge. The discharge may have been high since

the rainfall during the study period was 20% above normal. Hexazinone was also tested in incubated stream water. No significant degradation occurred in 260 days at 10ºC. Based on extrapolated data it was estimated it would take several years for 50% of the hexazinone to disappear at 30ºC.

D.G. Neary et al., 1983. Neary et al. studied the off-site movement of hexazinone in runoff water from a forest watershed. Hexazinone pellets were ground applied at a rate of 1.50 lbs. ai/ac (1.68 kg ai/ha) to four 1-ha forest watersheds in northeast Georgia. There were no buffer zones around drainage routes. Soil samples collected at 0 to 10 cm at several locations along the slope showed that, over time, the hexazinone moved in a pulse down the slope. Hexazinone and metabolites A and B peaked at the top of the slope three days after the first rain and then dropped below the detection limit (0.1 ppm) within two weeks. The midslope levels peaked in three days as well, but took a month to fall below the detection limit. At the bottom of the slope the peak was at 60 days after rainfall, and diminished after 90 days. It was noted that movement laterally and vertically is delayed by high organic matter content or by the clay cation exchange capacity. The half-life was determined to be 10 to 30 days in mineral soil.

Hexazinone can be recycled due to its chemical properties. It was shown that small-diameter hardwoods, due to widespread pellet spacing, demonstrated no affects soon after treatment until the tree canopy above began defoliating. Uptake by the small hardwoods may have increased due to additional residues that leached from leaf fall and returned to the soil and then entered their root zone. The level detected in leaf fall averaged 3 ppm. The level was as high as 6 ppm during the 3rd month post application at the point where the greatest amount of leaf fall occurred.

Runoff from twenty-six storms were monitored for hexazinone and metabolite A and B. The residues detected were highest in the first storm after the application with a mean detection of 442 ppb. The levels dropped over time and were detected for up to 11 months. Only 0.53% of the hexazinone applied to each watershed was detected, some of which may have come from pellets that fell directly into ephemeral drainage routes. Only one storm generated sediment. Hexazinone was detected in the sediment, however the amount detected was small compared to the dissolved hexazinone detected in runoff from other storms. In addition to being detected in storm runoff and sediment, hexazinone was detected in baseflow. Hexazinone began to be detected in baseflow about two months after treatment. The highest detected pulse was 23 ppb. They note that the baseflow pulses follow the drop in herbicide residue in the soil.

Plant residues and uptake:

McNeil et al. (1984) found hexazinone moves inside plants in the transpiration stream (apoplastic movement). The hexazinone parent compound was not detected in the foliage (needles) of two resistant species, loblolly pine and eastern red cedar. For loblolly pine, this was due to the species rapidly degrading hexazinone before it could accumulate in the foliage. For Eastern red cedar, resistance was due to the limited movement of the hexazinone to the foliage. The greater the amount of hexazinone the plant accumulates in the foliage, the less resistant the plant is to photosynthesis inhibition. Baron and Monaco (1986) found that blueberry's resistance, like eastern red cedar, was due to restricted translocation of the herbicide from the roots to the shoot, where it can act on the chloroplasts. Jensen and Kimball (1990) found that both metabolism and restricted uptake contribute to tolerance in the two woody weed species they compared.

Since hexazinone is applied in crops that are tolerant to the herbicide, studies of non-target plant uptake have been conducted with concern for these crops. When dormant alfalfa was treated with 1 lb. a.i./acre ^{14}C-labeled hexazinone, and harvested at two, three and six months after application, 0.5, 0.5, and 0.1 ppm respectively, was detected. Of the 85 percent recovery of the residues from the two month harvest, about 70% was identified as natural products, 12% as free and conjugated metabolites A, B, and C, and 3% as intact hexazinone. No intact hexazinone or the metabolites were detected in the three and six month samples (Rapisarda 1980). In a study conducted in highbush blueberries prior to berry emergence, no detections of hexazinone nor its metabolites were detected at the 50 ppb detection level in samples collected at 68-97 days after treatment with both Velpar and Velpar L at 3 to 6 lbs. ai/ac (Bollin and Hay 1991).

Four species of hardwood cut for firewood were sampled to determine hexazinone residues four and six months after 1.5 lbs a.i./acre was applied to a forest in Georgia. Predominately metabolite B was detected. The highest detection of metabolite B was 1.76 ppm in bark. Only 7% of the samples had detectable amounts of hexazinone and metabolite A. The level of detectable hexazinone was less than 90 ppb. It was concluded that since residues detected were below the 200 ppb Health Advisory, the low residues detected in firewood would not produce adverse health problems (Bush et al. in Ghassemi et al., 1981). Neary et al. (1993) reported that studies conducted on the combustion of wood indicated that smoldering fires volatilize a small amount of hexazinone, but it does not pose a health risk. There is no detectable hexazinone that volatilizes from wood burned in a hot fire.

Conclusion

The chemical properties of hexazinone generally support the findings of the summarized studies. The studies indicate, as well as having a low Koc, that hexazinone does not partition into soil or

sediment to a great extent. It tends to leach from soil and tends to stay in water due to its high solubility. Hexazinone binds better to organic matter, however, it can be released from it by leaching. Its movement laterally or vertically in soil is delayed by higher amounts of organic matter or clay content. Hexazinone is adsorbed onto leaf litter, especially in dryer conditions when there is less competition with water, which can take up active sites on the litter. Hexazinone has a long half-life, especially in colder temperatures and has been detected up to two years after application in surface water. The most residue transport in runoff takes place during the first three to six storms and tends to increase with increasing discharge. Hexazinone has a low BCF and Kow and is therefore unlikely to bioaccumlulate.

The physical properties of hexazinone which make it an effective herbicide for forestry use are the same properties that make it mobile in the environment. It is applied before rain or snow events so that water will leach the herbicide into the soil, into target plant root zones. Due to hexazinone's leaching capacity, using the lowest possible application rates and utilizing buffer zones seem to be the best ways to keep it from moving into protected areas. Buffer zones are also useful in preventing hexazinone from moving into surface water and can at least keep the concentrations within water quality standards if ephemerial drainage routes can be avoided. Another reason hexazinone is effective is that it has a long half-life and therefore provides residual control. However, longer persistance increases the probability that it may move off-site.

Hexazinone fate in vegetation seems to be the least studied. The studies examined in this report focused on plants collected inside treatment areas. Since hexazinone is found in baseflow and can move by leaching laterally through soil, subsurface transport may affect non-target species adjacent to treatment areas. Some questions that remained are how far off-site does hexazinone move due to lateral movement in the soil, how much of the herbicide will be detectable in vegetation and for how long after the application and what are the detectable levels in plants prior to signs of necrosis. Plants collected for food, medicine or fiber that may show no signs of necrosis but may contain hexazinone residues. In addition, there are other plant parts, such as edible roots and bulbs that have not been studied for hexazinone uptake.

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