CHEMIGATION - SAFETY, EQUIPMENT AND RECOMMENDATIONS

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SAFETY

Hazards

There is considerable concern about potential groundwater contamination resulting from chemigation. The primary concern is back flow of chemicals into the aquifer in the event of pump failure. Other concerns deal with overflow of the chemical tank in case of injection pump failure causing a concentrated chemical spill. Additional potential hazards include non-point chemical pollution from runoff and also spray drift.

Backflow. It is understandable that a major concern with protecting groundwater deals with backflow prevention. The fear of back-siphoning a large quantity of chemical directly into the groundwater is a valid one. However, the probability of this happening where strict adherence to state and federal regulations is being carried out is very remote. In the unlikely event that it did happen, the threat of contamination to the aquifer past the point of contamination is still small. The chemical will either be absorbed on the aquifer materials, or if it stays in solution, will not move far from the point of injection (Warner, et al., 1989, Scalf, et. al 1968). The net water movement in the aquifer after pump stoppage is back toward the well bore since the cone of depression is several hundred to several thousand orders of magnitude greater than the volume of water in a center pivot and column pipe. Even if this were not the case, movement away from the well would be very slow under the natural hydraulic gradient of the Ogallala aquifer. If the pump can be restarted within several days after stoppage the threat of large area contamination is very small.

Overflow. Failure of the chemical injection pump, in the absence of a check valve or solenoid valve between the pump and tank, could result in water flowing from the pivot back into the tank and overflowing its contents. This would result in a concentrated spill which could contaminate runoff and eventually surface water or be subject to leaching to the water table. If located near the well, it might find its way down the bore hole if surface sealing was improper. In this case, pumping should again remove the threat of significant aquifer contamination.

Non-point or Runoff. Potential runoff from center-pivot irrigation systems is that portion of irrigation water that is applied at rates exceeding soil intake rate. The area toward the outer end of a pivot offers the greatest potential for runoff since it has the highest application rate. The actual runoff is not only a function of the potential runoff but also of the surface storage. Surface storage is in turn a function of soil surface roughness and slope. The roughness or shape of the surface can be modified by tillage. One drastic modification to prevent runoff is furrow diking. Runoff potential should be low for most chemigation applications where 100% pivot speed is used. However, fertigation at lower speeds could result in excess accumulation in low areas in the field where leaching could then move it to the water table.

Drift. Drift is usually defined as the part of the fine spray droplets carried away from the application area by wind. This can be considerable in high wind conditions. In one study where the average wind speed was measured at 22 miles/hr with peak gusts to 40 miles/hr, 94 percent of the water was carried away from the application area

(Lyle and Bordovsky; 1983). Drift creates a hazard of dermal exposure to persons in the drift area. Drift is not limited to chemigation but is associated with most agricultural spray operations. It sould be noted that relative concentrations of pesticides in irrigation water is several hundred times less concentrated than that of ground application and on the order of 1000 times less concentrated than aerial application. Therefore much longer contact time would be required to receive a life threatening dose. Also the recent development of in-canopy chemigation nozzles associated with LEPA systems reduce the potential for drift. However, chemigation should not normally be attempted when wind speeds are greater that 10 miles/hour.

Regulations

Regulations in regard to equipment are very similar among states. Administration and permitting, however, may differ from state to state. Minimum regulations in any state must meet those established by the EPA under its Label Improvement Program and the regulations regarding chemigation published in March, 1987 as PR-Notice 87-1 which became effective April, 1988. It requires pesticide registrants to include labelling information regarding chemigation of their product. As the pesticide label is a legal document and use of pesticides inconsistent with the label is prohibited, adherence to label instructions and prohibitions is mandatory. The general regulations and those specific to center pivot irrigation are as follows:

What pesticide products are addressed? The regulations apply to pesticides registered under FIFRA by EPA including Section 3 Registration, Sec. 5 Experimental Use Permit, Section 18 Emergency Use or Section 24 (c) Special Local Need. Fertilizers do not require registration under FIFRA.

What pesticides can be chemigated? The label must address chemigation of the product by either a) prohibiting chemigation or b) permitting chemigation. The label cannot remain silent in reference to chemigation. If chemigation is approved, the label must provide directions on safe and effective use as detailed in Pr-Notice 87-1. Additional label instructions address mixing, agitation, tank mixing with other pesticides, when to apply during the irrigation, and quantity of water to be applied.

What anti-pollution and safety features are required for sprinkler chemigation? Required equipment and safety features of the chemigation system must be listed on the label and include:

1. "The system must contain a functional check valve, vacuum relief valve, and low pressure drain appropriately located on the irrigation pipeline to prevent water source contamination from backflow."

2. "The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back toward the injection pump."

3. "The pesticide injection pipeline must contain a functional, normally closed, solenoid-operated valve* located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the irrigation system is either automatically or manually shut down."

*Approved alternatives to normally closed solenoid valve in 3.

Alternative a: Functional spring-loaded check valve with a minimum of 10 psi cracking pressure to prevent irrigation water from entering the chemical injection line under operating pressure and during system shutdown.

Alternative b: Functional normally closed hydraulically operated check valve connected to the main water line such that the check valve opens only when the mainwater lie is adequately pressurized.

Alternative c: Functional vacuum relief valve located in the chemical injection line between the positive displacement injection pump (not approved for Venturi injection systems), elevated at least 12 inches above the highest point in the injection line. the valve must open at six inches water vacuum or less and be constructed to not leak on closing.

4. "The system must contain functional interlocking controls to automatically shut off the pesticide injection pump when the water pump motor stops."

5. "The irrigation line or water pump must include a functional pressure switch which will stop the water pump motor when the water pressure decreases to the point where pesticide distribution is adversely affected."

6. "Systems must use a metering pump, such as a positive displacement injection pump* (e.g., diaphragm pump) effectively designed and constructed of materials that are compatible with pesticides and capable of being fitted with a system interlock."

* Approved alternative to positive displacement pesticide injection pump in 6.

Alternative: Venturi systems including those inserted directly into the main water line, installed in a bypass system and bypass systems boosted with an auxiliary pump. Auxiliary pump power must be interlocked with the irrigation pump power and low pressure cut off. The line from the pesticide supply tank to the Venture must contain an automatic, quick close check valve.

7. "Do not apply when wind speed favors drift beyond the area intended for treatment."

When is field posting required? Fields must be posted if chemigated with Toxicity Category I products (those with the label signal word DANGER) which allow chemigation. The label must include the following statements:

"Posting of areas to be chemigated is required when 1) any part of a treated area is within 300 feet of sensitive areas such as residential areas, labor caps, businesses, day care centers, hospitals, in-patient clinics, nursing homes or any public areas such as schools, parks, playgrounds, or other public facilities not including public roads, or 2) when the chemigated area is open to the public such as golf courses or retail greenhouses."

"Posting must conform to the following requirements. Treated areas shall be posted with signs at all usual points of entry and along likely routes of approach from the listed sensitive ares. When there are no usual points of entry, signs must be posted in the corners of the treated areas and in any other location affording maximum visibility to sensitive areas. The printed side of the sign should face away from the treated area towards the sensitive area. The signs

shall be printed in English. Signs must be posted prior to application and must remain posted until foliage has dried and soil surface water has disappeared. Signs must remain in place indefinitely as long as they are composed of materials to prevent deterioration and maintain legibility for the duration of the posting period.

"All words shall consist of letters at least 2 and 1/2 inches tall, and all letters and the symbol shall be a color which sharply contrasts with their immediate background. At the top of the sign shall be the words KEEP OUT, followed by an octagonal stop sign symbol at least 8 inches in diameter containing the word STOP. Below the symbol shall be the words "PESTICIDES IN IRRIGATION WATER."

The above are minimum required regulations. Additional regulations may be imposed by State Legislation and should be closely checked and adhered to when chemigating.

EQUIPMENT

General. The proper equipment to be used in chemigation should be selected based on availability in the agricultural market, plus proven reliability, accuracy, dependability, safety, ease of operation and maintenance requirements.

All equipment, hoses, and accessories that come into direct contact with chemical mixtures must be resistant to all formulations of agricultural chemicals being applied, including emulsifiers, solvents, and other carriers. Hoses, seals, gaskets, and other components should be constructed of polypropylene, polyethylene, teflon, nylon, or viton. Products that contain polyvinylchloride, neoprene, butadiene, or styrene butadiene rubber are not satisfactory.

Chemical supply tanks should be constructed of materials that resist corrosion of agricultural chemicals. This would include stainless steel, fiberglass, nylon, and polyethylene.

Agitation of the chemical supply tank is recommended, and required where wettable powders, dry flowables, flowables, or other suspended formulations are being used. Mechanical and hydraulic are the two most common types of agitation.

The operator must follow strict safety procedures to prevent accidents.

Injection Metering. The chemical injection pump is the heart of the application system. Injection pumps should be accurate to within 1% of injection rate setting, easily adjustable for different injection rates, and mechanically rugged with internal and external components being constructed of noncorrosive materials. Positive displacement piston or diaphragm injection pumps are generally used for metering chemicals into pressurized irrigation systems.

Diaphragm pumps are normally preferred since they have a separating membrane between corrosive chemicals and pumping mechanism which eliminates daily maintenance, leaks to the environment. They should have built in pressure relief valve to insure against discharge line ruptures. The basic types of diaphragm pumps are cone, flat and tubular with all being used successfully in chemigation. Specific designs of the pumping mechanism and check valves should be used if pumping high viscous or slurry type materials.

Selected Equipment Specifications:

Pump. a.) Metering range should be in gallons per hour (gph). Capacity should be adjustable over full range whether operating or not. b.) Plus or minus 1% in repetitive accuracy. c.) Operating pressure - must have an internal pressure relief valve set at a maximum of 200 P.S.I. d.) Self-contained: 1.) No moving parts exposed. 2.) Diaphragm serves as separating membrane between corrosive chemical and pumping mechanism. e.) Forty to 175 strokes per minute are available, with 75 to 120 the best range. Higher range is best for chemical distribution, but can also cause excessive wear on the pump. f.) A 2-way interlock so that if either the injection pump or the irrigation pump stops, the other also stops.

Chemical Supply Tank. a.) Large enough to supply the period of application. b.) Domed top offering water shedding. c.) Completely drainable and easy to rinse and clean. d.) Built-in raised mounting plates for lid and mechanical mixer installation. e.) Closeable but vented. f.) Marked in gallons with plus or minus 2% accuracy.

Calibration Tube. a.) Sized to hold a minimum of 5 minutes of pumping, but small enough for accuracy in the amounts to be tested. b.) Completely drainable and easy to rinse and clean. c.) Covered and vented to keep out contamination. d.) Long enough to extend above the tank level to insure no accidental overflow. e.) Installed between tank and pump, or on the suction side of the pump. Injection pumps can vary in volume pumped at different pressures.

Injection Check Valve. a.) Positive closing to insure no flow of the chemical from the supply tank into the irrigation pipeline, or water from the irrigation system into the chemical supply tank. b.) Recirculating pumps may "shear" chemicals, causing separation. c.) Air agitation systems can cause separation or coagulation.

Strainer (20-50) mesh) - A 20-50 mesh/screen will prevent clogging or fouling of injection pump.

Shut OFF Valves - must be positive closing.

Fittings and Piping (for safety to operator and environment). a.) External tube connectors can be used instead of common hose barb fittings. b.) All discharge piping must withstand a minimum of 250 P.S.I.

Backflow Prevention on Main Line. Check and vacuum relief valves and a low pressure drain (anti-siphon devices) are needed in the irrigation main line. Located between the irrigation pump discharge and the place of chemical injection, they prevent drainage back into the water source and pollution of ground and surface water. The check valve must be positive closing, with a water-tight seal, and easy to repair and maintain. An inspection port should be provided to see they are functional.

APPLICATIONS AND RECOMMENDATIONS

Chemigation has been used successfully to apply most chemicals utilized in agricultural production. These include fertilizers, herbicides, insecticides and fungicides. Chemigation in research tests, demonstrations and in practice, has proven equal to or in many cases superior to conventional (ground or aerial) application techniques. Much data and tables could be included to support this but space is prohibitive. However, a few selected comparisons will be given.

Herbicides. Herbicides can be successfully applied through a moving irrigation system if adequate rates of the herbicide and irrigation water are used. The maximum rate allowed for the herbicide is normally required along with 3/4 to 1 inch of irrigation water. Results of herbicides applied to conventionally tilled and minimum tilled soils for 3 crops is given in Table 1.

Insecticides. Results of a demonstration on the control of first generation European Corn Borer with both aerial and chemigation methods are given in Table 2. Excellent control was obtained from the chemigation methods. Control of second generation corn borer by aerial application is shown in Table 3. Control by chemigation with many of the same insecticides is given in Table 4. Again, excellent results were obtained with chemigation.

The LEPA irrigation system with drop tubes in furrows led to the testing of numerous in-canopy nozzles and application techniques. Table 5 gives results of greenbug control from experimental moving in-canopy chemigation nozzles developed at the Texas Agricultural Experiment Station. Results with these nozzles are compared to control obtained from traditional overhead chemigation and aerial application. Good control was still being obtained 14 days after application with 1/16 the maximum labeled rate of Lorsban® 4E with the in-canopy treatment.

Table 6 gives Southwestern Corn Borer control results from alternate furrow and every furrow in-canopy Dipel® applications which were compared to overhead chemigation. Excellent control on most insects and with most chemicals has been experienced with this method since it directs water to the underside of leaves where a majority of insects reside. Fungicides have also been successfully applied by chemigation although no data will be given here.

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Table 1. Weed control from herbicide application by chemigation and ground application (Abernathy, Et al., 1985, Keeling, Et al., 1986).

Year	Crop	Herbicide	Rate (kg AI/ha)	Pigweed Control (Percent)			
				Chemigation		Ground Application	
				Conventional	Min-Till	Conventional	Min-Till
1985	Corn	Dual + Propazine	1.96 + 1.12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + 1.12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Soybeans	Dual + Lorox	2.22 + 1.46	95	70	100	70
		Prowl	0.78	85	65	70	55
	Cotton	Dual + Caparol	1.96 + 1.68	100	65	90	70
		Prowl	0.84	85	65	85	75
1986	Corn	Dual + Propazine	1.96 + 1.12	100	100	100	95
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + 1.12	100	85	100	85
		Propazine	1.12	100	90	95	85
	Cotton	Dual + Caparol	1.96 + 1.68	100	87	100	45
		Prowl	1.40	50	80	95	90

Table 2. First generation European Corn Borer Aerial and chemigated trials, Lentz Farm, Wray, Co. (Peairs and Pilcher, 1985.)

TREATMENT	LB. AI/ACRE	OIL	WATER	LARVAE*		TOTAL	% CONTROL
				AE	BE		
			AERIAL				
Furadan 15G	1.00	---	---	0	4	4	93
Pounce 1.5G	0.15	---	---	1	12	13	78
Ambush 2E**	0.1 + 0.1	---	2 gal.	1	16	17	71
Check	----	---	---	8	51	59	--
			CHEMIGATION				
Lorsban 4E	1.00	1 qt.	1.00"	0	2	2	98
Pounce 3.2E	0.15	1 qt.	1.00"	1	2	3	97
Lorsban 4E	1.00	---	1.00"	0	4	4	96
Pounce 3.2E	0.15	---	1.00"	0	7	7	93
Pounce 3.2E	0.15	---	0.28"	1	8	9	91
Lorsban 4E	1.00	1 qt.	0.28"	1	8	9	91
Check	----	---	0.28"	19	77	96	--

*Larvae in 40 plants: AE = above the ear, BE = below the ear.
**Two applications, 7 days apart.

Table 3. Aerially-applied insecticides for control of the second generation European Corn Borer. Bledsoe Cattle Company, Wray, Co. (Peairs and Pilcher, 1985).

TREATMENT	AI/ACRE	LARVAE*				TOTAL	% CONTROL
		AE	ET	ES	BE		
Capture 2E	0.04 (1 qt. oil)	1	2	1	1	5	95
Capture 2E	0.04	0	4	2	0	6	94
Karate 1E	0.02	1	2	2	1	6	94
Penncap M	0.75	0	2	3	1	6	94
Penncap M	1.00	1	4	0	3	8	92
Furadan 4F	1.00	2	3	4	0	9	91
Furadan 4F	0.75	3	6	2	2	13	87
Dipel 8L	2.0 pt.	6	10	3	3	22	78
Dipel 8L	1.5 pt.	7	12	4	3	26	75
Check	--	31	17	28	26	102	--

*Larvae in 40 plant: AE - above the ear; ET - ear tip; ES = ear shank; BE - below the ear.

Table 4. Chemigated insecticides for control of second generation European Corn Borer, Newton Farm, Eckley, Co. (Peairs and Pilcher, 1985).

TREATMENT	AI/ACRE	OIL	INCHES WATER	LARVAE*					% CONTROL
				AE	ET	ES	BE	TOTAL	
Capture 2E	0.08	1 qt. (soy)	0.22	0	0	0	1	1	99
Lorsban 4E	1.00	1 qt.	0.22	0	2	0	0	2	98
Capture 2E	0.08	--	0.22	0	1	0	1	2	98
Capture 2E	0.08	1 qt. (petro)	0.22	0	2	1	0	3	97
Lorsban 4E	1.00	1 qt.	0.84	0	1	1	1	3	97
Pounce 3.2E	0.15	--	0.22	1	0	0	2	3	97
Lorsban 4E**	0.5 + 0.5	1 qt.	0.22	3	1	0	0	4	96
Penncap M	0.75	--	0.22	1	3	1	2	7	93
Penncap M	0.75	1.5 pt.	0.22	0	3	1	3	7	93
Pounce 3.2E	0.15	--	0.84	1	5	2	0	8	92
Dipel 8L	1.5 pt.	1 qt.	0.22	3	2	2	1	8	92
Javelin	2.5 qt.	--	0.22	2	4	2	1	9	91
Dipel 4L	1.5 qt.	1 qt.	0.22	3	3	1	3	10	90
Dipel 8L	1.5 pt.	--	0.22	2	5	0	5	12	88
Dipel 8L	1.0 qt.	1 qt.	0.22	3	8	2	2	15	86
Check	---	--	0.22	35	27	14	28	104	--

*Larvae in 40 plants: AE = above the ear; ET = ear tip; ES = ear shank; BE = below the ear.
**Two applications, seven days apart.

Table 5. Greenbug control on grain sorghum with Lorsban® 4E, 1985.

Rate kg[AI]/ha	% Control, 3, 7, and 14 days Posttreatment								
	3 days			7 days			14 days		
	DI-C[1]/	S-O[2]/	A[3]/	DI-C	S-O	A	DI-C	S-O	A
0.57	-	-	99	-	-	99	-	-	99
0.28	99	99	78	99	99	80	97	98	63
0.14	99	97	83	97	99	85	84	96	55
0.07	99	55	-	96	67	-	81	75	-
0.035	75	-7	-	80	21	-	78	-5	-

1/ DI-C = Dynamic in-canopy spray application.

2/ S-O = Stationary overhead chemigation.

Table 6. Southwestern corn borer control with Dipel® (8L/ha) applied through in-canopy chemigation nozzles and traditional overhead chemigation nozzles, 1988.

Application Method	Percentage Plants ± S.D.				
	Infested	Tunneled	Girdled	Live Larvae	Lodged
In-Canopy (EF)1/	14.0 ± 9.6 b2/	8.0 ± 5.6 b	6.0 ± 5.2 a	10.8 ± 7.6 bc	7.2 ± 6.8 a
In-Canopy (AF)2/	12.0 ± 5.6 b	10.0 ± 5.2 b	2.0 ± 2.4 a	8.8 ± 5.2 c	2.0 ± 2.4 a
Overhead (0.26 ha-cm/ha)	7.2 ± 4.0 b	3.2 ± 2.0 b	4.0 ± 3.2 a	5.2 ± 5.2 c	3.2 ± 4.0 a
Overhead (1.29 ha-cm/ha)	38.0 ± 9.6 a	30.0 ± 9.6 a	8.0 ± 8.8 a	26.8 ± 12.0a	8.8 ± 8.4 a
Untreated Check	42.0 ± 8.4 a	28.0 ± 7.2 a	14.0 ± 12.4a	20.8 ± 8.4 ab	4.0 ± 5.6 a

1/ EF - Every Furrow

2/ AF - Alternate Furrow

3/ Means in each column followed by the same letter are not statistically different (0.05 Duncan)