TOTAL MAXIMUM DAILY LOADS (TMDL'S) IN ALFALFA — THE IMPLICATIONS FOR ALFALFA IRRIGATION MANAGEMENT

Terry L. Prichard[1]

The Maximum Daily Load (TMDL) process has far reaching ramifications for all growers of food and fiber crops. Complying with the goals set forth may restrict off site movement of waters carrying pollutants to water bodies. Alfalfa growers and other growers of primarily surface irrigated crops may find it necessary to reduce all off site movement of tail waters. This paper will address the TMDL process and possible structural and management practices needed to achieve the goals set forth in the TMDL process.

Key Words: TMDL, non- point source pollution, best management practices

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the maximum amount of pollution that a water body can assimilate without violating state water quality standards. Setting TMDLs has been required for years. It was mandated by Section 303(d) of the Clean Water Act (passed in 1972). At that time people had a more limited idea of what constituted pollution than we have now. They were picturing point source pollution something akin to a big pipe spewing undesirables into the river. We now know a whole variety of sources and activities can degrade water; widespread seemingly insignificant amounts of pollutants, which cumulatively threaten water quality and natural systems.

Non-point sources include but are not limited to septic systems, agriculture, construction, grazing, forestry, recreational activities, careless household management, lawn care, and parking lot and other urban runoff. Individually, each may not be a serious threat, but together they may be a significant threat

The TMDL Process is just that " a process" that if followed will result in meeting the mandate of the Clean Water Act. A US EPA report (US EPA, 1998) lists seven components of the TMDL program:

- Target identification: what is the problem and how can it be quantified?
- Identification of current deviation from the target or the level of pollution reduction necessary to meet the target: how different are current conditions from desired conditions?
- Source identification: where is the pollution coming from?
- Allocation of pollutant loads (or an alternative providing an equivalent demonstration of attainability of standards).
- Implementation plan: how will TMDL standards be achieved?
- Process for monitoring/assessment of effectiveness: is the implementation plan working?
- Process for TMDL revision: after data come in from BMP implementation and monitoring, are revisions in the TMDL justified?

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[1] T. Prichard, UCCE Water Management Specialist, Department of Land, Air and Water Resources, University of California Davis, 420 S. Wilson Way, Stockton, CA 95205; Email: tlprichard@ucdavis.edu

Implications for Alfalfa Irrigation Management

Alfalfa requires irrigation to produce an economic crop. The irrigation system most commonly used is surface irrigation where the soil controls the advance of water down slope and the infiltration rate. A consequence of good distribution with in the check is tail water runoff. If the runoff contains pesticides, sediment or nutrients it can be considered to be a source of non point source pollution. Additionally, winter rainfall can cause runoff containing these pollutants. In the quest to meet the specific goals set forth in the TMDL process these discharges to surface waters may be curtailed. The question is “How can this be done without cost prohibitive measures and without effecting production?: Typical surface irrigation results in about 15% tail water runoff. A four-acre foot application results in over 7 inches or 200,000 gallons per acre in runoff.

Do basic cultural practices have the potential to cause significant levels of pollution?

Studies conducted in alfalfa fields evaluating the irrigation water runoff have found high levels of applied insecticides and herbicides. A study conducted in the northern Sacramento Valley of California found that tail waters contained sufficient Chlorpyifos to cause nearly 100% water flea mortality in the standard 24 hr test. Water Flea (Ceriodaphnia dubia) is the standard invertebrate used to predict the environmental impact of pesticides. Samples were collected at the irrigation following application ranging from 22 to 66 days at different sites. Other researchers showed C dubia mortality in the tail water of Chlorpyifos treated fields after seven irrigations. Runoffs of adjacent areas treated with Pyrethroids were found to contain no residues.

A study was conducted to assess the fate of an application of herbicides, diuron and hexazinone within an alfalfa field located near Tracy, California. The field was approximately 17 ha in size entering the third season of alfalfa cultivation. The predominant soil-mapping unit was Capay clay. Based on local growers and resident recollection, ground water was shallow and located at around 4.5 m. Exact depth to ground water at the field site was measured in an area adjacent to the pond using a pressure transducer mounted in a an open ended, close fitting PVC pipe then affixed in the borehole.

Diruon and hexazinone are applied as pre-emergence herbicides to alfalfa during the dormant season in December and January to control existing winter weeds and to prevent subsequent weed germination. The climate is Mediterranean so the timing of application coincides with the rainy season and winter rains are used to incorporate the herbicide residues into soil. The method of irrigation was border check, where water is applied to the higher end of the field, advances down the length of the check, and the amount that is not infiltrated into the soil is collected at the lower end. The irrigation water was supplied via siphons from an open ditch. The water that runs off the field is denoted as tail water. Irrigation commences in the spring. Rainfall records for the month of March from a weather station located in Tracy indicated a range from 0 to 91.2 mm for the past 18 years with an average of 36.6 mm. For this study year, 1999, irrigation was initiated in late April.

Each irrigated check was 8.2 m wide by 335.4 m in length, which was equivalent to 0.28 ha. The rate of water flow onto the check was constant for each irrigation and it was measured at 795 L per minute for the first irrigation of the season and just slightly greater at 833 L gallons per minute for the second irrigation. Runoff water generated from either rainfall or irrigation was diverted from the tail end of the field to a small pond situated on the Northwest corner.

A randomized complete block design with 4 replicate blocks was utilized to compare environmental fate and efficacy among the following three main treatment effects:

1. Grower standard pre-emergence herbicide treatment of hexazinone and diuron applied at 0.56 and 1.68 kg/ha, respectively.
2. Effect of a surfactant added to Treatment #1 at a rate of 18.71 L/ha.
3. Efficacy and fate of alternative herbicides using trifluralin and paraquat applied at 0.56 and 1.68 kg/ha, respectively

Each treatment was applied to one check resulting in a total of 12 checks used for the study. Paraquat and trifluralin were tested as alternatives because there potential to move offsite would be much lower, which is based primarily on their much higher soil sorption potential, as indicated by their much higher Koc values.

Border irrigation could affect the distribution of residues because water is applied to the head of the checks and advances toward the tail. In order to measure potential spatial differences due to irrigation, each check was equally subdivided into thirds, with each third approximately 4.6 m wide by 111.6 m in length. Samples were taken from each third to represent the head, middle, and tail portions of the check.

The effect of winter rainfall and irrigation on the environmental fate of residues was determined by sampling the following media:

- Soil samples were taken from the field to the 0.9m depths in order to determine the extent of downward leaching from the site of application.
- Volume and concentration of herbicides were measured in runoff water from which an estimate of the mass lost in runoff was calculated.
- Water from the pond was sequentially sampled and surface and subsurface soil samples were obtained. Pond dimensions were measured to determine volume of water collected in the pond.
- Water table depth near the pond was measured with pieziometers located in boreholes drilled to ground water. These data were used to determine the fate of water collected in the pond.

Results

Prior to First Irrigation: The amount of water received by the plots between pesticide application and commencement of soil sampling on April 3 was 130 mm. Although location effects were not significant in the split-plot ANOVA, regression within treatments indicated residues increased from the head to tail end of the standard treatment. The distribution of residues throughout the soil profile was different between diuron and hexazinone. Very little diuron was detected beneath the first 0-69 mm depth, whereas, concentrations of hexazinone in the deeper segment were equal to those measured in the first segment. Little to no residues was measured for either herbicide in the third segment, which represented the 271-339 mm depth. Based on a comparison of their physical-chemical properties, greater movement through soil would be expected for hexazinone, caused primarily by its lower soil adsorption value (Koc) (Table 1).

Table 1. Estimates for pesticide active ingredient physical-chemical properties

Active Ingredient	Water Solubility (mg/L)	Koc (L/kg)
Diuron	42	480
Hexazinone	33,000	54
Paraquat	620,000	1,000,000
Trifluralin	0.3	8,000
Chlorpyrifos	1,180	6,070
Permethrin	6	100,000

The mass of residues recovered from the total soil core length averaged 0.58 kg/ha for diuron and 0.09 kg/ha for hexazinone. These values represented a decrease from the application day values of 66% for diuron and 79 % for hexazinone.

After Second Irrigation: The alfalfa field received two border check irrigations prior to this soil coring. The average depth of water received by the plots between pesticide application and commencement of soil sampling on June 26 was 498 mm. The magnitude of the residues for both pesticides was reduced to levels that were similar to those measured in the background samples. Statistical tests for effects of treatment and location were not significant. However, the observed patterns were similar to the previous soil coring date.

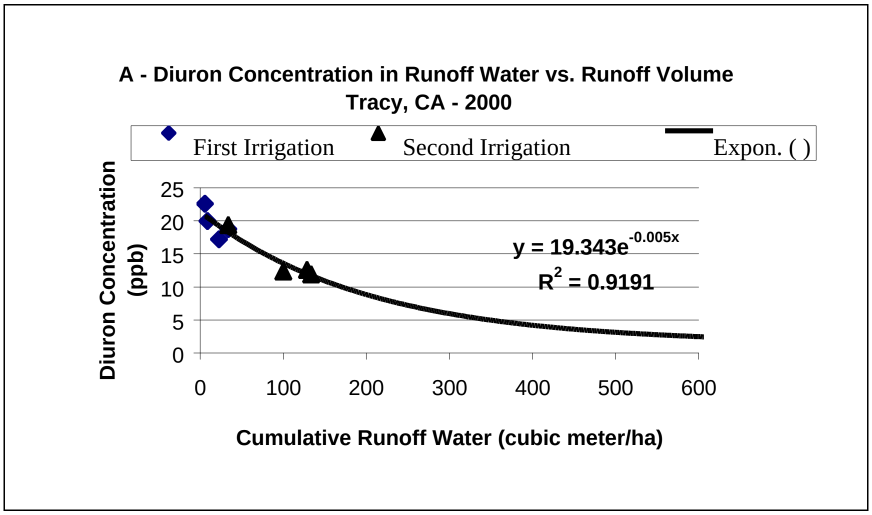
Herbicide Concentration and Mass in Runoff Water:

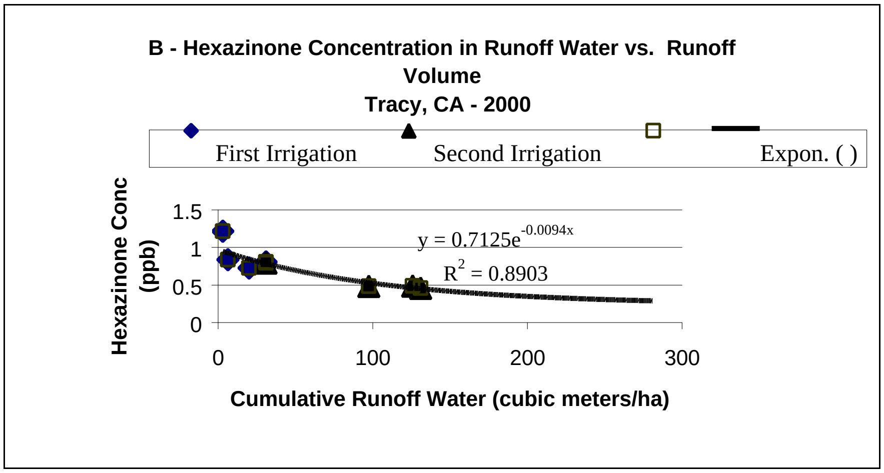
Significant differences in diuron concentration were measured between irrigations with the concentrations for the first irrigation runoff approximately twice the concentration of the second. Hexazinone concentrations also appeared greater at the first irrigation; however, the level of probability indicated only a trend (P= 0.0726). The addition of the surfactant did not significantly affect the concentration of herbicides in runoff water. The mass of both diuron and hexazinone in the runoff waters was calculated as the product of the concentration and volume of runoff water. No significant differences in mass of herbicide leaving the field were found between treatments or irrigations. Although the concentration of diuron herbicide was reduced in half from the first irrigation, the runoff volume had tripled in the second irrigation resulting in no significant differences in the mass leaving the field. The results for hexazinone were similar. No triflurilan or paraquat was detected in runoff waters.

Decline in concentration as a function of runoff volumes: The concentration of herbicide in the runoff water declines as cumulative runoff water volume increased both in a single and multiple irrigations. The initial 19L sample collected from each irrigation had a higher concentration than samples collected in subsequent sampling each irrigation. The herbicide concentration in the initial sample collected in the second irrigation was similar to samples collected the pervious irrigation with all subsequent samples being significantly lower.

Using data collected from both irrigations, a relationship between herbicide concentration in the runoff water and cumulative runoff was constructed (Figure 1). A significant relationship was found in both herbicides using an exponential fit. For diuron the model predicts 2 ppb or one tenth of the initial runoff concentration at a cumulative runoff of 460 m^3 per hectare. A reduction to one hundredth of the initial concentration would require 920 m^3 per hectare. The same type of model constructed for hexazinone concentration in the runoff water predicts 0.07 ppb or one tenth of the initial runoff concentration at a cumulative runoff of 246 m^3 per hectare and 490 m^3 at one hundredth. Essentially, hexazinone requires half the water runoff to decrease the concentration unit for unit as diuron.

Figure 1. Concentration of A) diuron and B) hexazinone measured in runoff water collected from irrigation treatments. The curve is an exponential fit through the data points.





How can growers comply with runoff restrictions and still survive?

- The answer is obviously not simple. If it were it would have already been done. The current term for practices, which mitigate the potential pollution are called "Best Management Practices." They can be structural or a management decision in nature. They are simply decisions made by the grower to minimize the impact of a specific pollutant. Listed below are typical best management practices for pesticide use:
- Practice Integrated Pest Management (IPM).
- Select pesticides that are labeled for the intended application site.
- Consider application site characteristics (soil texture, slope, organic matter).
- Consider location and conditions of wells.
- Measure accurately.
- Maintain application equipment and calibrate accurately.
- Mix and load carefully.
- Prevent back- siphoning and spills.
- Consider impact of weather and irrigation.
- Leave buffer zones around sensitive areas.
- Reduce off-target drift.

For example a change in class of control chemical such as Chlorpyifos to Pyrethroids can significantly reduce the off site movement of residuals. However, there might be additional concern for potential impacts upon beneficial insects of other pests that could require additional pesticide treatments. A switch from diuron and hexazinone to paraquat and triflurilan for winter weed control has the same effect of reducing herbicide concentrations in the tail water but at the cost of reduced efficacy.

Control of tail water runoff is an example of both a structural and management Best Management Practice. Tail waters containing pollutants can be held in temporary holding ponds and returned to that or adjacent fields. Longer-term storage can cause the waters to infiltrate the groundwater causing pollution of the underground water source. Returning the tail water to the field or adjacent fields to be used for irrigation is an option, which has worked well for sediment and pesticide mitigation.

<u>How well are the Best Management Practices (BMPs) working to bring a water body back into compliance?</u>

Where TMDLs are not met, stakeholders must develop watershed management plans that include BMPs designed to improve water quality. Monitoring is required to determine which BMPs are actually effective in improving water quality and to assess their degree of effectiveness. Although this can require a long-term commitment to high-quality discrete and continuous monitoring, the alternative is not knowing if implemented BMPs are actually working as intended to improve water quality. Without this information on BMP effectiveness, time and money may be wasted with little or no benefit to the water body.

CONCLUSION

As we know the times they are a changing. With these new challenges it will be necessary to modify existing practices to meet the goals set forth in the TMDL process. Controlling some pollutants may be as easy as a substitution of materials or as complex as complete control of tail water.