Project Title:	Water treatment technology using polyacrylamide (PAM) to mitigate sediment and pesticides in agricultural run-off and improve chlorine treatment of tailwater

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Abstract:

Leafy green growers will need to implement mitigation practices to comply with ever-stricter water quality regulations on the central coast. Sediment and pesticides in run-off from irrigated fields impairs water quality in creeks, rivers, and estuaries in most coastal valleys where vegetables are intensively produced. In addition, the leafy green marketing agreement (LGMA) now requires that farming operations that store water in open reservoirs or reuse tailwater for irrigation to maintain generic *E. coli* levels below 10 MPN/100 ml. In most cases open water reservoirs will need to be treated with chlorine to assure a low concentration of generic *E. coli*. This project developed and tested simple and inexpensive methods to minimize sediment losses from sprinkler irrigated leafy greens fields by treating the irrigation water with polyacrylamide (PAM) using an applicator designed for pressurized irrigation systems. Additionally, this project developed and tested equipment to apply PAM to irrigation runoff draining into tailwater ponds to reduce the concentration of suspended sediments and potentially improve the efficacy of chlorine to treat *E. coli* and coliform bacteria.

Objectives

Objective 1. Build and test scaled-up applicator for injecting dry PAM product into pressurized water at the well. **Deliverable:** Determine the efficacy of the full-scale PAM applicator to reduce suspended sediments in runoff for an entire field of lettuce.

Objective 2. Improve the reliability and efficacy of equipment for automatically dosing runoff flowing in farm ditches with PAM. **Deliverable:** A prototype of an automated system for dosing PAM into open ditches and data on the efficacy of this practice to mitigate suspended sediment in runoff.

Objective 3. Extend results to the leafy green industry. **Deliverables:** 1 to 2 oral presentations at grower meetings, 1 newsletter/blog article.

Procedures (Objectives 1 -2):

Objective 1. *Build and test scaled-up applicator for injecting dry PAM product into pressurized water at the well.*

The prototype PAM applicator field tested in previous years was scaled up and installed at a well located on a commercial vegetable farm (Fig. 1). The full-scale applicator consists of 14 chambers containing cartridges filled with granular PAM (Soilfloc 100D, Hydrosorb Inc.). Several updates to the original design were made to improve the ease of use and reduce pressure losses through the applicator. The final version of the applicator was designed to treat irrigation water at flow rates as high as 1500 gpm. A small booster pump diverts approximately 500 gpm of the flow through the applicator and returns the treated water to the main irrigation line. The full-size applicator was tested in vegetable fields irrigated with overhead sprinklers. Grab samples of runoff at the lower end of PAM treated and untreated vegetable fields were evaluated for turbidity and suspended sediment concentration.

Objective 2. Improve the reliability and efficacy of equipment for automatically dosing runoff flowing in farm ditches with PAM.

Three prototype PAM applicators were developed and tested for dosing PAM into ditches that drain irrigation runoff into tail water ponds on a vegetable farm during the 2022 season. The applicators were mounted onto wood frames that spanned across the drainage ditches and consisted of a hopper filled with granular PAM (Soilfloc 100D, Hydrosorb Inc.) that emptied into an electric powered auger, which slowly pushed granular PAM into a vertical “drop” tube suspended over the flowing runoff. The electric motor was controlled by a datalogger programmed to dose the flowing runoff with a concentration of 7 ppm of PAM. The flow rate in the drainage ditch was monitored using a “v” notch weir positioned upstream of the PAM applicator equipped with a float mechanism to monitor the height of runoff on the upstream side of the weir. The float was interfaced to a datalogger and a calibration curve was used to convert height of the runoff water to flow rate.

Samples of the upstream and downstream runoff water were collected from April through August during the 2022 season. During runoff events grab samples of the water were collected upstream and downstream of the PAM applicator. The downstream sampling points were located 400 to 500 ft from the PAM applicator. Samples were analyzed for turbidity and total suspended solids to determine the efficacy of the PAM treatment to settle out suspended sediment carried in the runoff. Samples were also analyzed for total P, orthophosphate, and total N.

Results and Discussion

PAM well applicator performance

Testing of the full-scale well applicator was conducted in a field initially irrigated with untreated water. Irrigations with PAM treated water were made on 11/18/22 and 11/21/22. Runoff samples were collected at various locations in the tail ditch and in the drainage ditch downstream from the treated field. Runoff was also collected from a nearby field irrigated with untreated water at the same time as the test field. Runoff was visibly clear in the tail ditch of the treated field (Fig. 2). Water samples demonstrated a substantial reduction in turbidity and suspended sediments in runoff collected in the tail ditch and drainage ditch compared to runoff from the untreated field (Fig. 3). There was some increase in turbidity and suspended sediments in the treated runoff where the tail ditch flowed at a high velocity into the farm drainage ditch. However, the sediment and turbidity concentration of the runoff decreased as the flow slowed downstream (Fig. 3). Reduction in turbidity and suspended sediments in the runoff collected in the tail ditch of the treated field averaged 95% and 92%, respectively, compared to runoff from the untreated field for the two dates. Reduction in turbidity and suspended sediments in the runoff collected in the drainage ditch below the treated field averaged 94% and 87%, respectively, compared to runoff from the untreated field for the two dates.

Further evaluation of the well applicator during the 2023 season showed similar results for the reduction in suspended sediment in runoff from sprinkler irrigated vegetable fields. Collected runoff samples have not yet been analyzed but they visually showed a significant reduction in turbidity compared to untreated fields. This observation was especially evident in the drainage ditch (Fig. 2). Additionally, a preliminary estimate of the amount of PAM used per unit volume of irrigation water treated was made by measuring the amount of PAM required to refill the cartridges. Approximately 0.75 to 1.4 lbs of PAM are used with each acre-ft of water treated. However, when the treated water recombines with the total flow from the well the concentration of PAM is further reduced by a factor of 2 to 3.

Several lessons were learned to improve the performance of the well applicator. The first was that a backflow check valve needed to be installed on the main line downstream from where outflow from the PAM applicator enters to allow the applicator to automatically drain when the well was shut off. This modification was needed because the applicator and well are positioned at a lower elevation compared to the far end of the mainline and when the well was shut off pressure from water in the main line prevented the PAM applicator from automatically draining. The second lesson was that the most efficient way to refill the cartridges was to wrap a moist cloth around the outside of the cartridges before adding PAM. The moisture from the cloth transferred to the PAM particles so that they expanded and did not leak out of the holes in the cartridge. Finally, several safety measures were identified to reduce the risk of injury when opening the PAM chambers. A pressure gauge and valve were installed on one of the chambers so that the operator can check that the system is not under pressure when removing the caps from the chambers. Also, a Tyvek suit, goggles, dusk mask, and rubber gloves are recommended for workers who are refilling the cartridges with granular PAM.

PAM ditch applicator performance

Several modifications were tested to improve the reliability of the PAM ditch applicators. Auger components were improved by using lighter weight material and a more reliable collar to join the auger to the electric motor. The stilling well size was increased to accommodate a greater volume of sediment settling out from the runoff and facilitate cleaning. When possible, weirs were installed upstream from the ditch applicators to settle out sand size particles which eventually clog the v-notch weir used to monitor the flow rate of the runoff. Finally, the height of the drop tube and v-notch were optimized to minimize maintenance. Installing the weir so the bottom of v-notch was 8-inches above the bottom of the ditch created enough force from the flowing runoff to prevent the build up sediment below the drop hose. Adjusting the length of the drop hose so that the lower end was approximately 6 to 8 inches above the top of the v-notch weir prevented runoff from splashing the mouth of the drop tube, which moistens the PAM grains and causes plugging of the drop hose.

Samples collected upstream and downstream of the PAM applicators during the 2022 season demonstrated substantial reduction in suspended sediments, turbidity, and total phosphorus (Figs. 5-6). Significant reductions in total N and soluble P in runoff were also measured (Table 1). The average reduction in suspended sediments (TSS) in the runoff was 98% during the season (Table 1). Based on the total runoff measured in a single drainage ditch during the 2022 season, an estimated 106 tons of sediment were removed.

Extension of results: The results of this project were presented at the fall meeting held by the California Leafy Green Research Board in October 2022 and at the annual meeting held in March 2023. A presentation on the results of the project were also made at the annual UC Irrigation and nutrient management meeting in February 2022. In addition, articles summarizing the use of polyacrylamide for sediment control was published in the UCCE Salinas Valley Agriculture Blog (January 2021, August 2023) and Vegetables West Magazine (Cahn et al. 2021).

Conclusions

The dry PAM applicator developed through this project was demonstrated to be easy to operate and greatly reduced suspended sediment in run-off from sprinkler irrigated vegetable fields, thereby helping growers meet water quality targets required by regulatory agencies. The design of the applicator is scalable to suit irrigation systems with a range of flow rates. The applicator also minimizes labor and product required for treating irrigation water with PAM. The auger system for dosing runoff also greatly reduced suspended sediment and turbidity in runoff, and was shown to also reduce phosphorus and nitrogen concentrations. Greatly reducing suspended sediments in the runoff using PAM applications would potentially reduce the chlorine requirement to control *E. coli* and meet LGMA food safety requirements.

Table 1. Average concentration of N, P, and sediments carried in irrigation runoff before and after treatment with the PAM ditch applicator (April – October 2022).

Sample Location	Total N	PO_4-P	Total P	Total Suspended Solids	Turbidity
	---------------------- mg/L			------------------	NTU
Upstream (untreated)	6.7	1.2	9.0	3819	4362
Downstream (treated)	2.7	0.8	1.0	60	20
% Reduction	60.1	30.9	89.0	98.4	99.5

Figure 1. Full-scale PAM applicator for treating well water.

Figure 2. Runoff from a brassica field that was sprinkler irrigated with water treated with PAM using the well applicator.

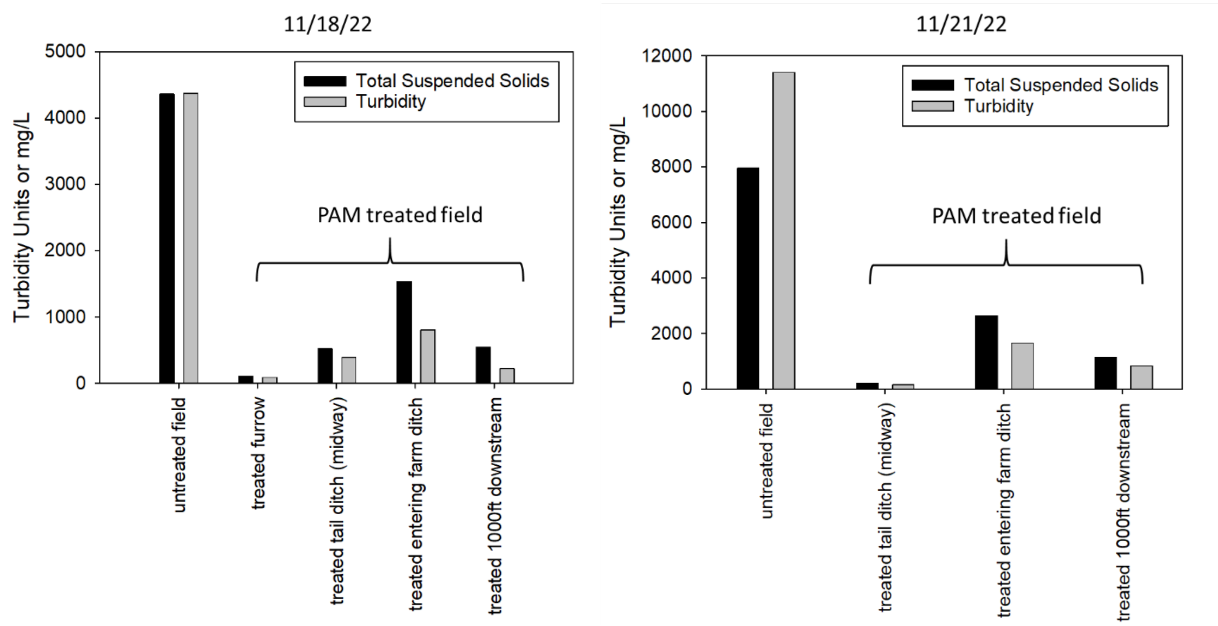

Figure 3. Concentration of suspended sediments and turbidity in runoff samples collected from different locations downstream from a vegetable field treated with the PAM well applicator and downstream from an untreated field. Samples were collected during irrigations on 11/18/22 and on 11/21/22.

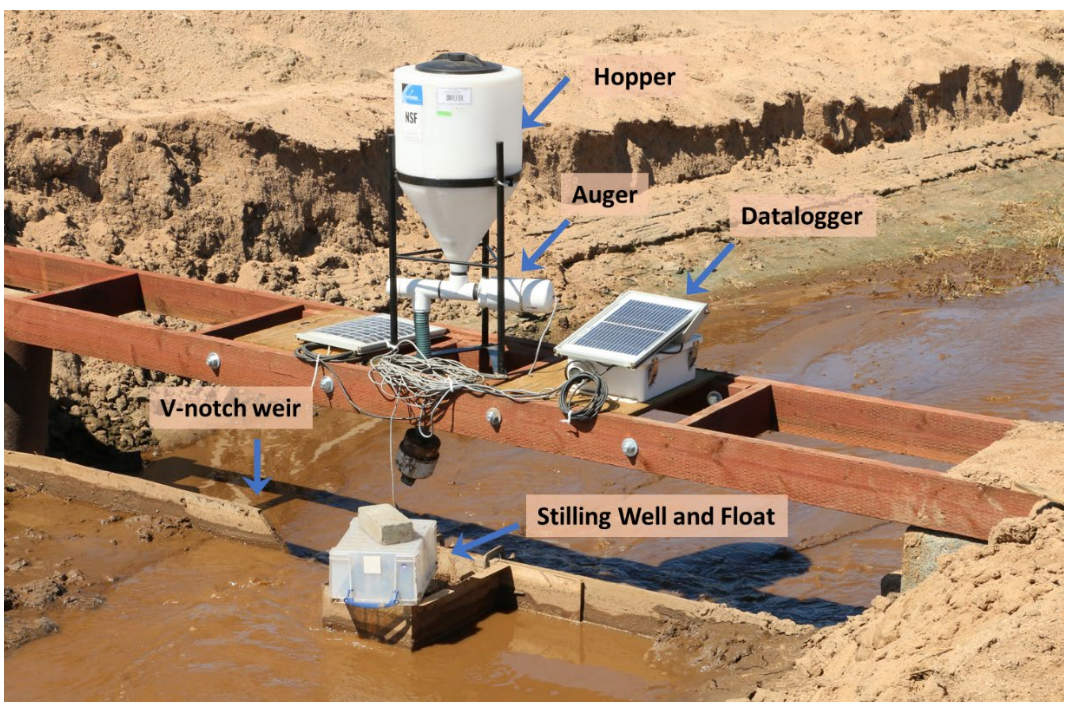

Figure 4. Applicator for dosing granular PAM into drainage ditches.

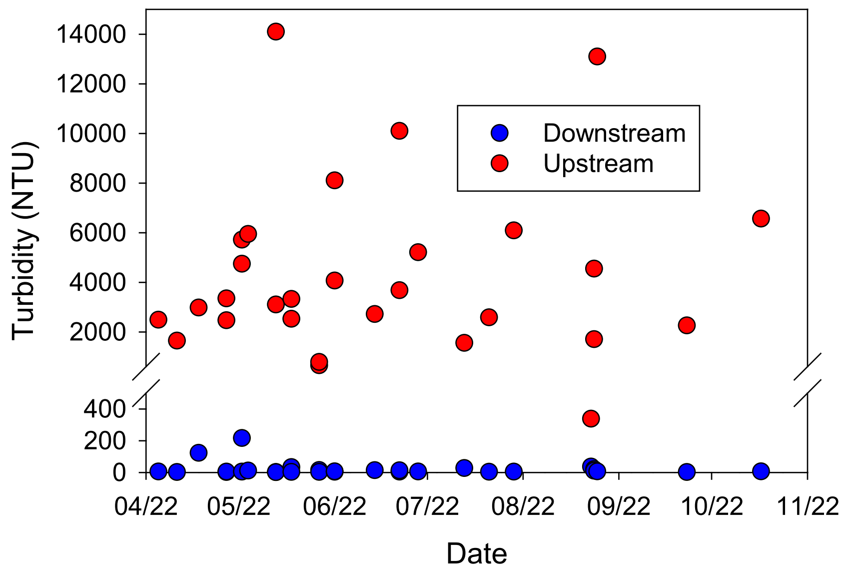

Figure 5. Turbidity of irrigation runoff upstream and downstream of the PAM ditch applicators sampled from April – October 2022.

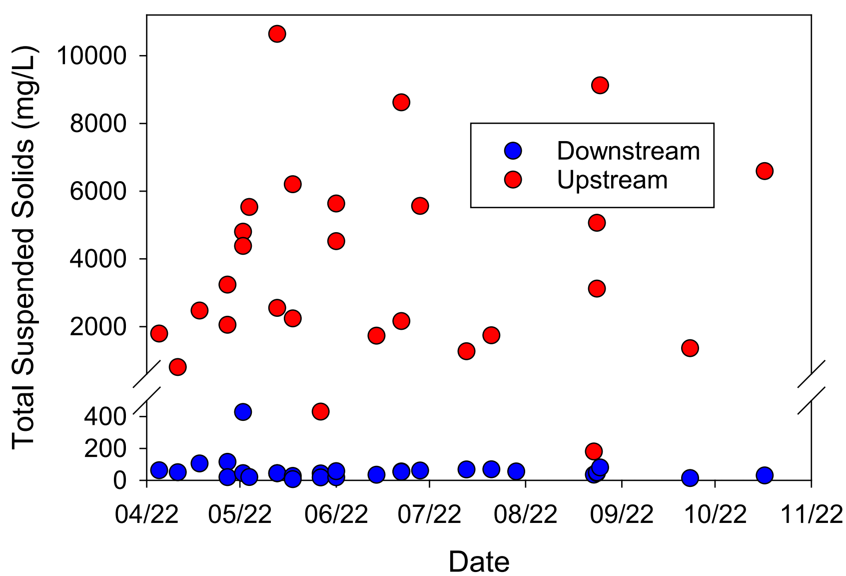

Figure 6. Total suspended solids in irrigation runoff upstream and downstream of the PAM ditch applicators sampled from April – October 2022.

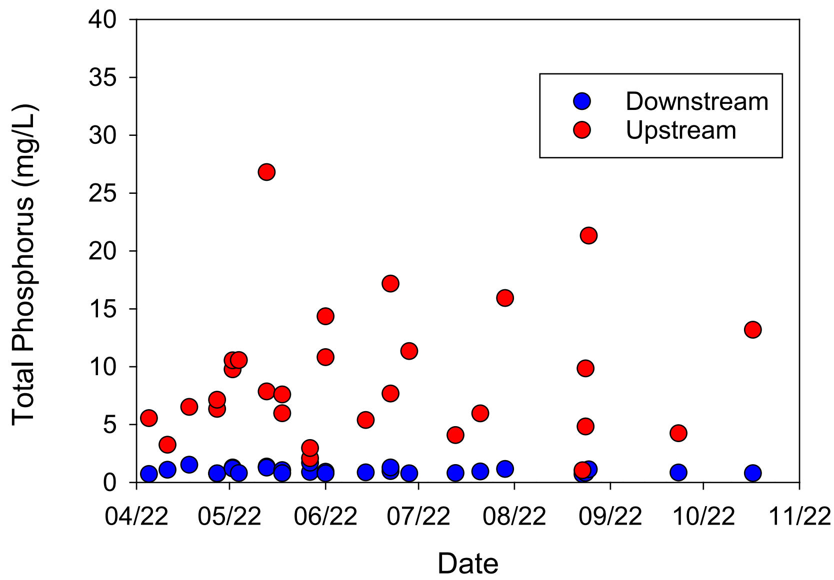

Figure 7. Total phosphorus in irrigation runoff upstream and downstream of the PAM ditch applicators sampled from April – October 2022.

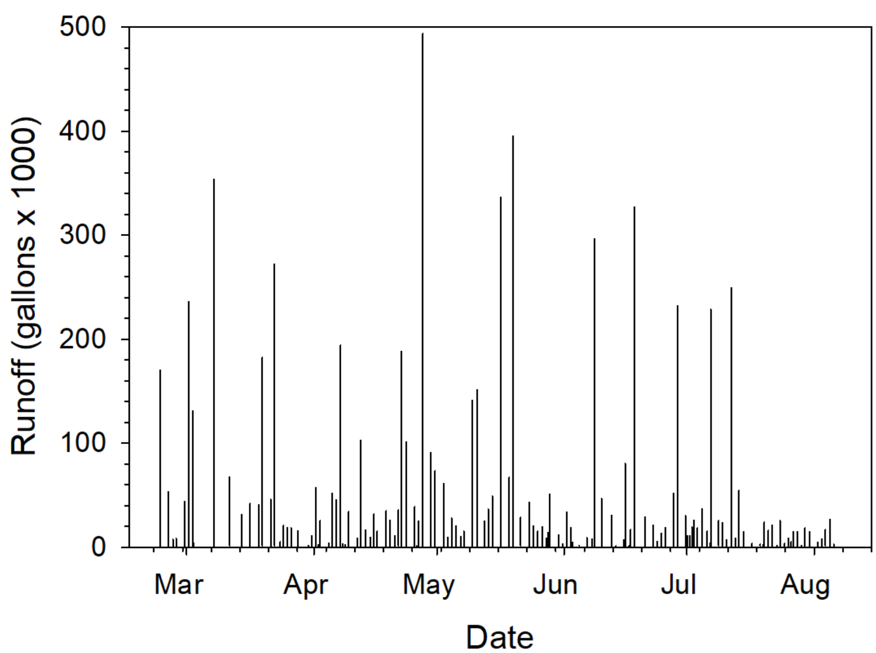

Figure 8. Runoff volumes measured at the PAM ditch applicator in a single drainage ditch. Total runoff volume measured from March – August 2022 equaled more than 7 million gallons (21.5 acre-ft).