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A Technique for Computer-controlled Toxicant Injection

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A technique has been devised to accurately inject relatively large quantities of a toxic compound into an experimental aquatic system for toxic stress experiments. This technique has proven superior to the more conventional methods of injecting the toxicant dissolved in a solvent or in an aqueous solution near saturation. In addition to the large volumetric delivery capability, it was desired to control the injection rate by an on-line monitoring and control computer system. The resulting design resolves the difficulties of:

1. test compounds exhibiting low-solubility in water;
2. highly volatile compounds;
3. rapidly biodegradable compounds;
4. compounds with a high melting point; and
5. accurately preparing and maintaining large quantities of known-concentration solutes.

This technique was devised to inject the compound, p-Cresol, at rates up to 85 mL/min into an experimental recirculating stream ecosystem. This chemical is water soluble up to 1.8 mg/mL at 25°C, and has a melting point of 23.8°C. A pre-mix at saturation would thus require metering 2800 L/h, a clearly impractical task.

The basic procedure is to meter a controlled amount of liquified pure toxicant into a carrier stream of water (from the test system or other source) that has been heated (if necessary) to a temperature greater than the melting point of the toxic compound. The carrier liquid is then released into the receiving system at a point of high turbulence.

A. The digitally-controlled injector: This scheme is easily interfaced with almost any digital computer, requiring only a timed logic level signal as control. A continuous flow pump, delivering a calibrated flow, pumps the chemical from the injector reservoir to a 3-way teflon solenoid valve, as depicted in Figure 1. The two selectable valve outputs are directed to (a) the carrier water stream, and (b) a return line to the toxicant reservoir, depending on solenoid activation. Route (a) corresponds to the solenoid "ON" condition.

Clearly, during a dosing operation, the toxicant in the carrier water stream is either zero or delivered at some maximum rate, q. The desired delivery, αq, is attained by controlling the injector solenoid to be "ON" for αT seconds of the duty-cycle period, T. This pulsing in concentration is smoothed out by the mixing in the receiving aquatic system. Accordingly, this dosing

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technique is appropriate only if the experimental system has a mixing volume, V_m, that is appreciable relative to the system flow rate, Q; i.e., the mixing time constant, $T_m = V_m/Q$, is greater than, say, 1 min. Further, the mixing volume must

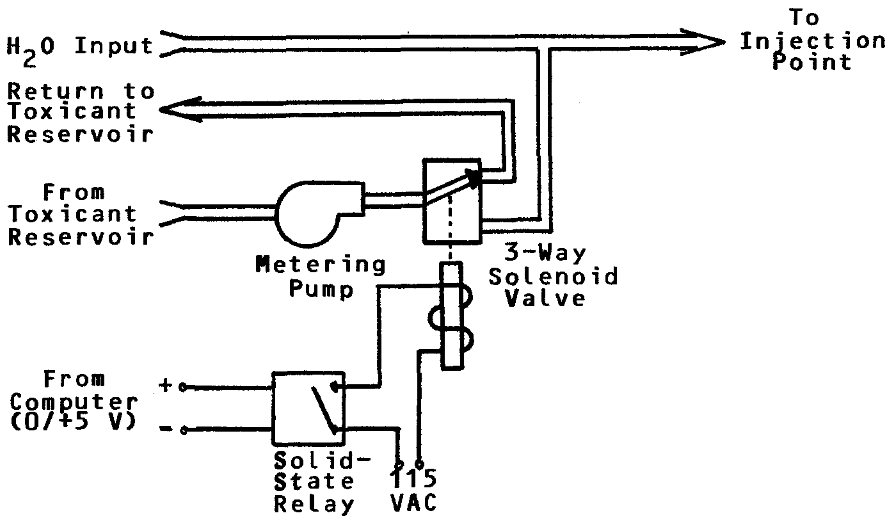

Figure 1. Computer-controlled Toxicant Injector

exhibit rather thorough mixing characteristics, as close as possible to an ideal continuously-stirred tank reactor (CSTR). For an ideal CSTR in steady state, letting T be the duty-cycle period, and $z = T/T_m$, the instantaneous fractional concentration error is bounded by

$$E_{max} = \begin{cases} \dfrac{(1 - \varepsilon^{-\alpha z})}{\alpha(1 - \varepsilon^{-z})} - 1 ; & 0 < \alpha < 0.5 \\ 1 - \dfrac{(\varepsilon^{\alpha z} - 1)}{\alpha(\varepsilon^{z} - 1)} ; & 0.5 < \alpha < 1 , \end{cases}$$

where ε is the base of natural logarithms.

Although the time-averaged concentration will be the desired value, this equation shows that the maximum deviation from this value is directly related to z, and inversely related to α. In particular, if $z < 0.1$, and $\alpha > 0.05$, the resultant mixing volume concentration will be within 5% of the desired (mean) value. Some difficulty may be experienced with doser linearity near the low end of the duty cycle commands, due to the finite response time of the solenoid valve.

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