United States
Environmental Protection
Agency

Water Engineering Research
Laboratory
Cincinnati, OH 45268

Research and Development

EPA/600/S2-85/126 Dec. 1985

EPA

Project Summary

Evaluation of Erosion Feed Chlorinators

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Erosion chlorinators were evaluated to determine their reliability in delivering a constant chlorine dose for disinfecting potable water sources. Several erosion chlorinators are on the market, but only one has been approved for use with potable water systems in the United States.

The erosion chlorinator was shown to provide unstable dose rates when operated in a continuous-flow mode. Intermittent-flow operation provided a more stable dose rate. But the greatest degree of dose stability resulted from a flow rate of 40 gpm (150 L/min) with operating periods of 10 min on and 10 min off. The use of erosion chlorinators should therefore be limited to intermittent operation. Additional studies are needed to determine the behavior of the tablets used in the chlorination process.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Disinfection is an essential barrier to the transmission of pathogens in a potable water system. Of the disinfection agents available, chlorine is the most widely used. This project was undertaken to evaluate the reliability of erosion chlorinators for delivering a constant chlorine dose under determined conditions and to evaluate their overall performance and operation in the laboratory and in the field.

Erosion feed chlorinators use pressed chlorine tablets that are eroded (or dissolved) as water passes over their surface. The unit generally consists of a canister that stores a supply of tablets and positions them in a moving stream of water and a contact chamber that provides an interface between the tablets and water. Adjustments of the chlorine dose rate are made by changing the tablet surface area immersed in the water stream. Presently, only one erosion feed chlorinator is marketed for potable water systems—the Water Sure* chlorinator (in two models), manufactured by World Water Resources, Rockville, Maryland.

The erosion feed chlorinator provides several advantages over gas chlorinators and hypochlorinators. The use of tablets reduces operator exposure to caustic chlorine dust. Tablets are easier to handle and store than are gas or powder. Safety equipment is not required, and the operation of the chlorinator does not require as much technical knowledge. However, the capabilities of the erosion feed chlorinator needed to be determined.

Test Procedures

Testing was conducted at the U.S. Department of Agriculture Forest Service Equipment Development Center, San Dimas, California, in two phases: (1) continuous flow and (2) intermittent flow.

Continuous-flow testing was conducted with two models of the Water Sure chlorinator in modified installations. Model 101 was installed to ensure continuous flow. The Model 050 installation was truncated, with only the chlorinator head installed in the test stand. Four flow rates (7, 15, 25, and 40 gpm) (26, 57, 95, and 150 L/min) and two chlorine dose

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

rates (1 and 5 mg/L) were used to evaluate performance.

Two flow/dose rate combinations were tested simultaneously for 4 consecutive days. Chlorine analyses were performed at alternating 10-min intervals. The continuous-flow testing was performed to obtain performance data, even though the manufacturer does not recommend continuous flow operation.

Intermittent flow testing was conducted with the Model 050 chlorinator. A solenoid valve was installed upstream at the chlorinator to interrupt the water flow for desired intervals (10, 30, and 60 min). The desired flow interval, or on cycle, was determined at the beginning of this test phase. Free chlorine residuals were measured with a continuous amperometric analyzer and recorded on a strip chart. Grab samples obtained from the test stand were analyzed with an amperometric titrator and compared with the continuous monitor reading at the time of sampling. The accuracy of the instruments was checked at the beginning of the test and periodically thereafter with known solutions of calcium hydrochlorite that were analyzed with the titrator and run through the analyzer. Method 408C from Standard Methods (1) was used in the analysis procedures.

Results and Discussion

Continuous-Flow Tests

Results of the continuous-flow tests were not encouraging. When first operated with fresh tablets, the chlorinator achieved a stable dose rate within 4 hr and could be adjusted as desired. After 2 days, however, chlorine concentrations fluctuated over a wide span and became uncontrollable, especially at the high rate. Tablet bridging (or jamming) in the canister occurred frequently. Examination of the chlorinator revealed condensation inside the canister on the lid, walls, and tablets. The initial theory was that moisture caused premature release of the chlorine, which entered the water stream at an uncontrolled rate. Operating the chlorinator without the lid provided only limited correction of the problem. Consistent dose rates were achieved for a week, and tablet bridging was significantly reduced; but fluctuations recurred, and the dose settings again became uncontrollable.

Presence of Moisture—

During testing, visual observations were made of the top layer of tablets in the canister each time fresh ones were added. The amount of moisture present on these tablets varied from slight to heavy, depending on the flow rate and the humidity. At a flow rate of 7 gpm (26 L/min) and low humidity, the top layer of tablets showed a slight discoloration but was dry to the touch. This condition was detected after a day's operation and could also have been caused by the higher humidities at night. At a flow rate of 40 gpm and low humidity, discoloration occurred within 3 to 5 hr, and dampness could be detected within 5 to 8 hr. As the humidity increased, the amount of moisture present on the tablets increased significantly. During periods of fog or rain, water droplets 1/16 to 1/8 in. in diameter were discovered within 2 to 4 hr after fresh tablets were added to the canister.

Visual inspections of the tablets layered throughout the canister showed that the bottom layer of tablets (1 to 1.5 in.) was saturated. Tablet erosion occurred within this layer. Above this erosion zone, moisture present on the tablets was approximately the same as that on the top layer of tablets. While there was an increase in moisture with depth, the difference did not appear greatly different.

Tablet Bridging—

Moisture present in the canister was absorbed by the tablets. This absorption in turn caused tablet bridging and may have contributed to the formation of calcium deposits on the tablets, which interfered with the release of chlorine. During testing, tablet bridging was generally associated with high moisture levels. Absorption of moisture by the tablets created a paste-like coating on the tablet surface and also caused them to swell. A slightly adhesive quality of the paste, the increased tablet size, and the inward taper of the canister caused the tablets to bond together. When still wet, the bridge was easily broken by tapping the canister; but if drying occurred, the tablets were difficult to break. Evaluation of the Water Sure showed that the tapered canister contributed to bridging. In chlorinators with untapered canisters, tablet bridging was reported to occur when swelling caused the tablet to stick in the canister. The general result of a tablet bridge was an interruption of chlorination when the tablet supply below the bridge was depleted. The saturated layer of tablets in the erosion zone was not affected by bridging. Along with service interruptions, the occurrence of bridges was detected during testing by tapping the canister and noting any significant settling of the tablets. A settling of about 0.5 in. was generally due to tablet shifting. Bridges resulted in a settlement of 1 in. or more, usually 1.5 to 2 in. Undetected bridges may also have occurred and may have been broken by the weight of the tablets above the bridge or by some disturbance to the chlorinator.

Calcium Deposits on the Tablet Surface—

Although tablet bridging was a definite interference, it was not significant in the overall performance of the chlorinators. Of more importance was the apparent deposition of calcium on the tablet surface. Observations of the chlorinator revealed that only a portion of the total water flow entered the contact chamber. The amount depended on the depth of the canister in the water stream, which varied according to the flow rate and canister adjustment. Conditions within the canister were conducive to the formation of a calcium coating, with a calcium concentration at or above the saturation level. Evaluations of the chlorinator, events occurring during testing, and the environment of the tablets supported this theory. However, tablet analysis could not be performed to confirm this behavior.

As the calcium coating covers the tablet surface, it reduces the exposure of hypochlorite ions to the water flow in the canister. Although the coating is not watertight, it acts as a barrier, reducing the amount of water in contact with the calcium hypochlorite surface and restricting the flow of hypochlorite ions from that surface. The continued formation of this barrier would result in decreased chlorine concentrations in the water stream. A periodic sloughing of portions of the barrier would temporarily expose fresh hypochlorite surfaces and cause fluctuating chlorine concentrations.

Disturbances to the Chlorinator—

Disturbances to the chlorinator resulted in increased chlorine doses. The magnitude and duration of these increases depended on the severity of the disturbance. The addition of tablets, sudden flow rate changes, canister adjustment, and movement of the chlorinator caused chlorine concentrations to increase. The most common disturbance during testing was rapping the canister to settle tablets or to release a tablet bridge.

Intermittent-Flow Tests

Intermittent-flow testing revealed improved chlorinator performance, primarily because of the interruption of water flow through the unit. The ideal conditions for this test phase and for overall operation of the chlorinator were found to be a flow rate of 40 gpm (150 L/min) with an operating period of 10-min on, and 10-min off. Increasing both the on and off cycles resulted in greater dose fluctuations, as did reducing the flow rate. The various weather conditions encountered during testing revealed that dose stability was heavily influenced by humidity levels. Erratic chlorine concentrations were observed only during periods of high humidity.

Tablet Moisture—

Visual inspection of tablets in the canister did not show that moisture levels changed substantially with flow rates. With similar humidity conditions, tablet moisture appeared constant. Surface textures, observed visually and by touch, retained the same graininess and pasty feeling. The depth of the moisture, detected by scraping the tablet surface, did not appear to change at the various flow rates. Increased moisture levels were detected only during periods of increased humidity. As moisture levels increased, the tablet surface became grainy and paste-like, but not to the degree observed in continuous-flow testing. Only during periods of heavy rain or fog did water droplets (1/16 to 1/8 in. in diameter) occur. The absorption of tablet moisture was primarily governed by humidity levels. Once tablets absorbed moisture, however, they tended to retain it. The anticipated drying of tablets during the different periods of no-flow (off cycle) was not observed to be significant. Although the tablets were exposed to air for up to 60 min, appreciable improvement in the appearance of the tablet surface was not detected. The only improvement noted was the disappearance of water droplets from the top layer of tablets, which could have been due to their absorption by the tablet. The lack of drying during the off cycles was attributed to the lack of air flow through the chlorinator. Depending on the humidity, drying occurred only when the test stand was shut down for 1 day or more. However, this procedure occasionally resulted in the bonding of tablets. Overall, less tablet moisture was observed during intermittent flow than during continuous flow. Intermittent operation reduced moisture on the tablets.

Interrupting the water flow through the chlorinator reduced the exposure of tablets to moisture by allowing the erosion zone to drain and dry, at least partially. The periodic draining of the erosion zone reduces the migraton of water into the upper tablet level by reducing the water tablet contact time. Also, any free water on the tablet surface just above the erosion zone would have drained and been exposed to air. Though tablet drying in the upper level of tablets was not apparent, it did occur in the erosion zone. After a 10-min off cycle, the tablets in the latter zone (1 to 2 in.) had a loose, granular texture that was easily dislodged and could not be measured. Regardless of the flow rate, the same texture was observed. Tablet drying in the erosion zone was attributed to this texture, which permitted a greater surface area to be exposed to a larger volume of air. In the upper tablet level, air was present only in the voids between the tablets.

Chlorinator Turbulence—

Observations of the chlorinator's operation showed an initial turbulence at the start of each on cycle, which quickly subsided to the quiescent flows observed previously. Fluctuating water surfaces and splashing accompanied the entry of water into the contact chamber. Although the event could not be observed with tablets in the canister, the initial turbulence dislodged the loose tablet surfaces. This fact was indicated by the presence of tablet residue found in the contact chamber, the mix tank, and the carbon filter. Although residue was found during continuous-flow testing, its frequency was less than that during this test phase. Tablet material may also have been dislodged by jarring of the canister at the beginning of each flow cycle. A vibration of the canister was observed at 40 gpm (150 L/min), but its strength was not great and decreased with flow so that it was not detected at 7 gpm (26 L/min).

Turbulence at the beginning of each on cycle tended to improve the performance of the chlorinator by removing loose tablet material and providing relatively uniform calcium hypochlorite surface in the erosion zone. Although turbulence was important to achieving dose stability, its impact was diminished by humidity.

Dry Weather Operation

Greater variations in chlorine concentrations generally occurred during periods of high humidity. Data patterns for dry weather operation are interrupted, but data are sufficient to indicate a relative stability of chlorine doses during intermittent operation of the chlorinator in dry periods.

Comparisons of data from periods of low humidity indicate that the drying of the erosion zone results in expanded fluctuation ranges for chlorine concentrations. Decreased flows with a 10-min off cycle did not result in a significant degradation of dose stability. The data from these periods showed stable average concentrations with deviations ranging from 0.4 to 0.8 mg/L (Figure 1). Greater fluctuations (about 1 to 1.5 mg/L) were also seen during periods of high humidity when the off cycle was increased (Figure 2).

Increasing the off cycle duration resulted in drying of the erosion zone. Although this increase was expected to be a benefit, it proved otherwise. Since the continued exposure to moisture followed by drying increased the amount of loose tablet material, the onset of the next on cycle resulted in increased exposure to calcium hypochlorite surfaces. The amount of loose material present depended on the amount removed during the previous on cycle and the rates of moisture absorption and evaporation. Fluctuating amounts of loose tablet material from cyclic buildup and removal would result in fluctuating chlorine concentrations.

Wet Weather Operation

As humidity levels increased, a number of related actions occurred to alter the impact of the off cycle. Tablets in the upper level of the canister were softened to various degrees, depending on the humidity. These tablets had varying initial erosion rates. The amount of moisture absorbed during the off cycle increased and the evaporation rate slowed. The impact of this depended on the flow rate. At 40 gpm (150 L/min), the undulating chlorine concentrations were attributed to changes in humidity levels during testing. The changes in chlorine concentration between successive on cycles were reduced by the turbulence associated with this flow rate. With reduced flow rates, the dose became erratic. The data patterns of wet weather operation resemble those seen in continuous-flow testing. These results were attributed to the interference of calcium deposits and the same moisture actions seen with continuous flow. The presence of high

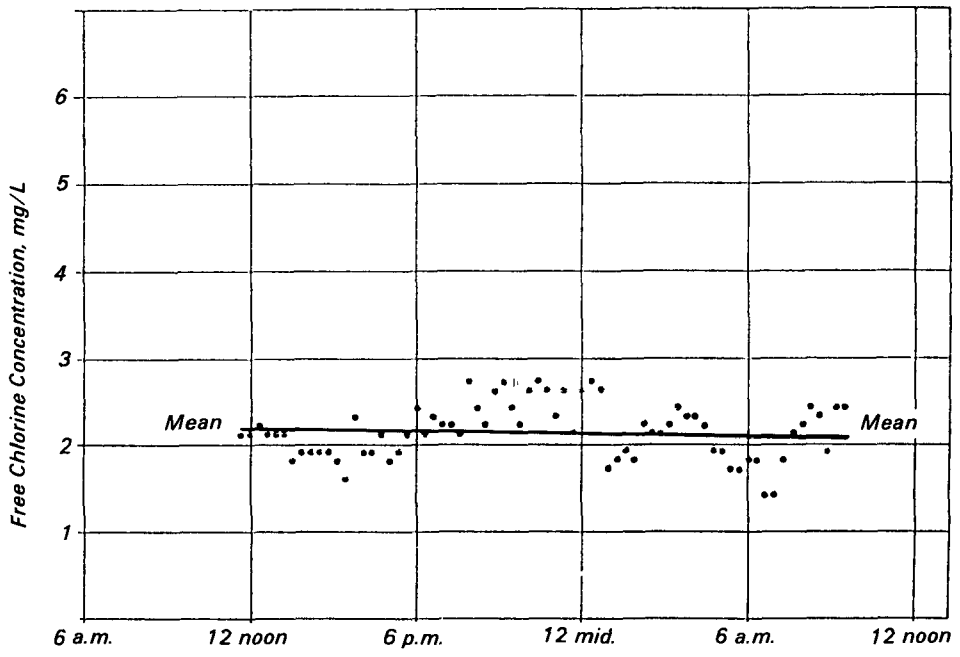

Figure 1. *Free chlorine concentrations for intermittent flow at 40 gpm with 10 min on and 10 min off.*

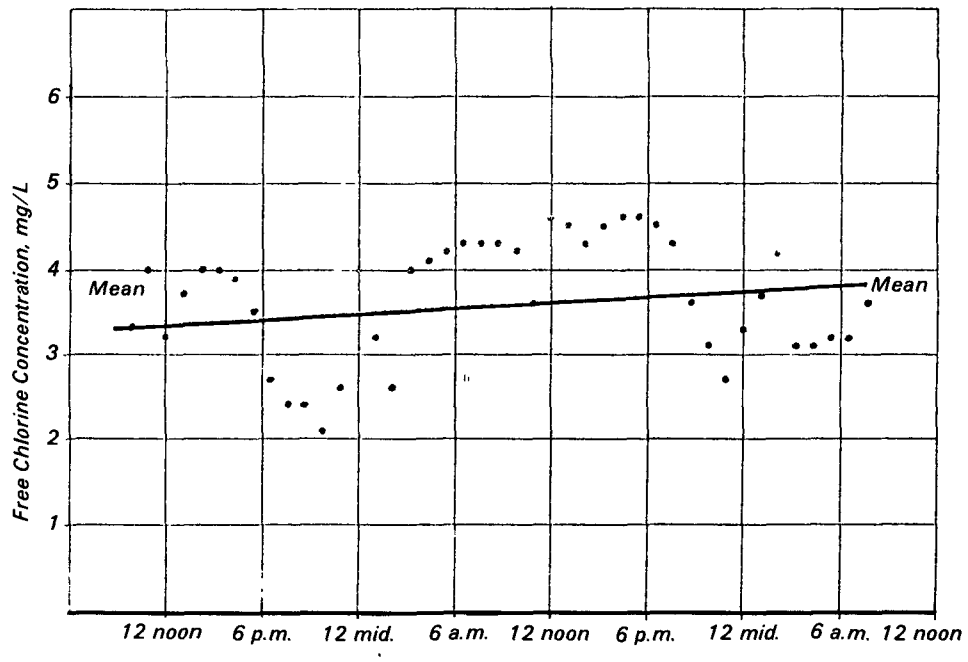

Figure 2. *Free chlorine concentrations for intermittent flow at 40 gpm with 10 min on and 60 min off.*

humidity results in operating conditions similar to those occurring with the continuous-flow mode when the flow rate is reduced.

Conclusions

1. When operated in a continuous-flow mode, erosion chlorinators provided unstable dose rates. Impaired performance resulted from moisture-induced tablet bridgng and the apparent formation of calcium deposits on tablets, which interfered with the release of chlorine. The continuous flow of water through the chlorinator caused elevated moisture levels in the tablet supply. Elevated humidity during the test period increased the adverse impacts of moisture. In accordance with the manufacturer's recommendation, these chlorinators should not be used for continuous-flow applications.
2. Intermittent flow operation of the erosion chlorinator yielded better results than continuous-flow operation. Although chlorine dose fluctuations occurred with elevated humidity, the impacts were mitigated by increased flow rates and short off cycles. The greatest degree of dose stability resulted from a flow rate of 40 gpm (150 L/min) with operating periods of 10-min on and 10-min off. Reduced flow and increased off cycles caused increased dose fluctuations, although long-term average chlorine concentrations generally remained fairly stable.
3. The greatest adverse impact on chlorinator performance was moisture in the tablet canister. All operating characteristics encountered during both test phases were attributable to the presence or absence of elevated tablet moisture.

The full report was submitted in fulfillment of Interagency Agreement No. AD-12-F-2-A201 by the U.S. Department of Agriculture Forest Service under the sponsorship of the U.S. Environmental Protection Agency.

☆U. S. GOVERNMENT PRINTING OFFICE:1986/646-116/20728

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The complete report, entitled "Evaluation of Erosion Feed Chlorinators," (Order No. PB 86-118 882/AS; Cost: $9.95, subject to change) will be available only from:
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