# LINEARITY OF THE RELATIONSHIP BETWEEN CONCENTRATION AND CONTACT TIME FOR STERILIZATION WITH CHLORINE DIOXIDE GAS (ID #8)

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## Abstract

**Objectives:** Discuss the linear relationship between concentration and contact time for achieving 6-log sporicidal kill with chlorine dioxide (CD) gas.

**Method:** 6-log biological indicators will be used to test the efficacy of chlorine dioxide gas when the overall dosage is held constant but the concentration and contact times are varied. Chlorine dioxide gas concentrations will range from 72 ppm up to 7200 ppm with the overall exposure dosage held steady at 720 ppm-hr.

**Results:** Preliminary data has shown that the concentration of chlorine dioxide gas used does not affect the overall efficacy of the sterilization cycle as long as the overall exposure dosage of 720 ppm-hr has been met. The study is ongoing.

**Conclusion:** The overall exposure dosage is the determining factor of sterilization cycle efficacy when using chlorine dioxide gas. Any concentration of gas can be used as long as it is held for the proper amount of time to achieve the correct overall exposure dosage.

**Outcomes:** Applying these findings to their own applications, would allow for faster cycle times or cheaper cycle costs depending on the parameters used.


## Equipment Used

- **1 Minidox-M CD Gas Generator**
  - **Control by PPM-Hrs**
- **17 cu ft Isolator (2 glove)**
- **NAMSA Spore Strips TCDS-06**
  - **Tyvek wrapped paper carriers**
  - ***Geobacillus Stearothermophilus (Lot # S94001, S86104, S84102)***
- **Namsa Color Change Culturing Media (Lot # GM004986)**
- **Incubation at 57 Deg C for 36 hours**
- **BSC Scrubber (remove CD gas)**



## Background Dosage / PPM-Hr Explanation

Dosage is described as an exposure at a concentration multiplied by an amount of time, typically hours (Hrs). For chlorine dioxide this is referred to as PPM-Hrs. To determine the PPM-Hrs the concentration in PPM is accumulated every minute. This accumulation then accrues PPM-Hrs.

**Standard sporicidal cycle parameters are:**

**RH - 65% with 5 minutes of condition time**

**CD Concentration - 1mg/L**

**CD Exposure time – 2 hrs**

**PPM calculation for 1mg/L**

**PPM = (mg/M$^3$) (24.45) / Molecular Weight**

**PPM = (mg/L) (1000) (24.45) / Molecular Weight**

**CD ppm = (1.0mg/L) (1000L/M3) (24.45) / 67.5**

**CD ppm = 362.2**

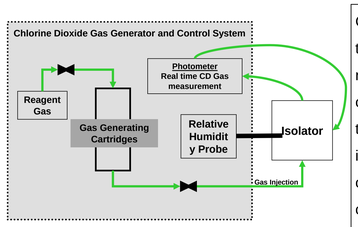
**Exposure Contact Time (CT)**

**Exposure CT = 362ppm * 2 hrs**

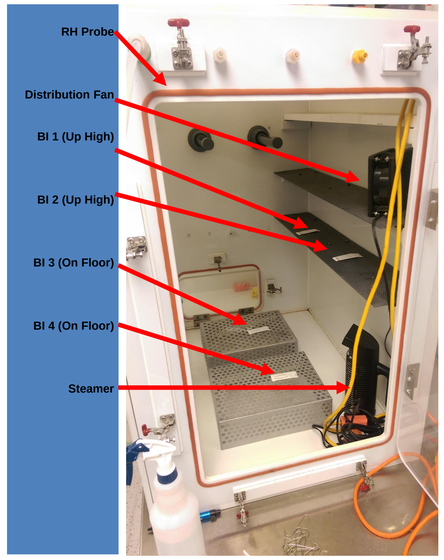
**Exposure CT = 724 ppm-hrs**

**24.45 = volume (liters) of a mole (gram molecular weight) of a gas at 1 atmosphere and at 25°C.**

The diagram below shows the gas production and control schematic.




CD gas is injected at 20LPM until the target concentration is reached. When this occurs the concentration is maintained until the target dosage (720 PPM-Hrs) is reached. At that point the chamber is aerated until the chamber is safe to remove the BI's (less then 0.1ppm)



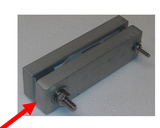

### Previous Results using *bacillus atrophaeus* spore strips*

The following table summarizes previous dosage data using SGM *bacillus atrophaeus* spore strips and SGM Releasat color change culturing media.

| ppm-hrs | mg/L | RH | Condition Time | Results |
|---|---|---|---|---|
| 450 | 1 | 65 | 5 | 0/3, 3/3, 3/3, 2/3 (N/A) |
| 550 | 1 | 65 | 5 | 0/3, 1/3, 0/3, 2/3, 0/3, 0/3 (0/1, 0/1, 0/1, 1/1, 1/1, 0/1) |
| 600 | 1 | 65 | 5 | 1/3, 0/3 (0/1, 0/1) |
| 550 | 1 | 65 | 30 | 0/3, 0/3, 1/3, 3/3, 3/3 (0/1, 0/1, 1/1, 1/1, 0/1) |
| 600 | 1 | 65 | 30 | 1/3, 0/3, 0/3, 1/3 (0/1, 1/1, 0/1, 1/1) |
| 720 | 1 | 65 | 5 | 0/3, 0/3, 0/3 (0/1, 0/1, 0/1) |

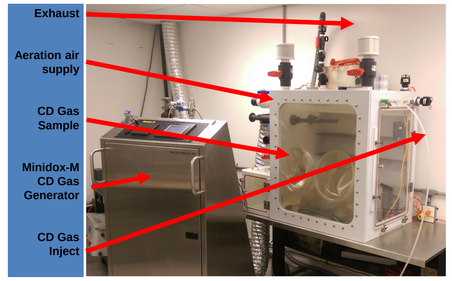
The following table shows the same PPM-Hrs used at various chlorine dioxide gas concentrations using *bacillus atrophaeus* spore strips.

| ppm-hrs | mg/L | RH | Condition Time | Results |
|---|---|---|---|---|
| 720 | 1 | 65 | 5 | 0/3, 0/3, 0/3 (0/1, 0/1, 0/1) |
| 720 | 5 | 65 | 30 | 0/3, 0/3, 0/3 (0/1, 0/1, 0/1) |
| 720 | 10 | 65 | 30 | 0/3, 0/3, 1/3 (0/1, 0/1, 0,1) |
| 720 | 20 | 65 | 30 | 0/3, 0/3, 0/3 (0/1, 0/1, 0/1) |



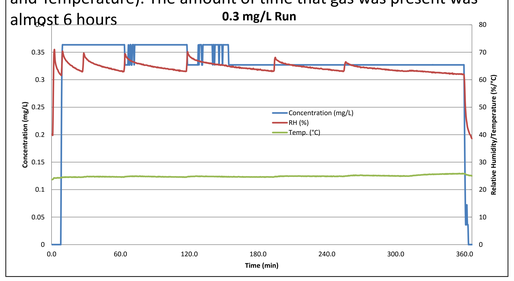
Results in parentheses are from BI Challenge Fixture. Test fixture was used to mimic small gaps (0.185″ [4.7mm])

* Presented at 54th annual ABSA conference, 2011, Effects of Relative Humidity, Concentration, and Exposure Time on the Efficacy of Chlorine Dioxide Gas Decontamination, Mark A. Czarneski



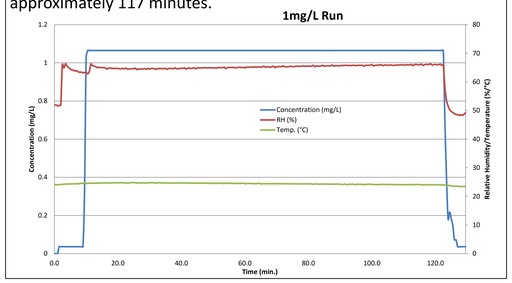

### Cycle Chart 0.3mg/L

The below cycle diagram shows the parameters (Concentration, RH and Temperature). The amount of time that gas was present was almost 6 hours



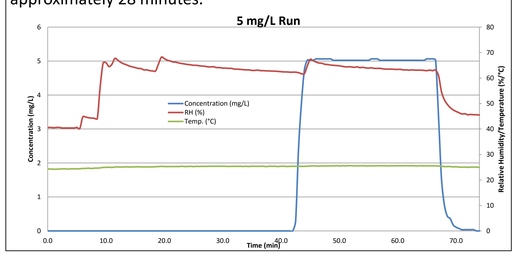

### Cycle Chart 1.0 mg/L

The below cycle diagram shows the parameters (Concentration, RH and Temperature). The amount of time that gas was present was approximately 117 minutes.



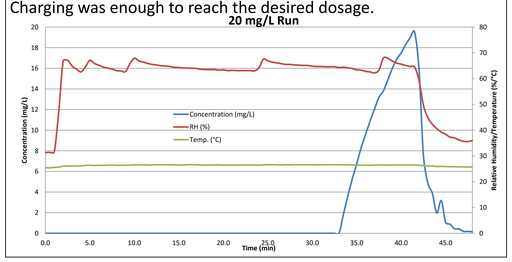

### Cycle Chart 5.0 mg/L

The below cycle diagram shows the parameters (Concentration, RH and Temperature). The amount of time that gas was present was approximately 28 minutes.




### Cycle Chart 20.0 mg/L

The below cycle diagram shows the parameters (Concentration, RH and Temperature). The amount of time that gas was present was approximately 14 minutes. Cycle never reached exposure. Charging was enough to reach the desired dosage.




### Results

The following table documents the required dosage to achieve kill with $10^6$ geo*bacillus stearothermophilus* spore strips.

| Target ppm-hrs | Actual ppm-hrs | Target Concentration mg/L | Condition % RH | Condition Time Minutes | Biological Indicator Results (positive / total) |
|---|---|---|---|---|---|
| 720 | 723 | 0.3 | 65 | 5 | 0/4 |
| 720 | 723 | 0.5 | 65 | 5 | 0/4 |
| 720 | 734 | 1 | 65 | 5 | 0/4 |
| 720 | 735 | 5 | 65 | 30 | 0/4 |
| 720 | 761 | 10 | 65 | 30 | 0/4 |
| 720 | 751 | 20 | 65 | 30 | 0/4 |

### Discussion

During large facility decontamination, many times the target concentration can not be reached due to loss, consumption, absorption or reaction with organic load. When this occurs the cycle can still be successful if this lower concentration is held for extended periods and therefore still have a successful cycle.

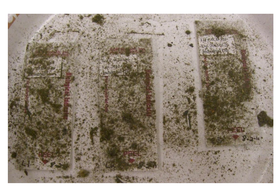
Decontamination cycles are typically set for a certain concentration at a certain time or inject a certain amount and hold it for a specific time. This exposure-concentration time can be calculated to a dosage. The question becomes, is this dosage the same for various concentrations. Does concentration affect the efficacy? Does time affect the efficacy? To test this, experiments were performed at various chlorine dioxide gas concentrations (0.3, 0.5, 1, 5, 10 & 20 mg/L) with BI's exposed to various exposure times with each cycle having a fixed target dosage of 720PPM-Hrs. What was found was that concentration did not matter and overall dosage was more important. A dosage of 720 was enough to get good results regardless of concentration.

What costs more $$, consumables or downtime? For many facilities the down time is more costly and others, it is the consumable cost. The data here shows that consumable usage can be reduced, but this will increase the downtime. If long downtimes is bad than increased concentrations can be used, but this will increase the consumable usage and consumable costs.

### Dirty Data – How Clean is Clean

Many times the question gets asked, How clean is clean. The first steps of a decontamination should be to clean. This cleaning step removes bioburden or organic load that many decontaminating agents have trouble penetrating. Many times facilities are not cleaned that well and there remains a dust layer on surfaces. A test was performed using spore strips exposed to chlorine dioxide gas. The spore strips were placed on a surface and then covered with dirt from the office vacuum cleaner (see pictures below). These BI's were then exposed to the standard cycle of 1mg/L for 720 ppm-hrs.

The results were that all 6 BI's were killed.



## Conclusions

The overall exposure dosage is the determining factor of sterilization cycle efficacy when using chlorine dioxide gas. Any concentration of gas can be used as long as it is held for the proper amount of time to achieve the correct overall exposure dosage. All runs performed had complete kill of all BI's regardless of concentration. For example the 20 mg/L run had the shortest gas time (14 minutes) and 0.3mg/L had the longest gas time (355 minutes). This shows that the overall goal of an exposure is to achieve a certain dosage (720ppm-hrs) regardless of the concentration or exposure time. This reduced concentration can save a facility consumable cost, but it does increase the cycle time; which some facilities may find not worth the cost.