

LAB #4

BENCH-SCALE JAR TESTING FOR THE REMOVAL OF MICROBIAL INDICATORS BY COAGULATION

Introduction

The fundamental purpose of water treatment is to provide safe drinking water to consumers. The water should be free from microbial and chemical contamination, which may cause adverse health effects. In 1890, George Fuller and his associates implemented a well-known water treatment process including coagulation (chemical addition and rapid mixing), flocculation, sedimentation, and filtration (Logsdon *et al.*, 1999). In combination, these treatment processes became known as the *conventional water treatment process*. Later, disinfection was added to the conventional water treatment train, thereby establishing the concept of *multi-barrier protection*. The operation of each of the units (coagulation, flocculation, sedimentation, filtration, and disinfection) collectively contributes to the quality of treated water.

Coagulation and flocculation processes involve the aggregation of small particles and the subsequent formation of large aggregated particles in the water (Letterman *et al.*, 1999). These larger particles, or flocs, are then removed from the water via gravity during sedimentation. These processes are generally designed to remove suspended particles, such as natural organic matter (NOM), but have also proven to be a successful means of removing some microorganisms.

There are four mechanisms that cause relative motion and the resulting collisions between particles. These include: Brownian diffusion, velocity gradient in laminar flow, unequal settling, and turbulent diffusion (Letterman *et al.*, 1999). During coagulation, rapid (flash) mixing is employed to disperse the coagulants (e.g., alum, ferric chloride, or polymer). During this period of high intensity mixing, velocity gradients and turbulence promote particle motion, such that the coagulants are evenly distributed throughout the reactor. Flocculation is used to initiate particle aggregation using lower mixing intensities. Finally, Brownian diffusion, unequal settling, and turbulent diffusion allow the particles to settle out of solution during the sedimentation period. Factors that influence sedimentation include: size, shape, and weight of the floc; water viscosity and temperature; and design parameters such as detention time, surface overflow rate, and flow rate (Crittenden *et al.*, 2005).

In water treatment plants, the optimal treatment conditions for coagulation are determined using a jar test apparatus to optimize the removal of organic matter. During this lab, we will use the jar test apparatus to evaluate the optimal treatment conditions for the removal of indicator microorganisms.

Procedure

Jar Test

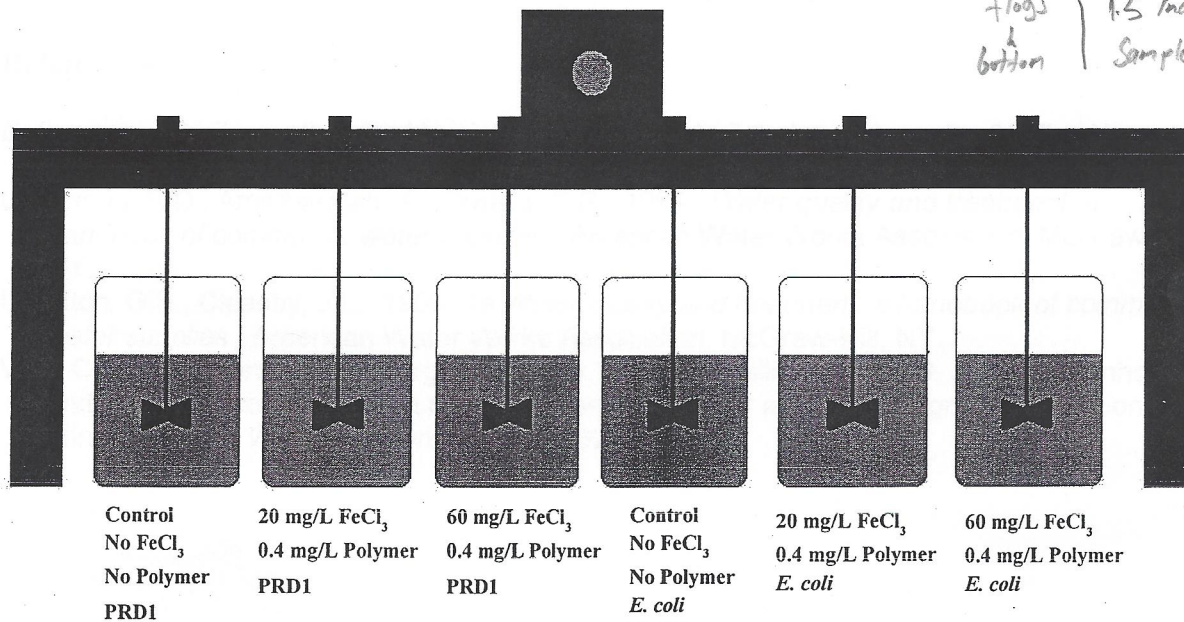
ADD: concentration  
Alum, magnesium chloride, cationic polymer  
Polymer: lower concentration  
help coagulant to be more appropriate and better

The Phipps & Bird (Richmond, VA) jar test apparatus that will be used for this experiment features six square 2-L acrylic beakers and variable paddle speeds ranging from 0 to 300 rpm. Each jar will contain 1.5 L of raw water seeded with the bacteriophage PRD1 and the bacteria *E. coli*. The jar testing protocol is based on that described by Volk *et al.*, 1999. After addition of the ferric chloride coagulant and the cationic polymer (at the concentrations shown in the figure below), rapid mixing at 100 rpm should be initiated for 1 minute. The mixing should be slowed

rapid

slow

to 40 rpm for 10 min., followed by 20 rpm for 10 min. for the flocculation stage: Mixing should then be stopped and the jars should be allowed to settle for 30 minutes.



### Sample Collection and Assay

Samples will be collected from the center of each jar near the water surface. The samples must be collected slowly and carefully to avoid disturbing the settled flocs.

The samples collected from the first three jars will be assayed for the bacteriophage P22 using the double agar layer technique described in Lab #3. The samples from the last three jars will be assayed for the bacteria *E. coli* using the spread plate technique described in Lab #1.

### Questions

1. Describe the importance/applications of the jar test technique for environmental engineers. 2 pts
2. Briefly describe the role of each of the processes in the conventional water treatment train (coagulation, flocculation, sedimentation, filtration, and disinfection) and how they may affect the removal/inactivation of microorganisms. 5 pts
3. Why are different mixing speeds employed for coagulation and flocculation processes? 2 pts
4. How is it possible to assay for one certain microorganism from an environmental sample that may contain many different types of microbes? 2 pts
5. Based on your previous knowledge, would you expect viruses or bacteria to be more efficiently removed by coagulation processes? Why? How does this compare with your actual findings? 2 pts
6. Name three commonly used coagulants. Many coagulants are multivalent cations. Why is this important? 4 pts

7. How do you think the following factors would affect microbial removal during coagulation: water turbidity, coagulant dose, pH? Explain. 3 pts.

### References

- Crittenden, J.C.; Trussell, R.R.; Hand, D.W.; Howe, K.J.; Tchobanoglous, G. 2005. *Water treatment: principals and design, 2<sup>nd</sup> Ed.* John Wiley & Sons, NJ.
- Letterman, R.D.; Amirtharajah, A.; Omelia, C.R. 1999. *Water quality and treatment: a handbook of community water supplies.* American Water Works Association, McGraw-Hill, NY.
- Logsdon, G.S.; Cleasby, J.L. 1999. In *Water quality and treatment: a handbook of community water supplies.* American Water Works Association, McGraw-Hill, NY.
- Volk, C.; Bell, K.; Ibrahim, E.; Verges, D.; Amy, G.; Lechevallier, M. 1999. Impact of enhanced and optimized coagulation on removal of organic matter and its biodegradable fraction in drinking water. *Water Resources.* 34:12:3247.