



Based on the small-scale experiments we conducted in lab, we calculated a few values that will be useful in scaling up our process to a pilot-plant size. Shown above is a simple process flow diagram (PFD) for a pilot scale wastewater treatment process utilizing our encapsulated bacteria. Wastewater is pumped through a heat exchanger and into a reactor packed with encapsulated bacteria where it is remediated. In practice, the remediation would be most suited to take place in a packed tower. In the PFD this tower is approximated as a plug flow reactor (PFR). Another simplifying assumption is that only mercury species and water is present in the wastewater stream. In practice, if the plant were to remediate a waste stream from an industrial plant, for example a chlor-alkali plant, additional steps will have to be added to remove other species (e.g. chlorine) and alter pH. Additionally, it should be noted that addition of a recycle stream can increase methylmercury conversion without requiring additional encapsulated bacteria or a larger reactor.

To start, we will assume that **0.1 m<sup>3</sup>/h** of wastewater is to be remediated. This value is within the range of flow rates used in conventional pilot plant bioreactor remediation processes.<sup>1</sup> The flow rate can be related to the volume of the packed bed by the following equation,

$$\tau = \frac{V}{v}$$

where  $\tau$  is the residence time,  $V$  is the volume of the packed bed and  $v$  is the flow rate. The residence time required to complete remediation depends on the number of encapsulated *E. Coli* and the concentration of methylmercury in the wastewater stream. We have completed time point studies that showed it takes **8 hrs** to completely remove water contaminated with **1 mg/L** of methylmercury. Although the number of immobilized *E. Coli* will be much higher in the scaled-up plant compared with our small scale studies, a residence time of 8 hrs can be used as a first approximation to err on the side of longer time. With a flow rate of 0.1 m<sup>3</sup>/h and a residence time of 8 hrs, a **0.8 m<sup>3</sup> packed bed** is therefore required.

Assuming a cylindrical geometry and a length to diameter ratio of 5, a 0.8 m<sup>3</sup> packed bed would have a **diameter of 0.6 m** and a **length of 2.8 m**.

Another value important to the scaling-up of this process is the pressure drop across the packed bed. This value is useful as it contributes to friction losses within the system and, when pipe diameters and

lengths for the final system are known, can be used to size the pump. The pressure drop across a packed bed is given by the Ergun equation

$$\Delta p = \frac{150\mu v' L}{D_p^2} \frac{(1 - \epsilon)^2}{\epsilon^3} + \frac{1.75\rho(v')^2 L}{D_p^2} \frac{1 - \epsilon}{\epsilon^3}$$

where  $\mu$  is the dynamic viscosity of the fluid in the bed,  $v'$  is the superficial velocity of the fluid,  $L$  is the length of the packed bed,  $D_p$  is the diameter of the particles,  $\epsilon$  is the void fraction and  $\rho$  is the density of the fluid.

The void fraction for a packed bed is defined as

$$\epsilon \equiv \frac{\text{volume of voids in bed}}{\text{total volume of bed}}$$

This value is obtained experimentally, but for a first approximation a value of **0.4** can be used for random packing of spheres.<sup>2</sup>

From our SEM images, we know the average particle diameter of our beads is **0.2 mm**. Since the fluid passing through the bed will be mainly water, the density is **1000 kg/m<sup>3</sup>** and the dynamic viscosity is **0.001 Pa•s**.

Solving the Ergun equation with the above values yields a **pressure drop of 5972 Pa**. Dividing by the density of the fluid, this value corresponds to a friction loss in the packed bed of **5.972 J/kg**. In terms of friction losses this value is not large enough to indicate that pumping a fluid through the packed bed will be very difficult.

In conclusion, based on data from our time point studies and SEM characterization of our encapsulated bacteria, it would be feasible to construct a pilot scale methylmercury remediation plant to remediate 0.1 m<sup>3</sup>/h of water containing up to 1 mg/L of methylmercury.

Additionally, a small scale device can be envisioned for household use in contaminated areas. Our system was tested to successfully remediate at least 1mg/L of methylmercury within a 5 hour time period. Water entering these homes will likely have methylmercury concentrations a hundred-a thousand fold lower than 1 mg/L. Based on our time-point degradation studies, a filter for this concentration level would need smaller residence times and consequently a smaller volume. Therefore, a filter using encapsulated bacteria on the scale of domestic water softener filters is possible.

## References

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1. I. Wagner-Dobler, et. al. "Removal of Mercury from Chemical Wastewater by Microorganisms in Technical Scale". Environ. Sci. Technol. 2000, 34, 4628-4634
2. [http://en.wikipedia.org/wiki/Random\\_close\\_pack#For\\_spheres](http://en.wikipedia.org/wiki/Random_close_pack#For_spheres)