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Toxicity of Polychlorinated Biphenyls (PCBs) in Biosolids from a Municipal Wastewater Treatment Plant

Chiara Draghi (Centers for Disease Control and Prevention, GA, USA)
Natasha Andrade and ***Birthe V. Kjellerup*** (University of Maryland, College Park, MD, USA)

Background/Objectives. Polychlorinated biphenyls (PCBs) are persistent organic pollutants (POPs) that were applied in industrial products such as electrical coolants and flame retardants from the 1930s to the 1970s, when they were banned. PCBs are environmental contaminants that are not easily degraded in nature, where they due to their hydrophobic nature adsorb to sediment and soil and bioaccumulate in the food chain causing detrimental health effects. PCBs are present in wastewater even though PCBs have a low solubility (0.0027-0.42 ng/L) in water due to their hydrophobic properties. Therefore, PCBs can mainly be found adsorbed to particles and in the biosolids fractions in wastewater treatment plants (WWTP). At an undisclosed American WWTP, the wastewater undergoes advanced biological treatment (nitrification/denitrification) for removal of organic matter and nitrogen in addition to chemical phosphorous precipitation. The dewatered sludge is digested anaerobically for methane production before the biosolids are dried, pelletized and sold as a commercial product. The use of biosolids recycles valuable nutrients in the form of carbon, nitrogen and phosphorous that all are beneficial for soil enhancement and plant production. However, this application might unintentionally provide toxic contaminants (such as PCBs) present in the biosolids thus causing an entry point for bioaccumulation in the food chain. The objectives of this study were to 1) examine the presence of PCBs in the WWTP and 2) investigate the abundance, diversity and activity of PCB dechlorinating bacteria during the treatment processes to evaluate the change of PCB congeners and associated toxicity before the final destination as fertilizer or structural support.

Approach/Activities. Wastewater samples were collected at three times during the year at five locations within the WWTP and analyzed for: dry matter content, concentration of PCBs (gas chromatography) and the abundance and activity of PCB dechlorinating bacteria. DNA was extracted and selectively amplified by PCR using the specific 16 S rDNA primer set 348F/884R, enumerated via Q-PCR and identified via DHPLC and sequencing. Microscopic analyses were performed to analyze the spatial arrangement of dechlorinating bacteria in the sludge using fluorescence in situ hybridization with specific probes for PCB dechlorinating bacteria, DAPI staining and microscopic examination with CLSM and SEM.

Results/Lessons Learned. PCB dechlorinating bacteria were present in all collected wastewater samples (PCB dechlorinating cells/g dry matter): $7.3x10^6$ in influent, 3.5x1011 in recirculating activated sludge, $1.3x10^{11}$ before digestion and $6.8x10^7$ after anaerobic digestion. DNA could not be recovered from the dried pellets due to the high temperature effects aimed at reducing pathogenic bacteria. The decrease in abundance after anaerobic digestion might be due to the change from mesophilic to thermophilic conditions. The WWTP reported that PCBs were not detected in any samples (detection limit 0.5 ng/g), but determination in our laboratory showed PCB concentrations ranging from 0.2-1.4 ng/g. The high abundance of PCB dechlorinating bacteria that can thrive at low PCB concentrations support the latter results. The EPA advised detection limit is high and since 180 million gallons of wastewater enter the WWTP daily the accumulated PCB concentration is higher as shown. Estimations based on the plant data show that approximately 670 g of PCBs could be discharged annually from WWTP. The degradation products and the resulting toxicity profiles showed that the toxicity of the PCBs increases in the biosolids part of the WWTP despite normalizing with the increased biomass

(Figure 1.1). A comparison with the guidelines from the World Health Organization (WHO) shows that this level (10 g-TEQ/kg) is exceeded during digestion and even more so for the dried pellets. The results show that emphasis should be put on increased anaerobic dechlorination of PCBs in the WWTP in addition to removal of PCBs attached to particulate matter during the initial treatment steps to limit the amount of discharged PCBs and the toxicity in the final product used for land application.