Potential Impacts of Treated Wastewater on Atlantic Bottlenose Dolphins

Atlantic Bottlenose Dolphins

The Atlantic Bottlenose Dolphin (*Tursiops truncatus*) observed in coastal areas off Delaware form part of the Northern Migratory Stock of coastal bottlenose dolphins. During summer months this stock occupies coastal waters between the Chesapeake Bay mouth and Long Island with a population size of approximately 9,600 (NOAA 2010). This species is protected under the Marine Mammal Protection Act (MMPA) and this stock is listed as "depleted" under this act.

Bottlenose dolphins are sighted daily from late spring to late summer traveling up and down the coast of Delaware, often approaching just outside the breakers and entering Delaware Bay. Dolphin watching cruises are popular with tourists and several companies are established in the Delaware area. Several calving areas are believed to be just north of, and outside the mouth of Delaware Bay (E. Stetzar pers. comm.).

Diet

Bottlenose dolphins are generalists and feed on a variety of prey items endemic to their habitat, foraging individually and cooperatively. Like other dolphins, bottlenose dolphins use echolocation to locate and capture prey (ACS 2004). Coastal dolphins prey on benthic crustaceans (shrimp and crabs), squid and fish including catfish, menhaden, spot, spotted sea trout, silver perch eels and mullet, consuming 13 – 20 lbs /day. Coastal estuaries provide habitat for many species of juvenile fish and, as many of these fish species migrate to the open ocean upon maturation, they may provide the main source of fish in the coastal dolphin's diet.

Estuaries have been shown to contain heavy contamination of organochlorines and other persistent organic pollutants (POPs) from agriculture and industry (Pulster *et al.,* 2005). Dolphin prey organisms that spend part or all of their life cycle in estuarine systems have the potential to bioaccumulate these pollutants as shown by Fair *et al.* (2009) and Houde *et al.* (2009). Therefore, dolphins are more likely to be exposed to these pollutants from a diet of estuarine fish species than a diet of exclusively marine fish species.

As dolphins are air breathing mammals they are not exposed to waterborne pollutants in the same manner as fish, which can uptake chemicals through their gills and by ingesting water, dolphins can only uptake pollutants via ingestion of prey items. This makes the bottlenose dolphin susceptible to bioaccumulation of lipophilic chemicals and heavy metals. Dolphin blubber contains over 90% of lipophilic contaminants in the dolphins body and these can be mobilised from the blubber during pregnancy, lactation and starvation (Yordy *et al.,* 2010a). Mature male dolphins have been shown to have the highest levels of contaminants in their blubber as female dolphins have the ability to offload high concentrations to their calves during gestation and lactation. These contaminants are discussed below.

Chemical Composition of Treated Wastewater

The chemical composition of treated wastewater (TWW) is dependent on many factors which include the following:

- The size and demographics of the population;
- The amount of industry and if the plant accepts trade waste;
- The presence of stormwater in the system; and
- The type of treatment.

Chemicals commonly present in treated wastewater include heavy metals (copper, zinc, silver and mercury), pesticides (if stormwater is entering the system), surfactants from detergents, natural and synthetic hormones, and bisphenol A, a plasticiser found in the urine of humans (Ying et al., 2008). Table 1 shows the chemicals detected in three samples of Rehoboth Beach wastewater treatment plant (WWTP) in the summer of 2010.

Table 1 Chemicals

Analyte	6/30/2010	7/7/2010	7/14/2010	Marine Chronic Guideline µg/L
Metals				
Antimony µg/L	<1.0	<1.0	<1.0	-
Arsenic µg/L	1.0	1.9	<1.0	36
Beryllium µg/L	<1.0	<1.0	<1.0	-
Cadmium µg/L	<0.5	<0.5	<0.5	8.8
Chromium µg/L	<1.0	3	2.6	50
Copper µg/L	1.8	7	4.6	3.1
Lead µg/L	<1.0	<1.0	<1.0	8.1
Mercury µg/L	<0.5	<0.5	<0.5	0.94
Nickel µg/L	3.4	6.2	3.8	8.2
Selenium µg/L	1.0	<1.0	<1.0	71
Silver µg/L	0.75	0.68	<0.5	-
Thallium µg/L	<1.0	<1.0	<1.0	-
Zinc µg/L	21.2	46.7	37.4	81
Volatile Organics	Not detected	Not detected	Not detected	-
Chloroform	1.1	Not detected	Not detected	-
Semi-Volatile Organics	Not detected	Not detected	Not detected	-
Bis(2-Ethylhexyl)phthalate	8.0	Not detected	Not detected	-
Phenolics	5	Not detected	Data not received	-
PCBs	9/22/2011			
∑PCBs µg/L	0.0018 – 0.016			0.03

Note: - = No guideline value

Substances of Concern from Treated Wastewater

TWW discharged from WWTPs may contain chemicals which have the potential to bioaccumulate through the food chain and adversely impact on higher order predators such as the bottlenose dolphin. POPs and heavy metals do have the potential to bioaccumulate, with the lipophilic POPs bioaccumulating in lipid rich organs and blubber. Other compounds of concern which may be present in TWW from heavily populated areas include non-ionic surfactants and steroidal estrogens, estradiol-17β and 17α-ethinylestradiol (Oberdorster and Cheek 2000).

Heavy metals; copper, nickel and zinc were detected in the Rehoboth Beach TWW during testing in 2010, however, the levels detected are below the EPA (2002) *Water Quality Criteria for Protection of Aquatic Life: Marine Chronic Criteria* (Table 1). The organics; chloroform, bis(2-ethylhexyl) phthalate and phenolics detected in the June 2010 sample may be due to laboratory procedures as these chemicals were not detected in subsequent samples. Further, as discussed by Greene (2011), the levels detected do not represent a threat to human or aquatic health. Polychlorinated biphenols (PCBs) were detected in picogram per litre concentrations and the total PCB concentration was below EPA (2002) criteria (Table 1).

Persistent Organic Pollutants

Persistent organic pollutants (POPs) are widespread in the aquatic environment. POPs include PCBs, organochlorine pesticides and brominated flame retardants that can bioaccumulate in aquatic organisms and biomagnify in higher trophic levels in marine ecosystems (Tuerk *et al.,* 2005, Yordy *et al.,* 2010b). Due to the marine mammals' position in the food chain and their longevity, lipophilic anthropogenic contaminants have the potential to interact with the endocrine and immune systems of marine mammals with deleterious effects, (Yordy *et al.,* 2010b). These deleterious effects can include reproductive failure and abnormalities, hormone disruption and immunosuppression (Tuerk *et al.,* 2005). These effects may be further compounded by exposure to natural and synthetic hormones, pharmaceuticals and personal care products which can enter the marine system from municipal and industrial wastewater effluents (Robinson *et al.,* 2009).

Yordy *et al*. (2010b) suggested that there was a positive correlation between estrogenic activity and selected POP concentrations in bottlenose dolphin blubber collected from two US Atlantic coast locations (Cape May, NJ and Holden Beach, NC). The three male dolphin blubber samples collected at Cape May, NJ, contained approximately double the concentrations of endocrine disrupting compounds (∑PCBs, ∑PBDEs, ∑DDTs, ∑CHLs, HCB, Mirex, Dieldren and ∑POPs) than the male dolphin blubber samples collected at Holden Beach NC. The levels of POPs observed were predicted to be insufficient to cause estrogenic or anti-estrogenic activity within the dolphin. However, a review of impacts of endocrine disrupting compounds by Oberdorster and Cheek (2000) reported that exposure and bioaccumulation of organochlorines did result in sea lions, seals and Dall's porpoise experiencing changes in steroid hormone metabolism.

Pulster *et al.,* (2005) showed that there is potential for common prey fish of the bottlenose dolphin to bioaccumulate POPs from contaminated estuaries. Several studies provide evidence that the bioaccumulation of POPs is occurring in the Southern Estuarine Stocks of bottlenose dolphins on the Atlantic coast (Schwacke *et al.,* 2002, Houde *et al.,* 2009, Pulster *et al.,* 2009, Yordy *et al.,* 2010a). The same level of bioaccumulation has not been demonstrated in the Northern Migratory Stock of coastal bottlenose dolphins. Further, the majority of POPs discussed above relate to industrial and agricultural activities, and the

chemistry results provided in Table 1 show that these chemicals in the Rehoboth Beach TWW, if detected, are below EPA (2002) guidelines.

The potential for the bottlenose dolphin to be exposed to any endocrine disrupting POPs from TWW from the Rehoboth Beach WWTP discharge is minimal as research has shown that advanced sewage treatment dramatically reduces the concentrations of POPs in the final effluent (Chapman 2003, Ying *et al.,* 2008). Research by Ying *et al.* (2008) showed that an advanced secondary sewage treatment processes similar to that at the Rehoboth Beach WWTP removed between 58 – 96% of selected endocrine disrupting compounds. Ying et al. (2008) attributed the removal rates of the compounds to the aerobic biological degradation during the treatment process. This type of treatment will also provide substantial removal of viral and bacterial pathogens.

Triclosan

Greene (2011) suggested that the detection of phenolics in one sample of the Rehoboth Beach WWTP effluent may be attributed, in part, to triclosan. Triclosan, an antibacterial product used in cleaning and personal care products, has been detected in the blood plasma of bottlenose dolphins in South Carolina and Florida at 0.12 to 0.27 ng/g wet weight (Fair et al., 2009). The triclosan was suggested to originate from two WWTPs in the Charleston area as concentrations in the effluent were 190 ng/L and triclosan was detected in estuarine surface water at concentrations ranging from 4.9 to 14 ng/L. Fair et al. (2009) also showed that approximately 94% of tricolsan was removed during the sewage treatment process. The US Food and Drug Administration is currently undertaking a review of ecological effects of triclosan and its findings will be made public in Winter 2012 (FDA 2010).

Conclusions

The contaminant levels in the Northern Migratory Stock of coastal bottlenose dolphins that spend the summer at or near Rehoboth Beach are unknown. However, due to the advanced secondary treatment at the WWTP, the lack of industrial waste, and low levels of heavy metals and organic contaminants in the discharge, it is unlikely that any bioaccumulation of persistent organic chemicals or heavy metals observed in the Northern Migratory Stock of Atlantic bottlenose dolphins could be attributed to discharge from the Rehoboth Beach WWTP. This is further supported by the small size of the mixing zone from the outfall being insufficient to sustain a large population of dolphin prey organisms as each dolphin requires up to 20 lbs of fish and crustaceans per day, with a group requiring up to 300 lbs/day. Therefore, the dolphins will not be feeding continuously at the outfall site and bioaccumulation of chemicals from the discharge is unlikely.

References

ACS. 2004. Bottlenose dolphin (*Tursiops truncatus*) Fact Sheet. American Cetacean Society. San Pedro CA.

Chapman H. 2003. Removal of endocrine disruptors by tertiary treatments and constructed wetlands in subtropical Australia. Water Science Technology. 47(9):151-156.

EPA (2002) National Recommended Water Quality Criteria (EPA-822-R-02-047). US Environmental Protection Agency, Office of Water and Office of Science and Technology, Washington, DC.

Fair P.A., Lee H-B., Adams J., Darling C., Pacepavicius G., Alaee M., Bossart G.D., Henry N. and Muir D. 2009. Occurrence of triclosan in plasma of wild Atlantic bottlenose dolphins (*Tursiops truncatus*). Environmental Pollution. 157(8-9):2248-2254.

FDA. 2010. Triclosan: What consumers should know. Consumer Health Information. US Food and Drug Administration. April 2010.

Greene R. 2011. Review of Rehoboth Beach, DE Sewage Treatment Plant Effluent Data for Toxic Pollutants. Review by Rick Greene, Delaware DNREC. May 16, 2011.

Houde M., Pacepavicius G., Darling C., Fair P.A., Alaee M., Bossart G.D., Soloman K.R., Letcher R.J., Bergman A., Marsh G. and Muir D.C.G. 2009. Polybrominated diphenyl ethers and their hydroxylated analogs in plasma of bottlenose dolphins (*Tursiops truncatus*) from the United States east coast. Environmental Toxicology and Chemistry. 28(10):2061-2068.

NOAA. 2010. Technical Memorandum NMFS-NE-219: US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments. National Oceanic and Atmospheric Administration. Seattle, USA.

Oberdorster E. and Cheek A.O. 2000. Gender benders at the beach: Endocrine disruption in marine and estuarine organisms. Environmental Toxicology and Chemistry. 20(1):23-36.

Pulster E.L., Smalling K.L., Zolman E., Schwacke L. and Maruya K.A. 2009. Persistent organochlorine pollutants and toxaphene congener profiles in bottlenose dolphins (*Tursiops truncatus*) frequenting the Turtle/Brunswick River estuary, Georgia, USA. Environmental Toxicology and Chemistry. 28(7):1390-1399.

Pulster E.L., Smalling K.L. and Maruya K.A. 2005. Polychlorinated biphenyls and toxaphene in preferred prey fish of coastal south-eastern US bottlenose dolphins (*Tursiops truncatus*). Environmental Toxicology and Chemistry. 24(12)3128-3136.

Robinson B.J., Hui J.P.M., Soo E.C. and Hellou J. 2009. Estrogenic compounds in seawater and sediment from Halifax Harbour, Nova Scotia, Canada. Environmental Toxicology and Chemistry. 28(1):18-25.

Schwacke L.H., Voit E.O., Hansen L.J., Wells R.S., Mitchum G.B., Hohn A.A. and Fair P.A. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. Environmental Toxicology and Chemistry. 21(12):2752-2764.

Tuerk K.S.J., Kucklick J.R., McFee W.E., Pugh R.S. and Becker P.R. 2005. Factors influencing persistent organic pollutant concentrations in the Atlantic white-sided dolphin (*Lagenorhynchus actutus).* Environmental Toxicology and Chemistry. 24(5):1079-1087.

Ying G-G., Kiikana R.S. and Kumar A. 2008. Fate of estrogens and xenoestrogens in four sewage treatment plants with different technologies. Environmental Toxicology and Chemistry. 27(1):87-94.

Yordy J.E., Pabst A.D., McLellan W.A., Wells R.S., Rowles T.K. and Kucklick J.R. 2010a. Tissue specific distribution and whole body burden estimates of persistent organic pollutants in the bottlenose dolphin (*Tursiops truncatus*). Environmental Toxicology and Chemistry. 29(6):1263-1273.

Yordy J.E., Mollenhauer M.A.M., Wilson R.M., Wells R.S., Hohn A., Sweeney J., Schwacke L.H., Rowles T.K., Kucklick J.R. and Peden-Adams M. 2010b. Complex contaminant exposure in cetaceans: A comparative E-Screen analysis of bottlenose dolphin blubber and mixtures of four persistent organic pollutants. Environmental Toxicology and Chemistry. 29(10):2143-2153.