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Effects of three different embryonic exposure modes of 2, 2′, 4, 4′-tetrabromodiphenyl ether on the path angle and social activity of zebrafish larvae

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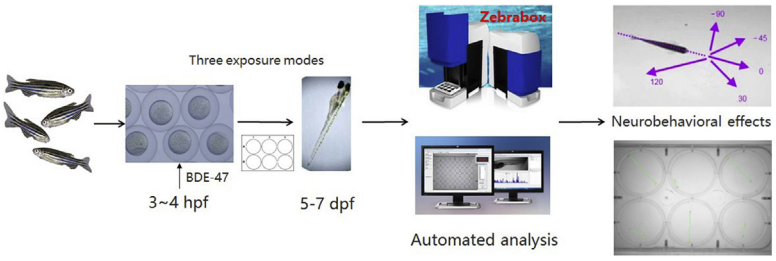
HIGHLIGHTS

- The neurobehavior effects of BDE-47 on larvae were assessed by locomotion indicators.
- Different exposure modes of BDE-47 have different neurobehavioral effects.
- BDE-47 disturbed the state of dark adaption of zebrafish larvae.
- BDE-47 treatments caused more responsive turns and more social contacts.

GRAPHICAL ABSTRACT



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ABSTRACT

The toxicological research of polybrominated diphenyl ethers (PBDEs) has focused on its neurotoxicity; however, many questions still remain. For example, behavioral effects other than basic locomotion are seldom reported. To further evaluate the neurobehavioral toxicity of 2, 2′, 4, 4′-tetrabromodiphenyl ether (BDE-47), a typical PBDE congener in animal tissues, we employed three different exposure modes, namely, continuous, early pulse, and interval exposure, to investigate the path angle and social activity changes of zebrafish larvae exposed to BDE-47 using automated equipment (Zebrabox). The results showed that different exposure modes might have different effects on the larval path angle and social activity. BDE-47 treatments caused more responsive turns in all exposure modes in the path angle test and more contacts in most of the two-fish social tests, indicating that the neurobehavior of larvae was disturbed by BDE-47. The light condition was also a key impact factor in the effects of BDE-47. The effects of BDE-47 were different during the dark and light conditions. Our study shows a useful neurobehavioral test method for environmental pollutant monitoring and further supports the utility of zebrafish to study neurobehavior, indicating that the path angle has the potential to be a practicable behavioral indicator.

1. Introduction

Polybrominated diphenyl ethers (PBDEs), a class of environmental endocrine disruptor chemicals commonly used as flame retardants, are ubiquitous in the environment and bioaccumulate

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in humans and wildlife (Gorga et al., 2013). Most PBDEs have been phased out from use in current products, primarily electronics and electrics (Wang et al., 2015) since commercial octa-BDE and penta-BDE were the first brominated persistent organic pollutants (POPs) listed in the Stockholm Convention (Sindiku et al., 2014). However, huge environmental reservoirs containing PBDEs still exist (Macaulay et al., 2015; Ortuno et al., 2015). PBDEs are similar in structure to polychlorinated biphenyls (Herbstman et al., 2015; Zhu et al., 2015), which suggested the following directions for toxicological studies of PBDEs: endocrine disruption and neurotoxicity (Blaser and Gerlai, 2006; Man et al., 2015).

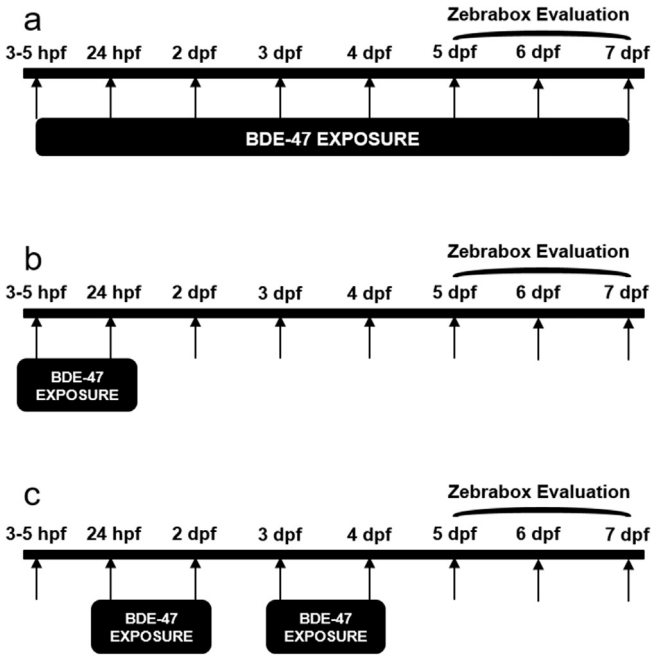

Fig. 1. Different exposure modes investigated for BDE-47 neurobehavioral toxicity on zebrafish larvae (a: Continuous exposure; b: early pulse exposure; c: interval exposure).

Neurobehavioral tests of zebrafish have been widely adopted in the development of psychopathic drugs (Riehl et al., 2011; Kyzar et al., 2012) and research on environmental neurotoxic pollutants (Faria et al., 2014; Liang et al., 2015; Tu et al., 2016). Some behaviors of zebrafish larvae develop early (Colwill and Creton, 2011) and can be observed during the first week of development after hatching from their protective chorions (between 2 and 3 dpf) (Kimmel et al., 1995). Many studies have investigated the effects of pollutants, including BDE-47 and other PBDE members, on the development of locomotion and swimming in zebrafish larvae in response to light-to-dark photoperiod stimulation (Chen et al., 2012b, 2013; Zhao et al., 2014). In addition to locomotion, other behaviors, such as rotation and social activity, have great implications regarding brain functions. Novel video-tracking tools and traditional manual analysis of shoaling phenotypes were adopted and compared to examine the effects of group size in the shoaling paradigm (Green et al., 2012). Moretz et al. used different zebrafish strains to test the effects of social environment experience on behavior (Moretz et al., 2007). Although some toxicological research has begun to focus on other types of zebrafish behaviors, studies regarding PBDEs have rarely been reported.

Because 2, 2′, 4, 4′-tetrabromodiphenyl ether (BDE-47) is a typical PBDE congener and a major constituent of animal tissues and environmental samples (Shao et al., 2008; Erratico et al., 2015), BDE-47was selected as a representative PBDE in this study. We employed three exposure modes as in our previous study (Zhao et al., 2014), namely, continuous, early pulse, and interval exposure, to assess and compare their different impacts on the path angle and social activity of zebrafish larvae. Our results showed that different exposure modes may lead to different neurobehavioral effects, and the path angle would be a practical behavioral indicator for environmental pollutant monitoring.

2. Material and methods

2.1. Experimental animals and BDE-47 treatments

Zebrafish were cultured in an auto-cycling aquarium system

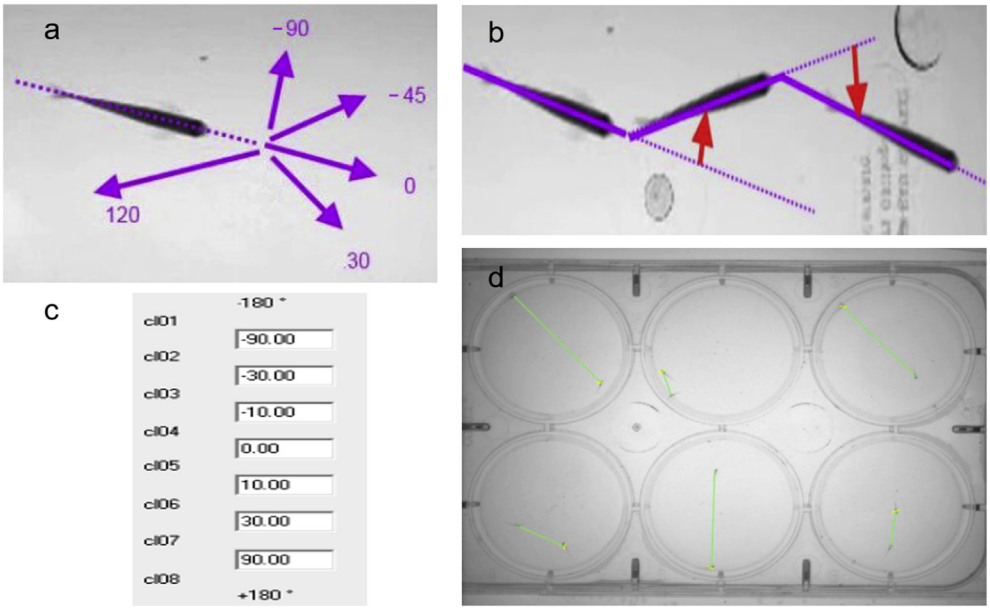

Fig. 2. Main behaviors detected by the Zebrabox. (a and b: schematic diagrams of the path angle; c: the ranges of the eight angle classes; d: a schematic diagram of two-fish social contact).