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Use, fate and ecological risks of antibiotics applied in tilapia cage farming in Thailand

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ABSTRACT

The use, environmental fate and ecological risks of antibiotics applied in tilapia cage farming were investigated in the Tha Chin and Mun rivers in Thailand. Information on antibiotic use was collected through interviewing 29 farmers, and the concentrations of the most commonly used antibiotics, oxytetracycline (OTC) and enrofloxacin (ENR), were monitored in river water and sediment samples. Moreover, we assessed the toxicity of OTC and ENR on tropical freshwater invertebrates and performed a risk assessment for aquatic ecosystems. All interviewed tilapia farmers reported to routinely use antibiotics. Peak water concentrations for OTC and ENR were 49 and 1.6 μg/L, respectively. Antibiotics were most frequently detected in sediments with concentrations up to 6908 μg/kg d.w. for OTC, and 2339 μg/kg d.w. for ENR. The results of this study indicate insignificant short-term risks for primary producers and invertebrates, but suggest that the studied aquaculture farms constitute an important source of antibiotic pollution.

1. Introduction

Aquaculture production has intensified at a rapid pace across Asian countries in order to supply the increasing demand of aquatic products at a national level and in importing regions such as European or North-America (FAO, 2012). As long as aquaculture practices have intensified and the quality of water supplies in aquaculture-clustered areas has deteriorated, the Asian aquaculture industry has been overwhelmed with a wide range of parasitic and bacterial diseases affecting the cultured species (Bondad-Reantaso et al., 2005). In order to prevent or treat such disease outbreaks, farmers often rely on a wide array of veterinary medicinal products such as antibiotics and parasiticides, which are mainly applied during periods of high stress in the cultured species (Rico et al., 2012, 2013). Residual concentrations of antibiotics used in aquaculture production have been measured in aquatic ecosystems down-stream of aquaculture production areas of Asia (Managaki et al., 2007; Takasu et al., 2011; Zhou et al., 2011; Zou et al., 2011; Shimizu et al., 2013), and due to the importance and the geographical spread of this economic activity throughout this continent, aquaculture production has been considered as one of the main pathways of veterinary medicines into the environment (Managaki et al., 2007).

Thailand is ranked sixth in aquaculture production globally, with tilapias (*Tilapia* spp.) being the most important cultured fish species group (FAO, 2012). About 30% of Thai tilapias are produced at high densities in floating cages placed on rivers or irrigation canals (Belton et al., 2009). Tilapias cultured under such open culturing systems are highly vulnerable to stress produced by water quality fluctuations and can easily be infected by naturally occurring microorganisms. Particularly, infestations with *Streptococcus* spp. and other bacteria (e.g. *Aeromonas* spp., *Pseudomonas* spp., and *Vibro* spp.) have been reported to be the main causes of mortality in caged tilapia (Belton et al., 2009). In order to prevent mass tilapia

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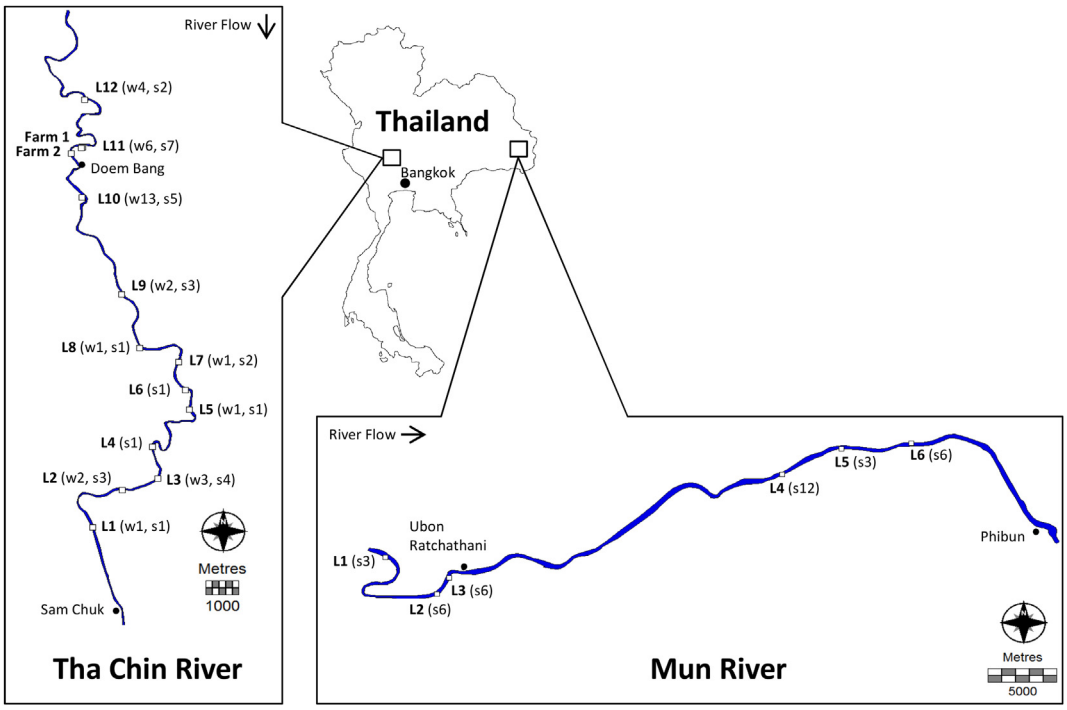

Fig. 1. Sampling locations (L) in the Tha Chin River and in the Mun River (Thailand), and number of water (w) and sediment (s) samples collected in each location. In the Tha Chin River: L1, 2, 3 and 4 were sampled in the dry season; L5, 6, 8 and 9 were sampled in the wet season; and L7, 10, 11 and 12 were sampled in both seasons. The location L3 in the Mun River was considered as the reference site.

mortalities, farmers often apply antibiotics mixed or/and coated with the fish diet. Large amounts of antibiotics applied in marine cage-based aquaculture production have been reported to end-up in the surrounding ecosystems through leaching or sedimentation of medicated feeds, or via excretion from the cultured species (Coyne et al., 1994; Capone et al., 1996). Similar situations are expected to occur in freshwater aquaculture, however, studies that report the environmental fate and distribution of antibiotics in rivers impacted by freshwater cage aquaculture are currently unavailable.

The main objective of this study was to investigate the use of antibiotics in tilapia cage farms in Thailand and to assess their environmental fate and risks for tropical aquatic ecosystems. Initially, we performed interviews with tilapia-cage farmers at two Thai rivers with significant aquaculture production. Then, we monitored residues of the most commonly used antibiotics, oxytetracycline (OTC) and enrofloxacin (ENR), in water and sediment samples collected in the environment surrounding the surveyed tilapia cage farms and in a 'non-polluted' reference area, and measured antibiotic concentrations in samples collected during and after antibiotic administration in two reference farms. In order to characterize the ecosystem sensitivity to antibiotics we performed toxicity tests with tropical invertebrates and derived safe environmental concentrations for primary producers and invertebrates. Finally, ecological risks for primary producer and invertebrate communities exposed to antibiotic residues were calculated based on the obtained measured environmental concentrations. To our knowledge, this is the first study describing the use and potential ecological risks of antibiotics applied in freshwater cage aquaculture production.

2. Material and methods

2.1. Study areas and antibiotic use data collection

This study was conducted in the Tha Chin River and in the Mun River (Fig. 1; see Supporting information for a description of the study areas). Both rivers are subject to monsoon climate, with the rainy season lasting from May to October. The Tha Chin and the Mun rivers significantly contribute to the total cage-based production volume of tilapia in Thailand. In these rivers, mono-sex Nile (*Oreochromis niloticus*) or (hybrid) red tilapias (mainly *O. mossambicus* × *O. aureus*) are cultured in 3 × 3 m (1.5–2.0 m depth) floating cages composed of steel frames and polypropylene mesh. Tilapias are fed with commercial pelleted feeds for a period of 4 months, until they reach a weight of 600–1000 g. Farms are formed by several tilapia cages (4–100) placed in parallel to the banks of the river, which normally operate in batches throughout the year.

Information on antibiotic use was collected by structured interviews conducted with 29 tilapia farmers (15 in the Tha Chin River and 14 in the Mun River) between November, 2010, and April, 2011. Information collected included names of antibiotic ingredients, dosages, and modes and frequencies of application. Additional information on farmer perceptions on water quality and disease occurrence was also collected.

2.2. Sample collection

2.2.1. River-scale sampling

Water samples were collected in the Tha Chin River during the dry season (March; $n = 24$) and in the wet season (June; $n = 10$) (Fig. 1). Sediment samples were collected during the dry season in the Tha Chin River (March; $n = 19$) and in the Mun River (January–February; $n = 30$), and during the wet season in the Tha Chin River (June; $n = 12$) (Fig. 1). In addition, six reference sediment samples were collected from a location in the Mun River isolated from the aquaculture farms. This area was assumed not to be impacted by anthropogenic activities and was considered as the 'non-polluted' reference site (Fig. 1). For a description of the antibiotic sample collection methods see the Supporting information.

2.2.2. Farm-scale sampling

In order to assess the fate and dissipation of the studied antibiotics during and after an antibiotic administration period, extra samples were collected in two tilapia farms located in the Tha Chin River. In both farms antibiotics were coated with the fish diet by distributing the antibiotics in powdered form on top of industrial fish pellets, adding river water as coating agent, and mixing them manually for about 15 min. Next, farmers let the fish diet containing antibiotics dry for about 1 or 2 h before administration. In the first farm (FARM 1), OTC was administered mixed with feed at a dose of 40 mg/kg fish body weight (b.w.). Six cages containing 600 fish per cage (approximate weight 300 g/fish) were treated. Water samples were taken in duplicate inside the cages and next to the cages at 15 min, 1 h and 15 h after the antibiotic administration. In the second farm (FARM 2), OTC and ENR treatments were applied to 14 tilapia cages with 600 fish per cage (approximate weight 600–700 g/fish). Both antibiotic treatments had a duration of 7 days and overlapped in