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Short communication

Influence of puddling procedures on the quality of rice paddy drainage water

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ABSTRACT

Drainage water quality in rice paddies was strongly influenced by the puddling of soil in the paddy fields by tractors and in response to opening of drainage gates. The concentrations of contaminants in drainage water increased rapidly when the puddling process began and were maintained at high concentrations throughout the puddling period. Moreover, the high concentrations did not decrease immediately after the puddling procedures ceased. Additionally, the ratio of dissolved nitrogen and phosphorous to total nitrogen and total phosphorous increased daily during the last half of the puddling period, due to discharge of chemical fertilizers with the drainage water. Also, the loads of particulate nitrogen and phosphorus discharged during the puddling period were larger than the loads discharge during irrigation. The discharge from paddy fields during puddling also increased the total annual contaminant load.

1. Introduction

The efflux of nitrogen (N) and phosphorous (P) from agricultural lands is believed to be a major contributor to the accelerated eutrophication of rivers and reservoirs worldwide (Kim et al., 2006). Agricultural lands are non-point sources of pollution, which contribute more pollutant load to many closed water areas than point sources (Takeda and Fukushima, 2006). However, it is difficult to evaluate the overall impact of agricultural farming activities such as irrigation and fertilizer application in a drainage basin. This is partially due to farmers cultivating many varieties of crops during the irrigation period, and to differences in their farming techniques.

This is especially true in rice fields, which use a large amount of water that is ultimately drained into surrounding aquatic systems. Rice fields account for a large portion of agricultural land in Japan and other East Asian countries (Tabuchi and Hasegawa, 1995). As a result, gaining a thorough understanding of the relationship between farming activities during the crop cultivation period and variations in water quality may facilitate improvement of the quality of aquatic systems located near rice fields.

Rice paddy fields accounted for approximately 54% of all farmland in Japan in 2005 (MAFF, 2005). Because paddy fields typically lie along rivers, they can have a major impact on water quality. In addition, the growing season of rice generally extends from May to October, which coincides with the hydrologically active period of most bodies of water.

Paddy fields can be managed in ways that enhance soil conservation, ground water recharge and denitrification, while contributing to food production (Mizutani, 1999). Furthermore, paddy fields can decrease the nitrogen load to the aquatic environment via increased denitrification under ponding conditions (Tabuchi and Kuroda, 1991; Yamaoka et al., 2003). Moreover, the volcanic ash soil that is present in many paddy fields in Japan readily adsorbs phosphorous (Shiratani et al., 2003; Takeda and Fukushima, 2004). However, even though rice paddy fields tend to purify water during the crop season, a large volume of drainage water with a high concentration of suspended solids (SS) is discharged during puddling and transplanting.

Puddling is a common practice in rice cultivation for the following reasons (Adachi and Sakaki, 1999; Kaneki, 2003): (1) it softens the soil in the plow layer, thereby facilitating transplanting or direct seeding, (2) it creates a level soil surface, which helps ensure a uniform depth of flood water for adequate water management, (3) it reduces the incidence of weeds, (4) it mixes fertilizer and soil in the plow layer, and (5) it reduces the percolation rate.

In this study, we examine the relationship between puddling procedures and changes in the quality of drainage water from paddy fields to determine the impact of paddy drainage water on the quality of aquatic systems located downstream.

2. Study area

The study area is in the southeastern portion of Matsue City in Shimane Prefecture, Japan (Fig. 1). The cultivated area is approximately 115,000 m^2. Irrigation water is supplied to paddy fields from the Hakuta River via a non-pressurized pipeline. The

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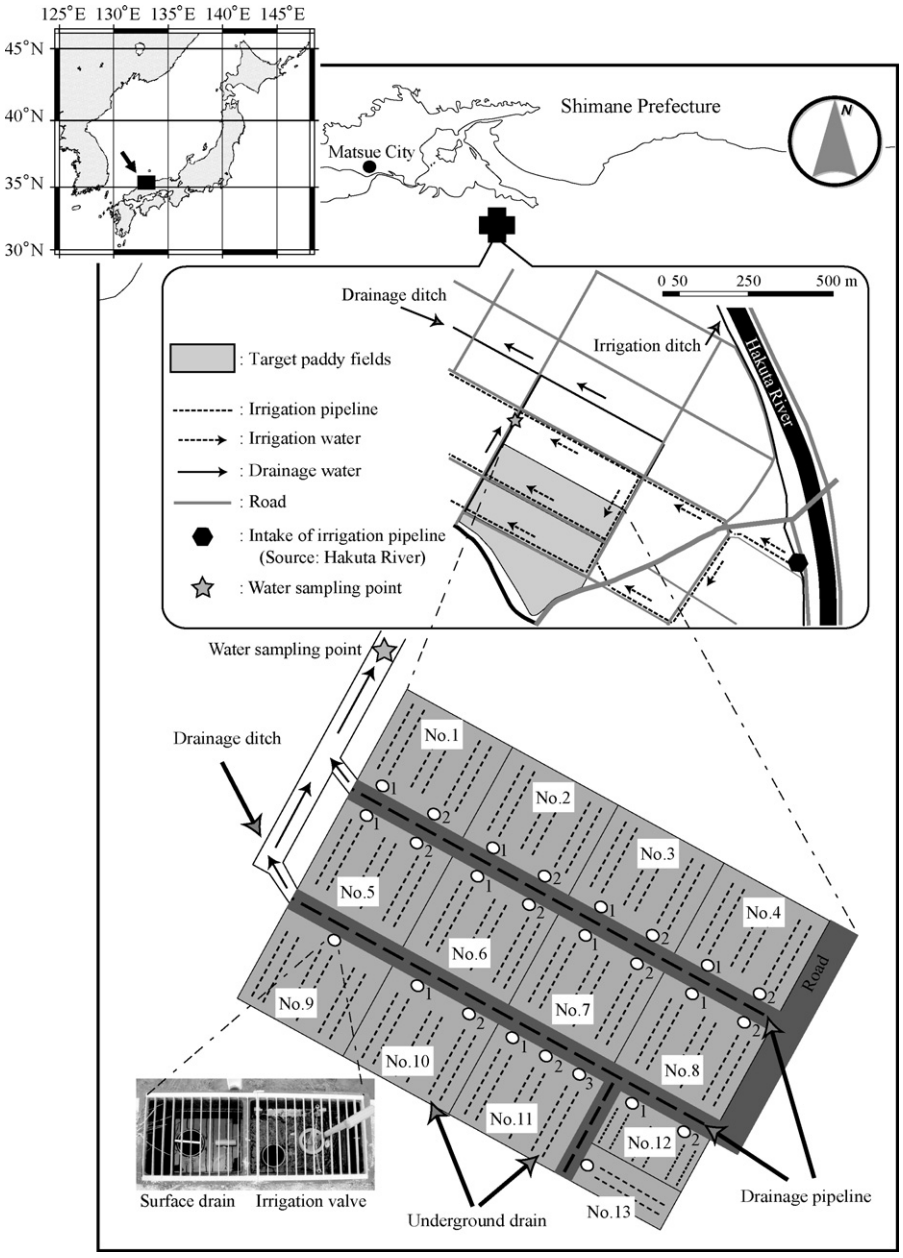

Fig. 1. Location of the study area and drainage system.

entire paddy system, which was constructed during a farmland consolidation program at the end of 2003, comprises 13 paddy fields with underground drainage systems that were installed following the harvest of rice in 2005. The underground drainage systems comprise vitrified-clay pipes that guide water from the paddy fields to a common drainage ditch. The water then flows through the drainage ditch and is finally discharged to the Yoshida River, which is located downstream of the paddy fields.

3. Methodology

A field investigation was conducted from April 2005 to December 2006 to evaluate water quality. Water samples were collected approximately once each week during the irrigation period and twice each week during the non-irrigation period. In addition, the water was collected almost every hour from early in the morning to late at night during the puddling and transplanting period from 29 May to 3 June in 2006 (Table 1). Moreover, farming activities such as puddling, transplanting and gate operation of surface drains were monitored visually at each paddy field and evaluated via interviews with farmers during that time. Based on the results of the field investigation, the irrigation periods were set from 27 May to 8 October in 2005 and from 29 May to 9 October in 2006, while the non-irrigation periods were set from 12 April to 26 May in 2005, from 9 October to 28 May in 2006 and from 10

Table 1
Date and time of the investigations conducted during the puddling period in 2006.

Date	Investigation hours
29 May	9:00–21:00
30 May	5:00–21:00
31 May	6:00–21:00
1 June	6:00–20:00
2 June	6:00–21:00
3 June	3:00, 6:00, 9:00, 18:00