論文の内容の要旨

論文題目　Material Flow Analysis of Nitrogen through Food Production　and Consumption　for Watershed Management in Chaophraya River Delta, Thailand
(タイ国チャオプラヤ流域における窒素管理のための食料生産と消費にともなう物質フロー解析)

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Traditionally, wastewater and solid waste have always been managed separately. However, in the real world, they exist together and an integrate approach to control both as one system is needed. On the other hands, urban activities are sustained by agricultural and industrial activities. These hindered activities are intensified to support urban growth and have not yet been accounted for as an indirect urban contribution. This study aimed to integrate wastewater and solid waste management, as well as, point source and non-point source control based on concept of pollution prevention and waste minimization.

A globally common issue of anthropogenic nutrient enrichment in coastal estuary is selected as a target of environmental system management. The research objectives are (1) to develop upstream pollution reduction approach through case study of nutrient management in the Chaophraya River Delta, (2) to propose nutrient reduction scenarios in integrated watershed management scheme to apply for provincial up to regional scale, (3) to elucidate pollution generations in domestic sector through food consumption and production activities in agricultural and industrial sectors utilizing material flow analysis (4) to identify and prioritize nutrient pollution sources, generated activities, and pathways in term of loading contributions and effects on eutrophication in the Upper Gulf of Thailand

Material flow analysis (MFA) of total nitrogen (TN) in Chaophraya River Delta, Thailand, is developed. MFA model is developed for dry season (November 2006 to April 2007) and wet season (May 2007 to October 2007) covering agriculture, industry, and domestic sectors of 11 provinces in Central. Major activities are categorized for crops land, animal husbandry, aquaculture, agro-industry, related food industry, organic fertilizer, domestic consumption, wastewater treatment plant (WWTP), landfill, and water supply production (WS). Mass balances are developed for each activity based on local field measurement, statistics, and literature; as well as regional and global applicable data.

Nitrogen flows of Chaophraya River Delta reveals dominated activities in the area. Agriculture’s crops land and aquaculture are the major activities. If ranking by magnitude

of the annual flows, top flows are input feeding food to aquaculture (107,363tN), output excess food to aquaculture's pond sediment (89,793tN), intermediate products from crops land to industry (86,527tN), input fertilizer to crops land (74,940tN), and input feeding food to animal husbandry (61,850tN). The ranks are similar for both annual and season flows. However, the dominated activities differ among provinces.

In both seasons, the primary flows were; input flows of fertilizer uses in crops land (45,305tN in dry season and 29,636tN in wet season) and feeding food to animal husbandry (30,925tN in both dry and wet season), internal flows of products from agriculture to domestic via industry (52,629tN in dry season and 36,773tN in wet season), and output flows of wastewater from domestic (17,840tN in both dry and wet season) and animal husbandry (12,439tN in both dry and wet season). Noticeable seasonal differences were surface runoff flows from crops land in wet season (6,367tN) which was about 3 times higher than those in dry season (2,004tN).

Provincial differences are revealed in 2 aspects: first, the flows contribution from provinces to the total flows of the Delta in each type of activity; and second, the flows mechanism within a province. It can be conclude that from these aspects that provinces which need priority management are Suphanburi, Nakhonpathom, Samutsakhon, Singburi, Bangkok, and Samutprakan.

TN outputs can be summarized into fate to environment. TN flows to air, water, and soil are 33,263tN, 116,739tN, and 128,998tN, respectively. Crops land, animal husbandry, industry, and non-agriculture land are types of activities in which nitrogen can be transformed into gaseous including nitrogen gas. Crops land, aquaculture, domestic, and non-agriculture land are types of activities in which nitrogen can be deposited and accumulate in soil and be reused by plants. After performing sensitivity analysis using fate to environment as indicators, nature of the model is shown. Fate to air and soil are the most sensitive parameters. If to consider air and soil impacts, this model can be further developed to reduce sensitiveness of TN flows to air and soil.

TN fate to water is the only direct loads to environment and is analyzed further for uncertainty of flows. Uncertainty ranges of non-point source are found to be comparable to that of point-source. For non-point sources, crops land runoff, animal husbandry effluent, aquaculture effluent, and non-agricultural land runoff have uncertainty factors of 1.22 (or 22%), 1.13 (or 13%), 1.04 (or 4%), and 1.15 (or 15%), respectively. For point-sources, agro-industry WW effluent, domestic WW direct discharges, WWTP effluent, and landfill leachate have uncertainty factors of 1.03 (or 3%), 1.15 (or 15%), 1.15 (or 15%), 1.24 (or

24%). Overall uncertainty ranges of total wastewater output flows are 3 to 24 percent. Therefore, total TN WW loading to Chaophraya River Delta is more likely in between 105,217 to 129,751tN

Wastewater loads distribution among provinces in the Delta reveal fraction of loads from differences activities. Direct loads from domestic wastewater and indirect loads through agricultural and industrial activities were found to be 8.5, 14, and 1.7gTN/capita/day, respectively. When considering production-to-consumption factors derived from internal consumption and export flows, they range from 0.04:0.96 to 0.50:0.50. Agricultural based provinces with small population results in low internal consumption comparing with high export. On the other hand, suburban areas have similar trend to highly urbanized Bangkok in which highly relied on import food from other area. On average, about half of agricultural products produced in the Delta is used as internal consumption and other half is exported. Therefore, it can be conclude that about half of pollution generated within the Delta is due to food export activity.

Priority water pollution control should be given to animal husbandary effluent in Nakhonpathom, domestic WW direct discharges in Bangkok, aquaculture effluent in Samutprakarn and overall general agriculture activities in Suphanburi. In order to reduce loading to the environment, results shown possible nitrogen reuses and recovery within the system from wastewater and organic waste. If wastewater from animal husbandry (24,878tN/yr) and aquaculture (28,848tN/yr) were reused as fertilizer to crops land, we may reduce direct loading to water body 53,726tN/yr. If municipal solid waste (8,655tN/year) and septage (6,409tN/year) were recovered, we may reduce environmental loading and double the organic portion of total fertilizer uses 74,941tN/year from 13% (10,052tN/year) to 47% (25,116tN/year).