

Material Flux Analysis for Planning of Domestic Solid Waste and Wastewater Management: A Case Study in Pak Kret

Municipality, Nonthaburi, Thailand

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บทคัดย่อ

วัตถุประสงค์หลักของการศึกษา คือ การนำหลักการ Material Flux Analysis (MFA) มาใช้เพื่อการวางแผนการจัดการสิ่งแวดล้อมชุมชน พื้นที่ศึกษาคอบคลุมเขตเทศบาลนครปากเกร็ด จ.นนทบุรีและพื้นที่เกษตรโดยรอบ ในโตรเจน (N) ซึ่งเป็นส่วนประกอบในของเสียอินทรีย์และน้ำเสียชุมชนถูกเลือกเป็นตัวบ่งชี้ปัญหา การวิเคราะห์แสดงให้เห็นว่าปริมาณไนโตรเจนจากขยะอินทรีย์ถูกส่งไปยังสถานที่กำจัดมูลฝอยประมาณ 540 กิโลกรัมต่อวัน และจากน้ำเสียและสิ่งปฏิกูลถูกปล่อยลงสู่สิ่งแวดล้อมประมาณ 1,900 กิโลกรัมต่อวัน การศึกษานี้เสนอแนวทางการแก้ไข 3 วิธี ได้แก่ 1) การสร้างระบบบำบัดน้ำเสีย 2) การหมักปุ๋ยจากสิ่งปฏิกูลร่วมกับขยะอินทรีย์ และ 3) การสร้างระบบบำบัดน้ำเสียควบคู่ไปกับการหมักปุ๋ยจากขยะอินทรีย์ ผลการศึกษาแสดงให้เห็นว่าแนวทางที่สามารถลดการปล่อยไนโตรเจนสู่สิ่งแวดล้อมได้สูงสุด (45%) คือ แนวทางการแก้ไขที่ 3 และแนวทางที่สามารถลดการใช้ไนโตรเจนจากปุ๋ยเคมีได้มากที่สุด (77%) คือแนวทางการแก้ไขที่ 2

คำสำคัญ : การหมักปุ๋ย, การทำคูลมวลสาร, ไนโตรเจน, เกษตรกรรมชุมชนเมือง, การจัดการน้ำเสีย

Abstract

The main objectives of this study are to apply the Material Flux Analysis (MFA) approach in environmental sanitation planning in order to assess mitigating measures to maximize nutrient recovery and minimize environmental pollution. Pak Kret municipality in Nonthaburi province was selected as the study area. Nitrogen (N) fluxes in organic wastes and wastewater were chosen as the indicators. The results reveal that the N flux of approximately 540 kg N/day was disposed in an open dumping site in the form of organic solid wastes, whereas that of approximately 1,900 kg N/day from wastewater and septage was discharged into environment. The study has analysed 3 mitigating measures including (i) implementation of wastewater treatment plant, (ii) co-composting of solid waste and septage, and (iii) wastewater treatment plant and composting of solid wastes. The analytical results show that the highest reduction in N loading (45%) to environment could be obtained by the third measure. For optimizing nutrient recovery, the highest reduction in N requirement for chemical fertilizer is through the second measure (77%).

Keywords : Co-composting, Mass Balance, Material Flux Analysis, Nitrogen, Sewage Management.

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Introduction

Due to unsustainable nutrient management, organic waste, wastewater and septage that contain high amount of nutrients are discharged to environment without prior treatment causing large extent of environmental impacts. MFA has been applied successfully in industrialized countries for the early recognition of resource or waste management problems and the development of solutions to these problems [3], [5]. MFA has contributed to solutions in some developing countries, e.g. in Columbia [4] and in Ghana [8], [2] where MFA was applied to investigate the potential of reusing treated septage and solid waste (compost) as fertilizer in agriculture. However, MFA has never been applied in Southeast Asian Countries in the field of environmental sanitation. Therefore, this research aims to optimize environmental sanitation from a nutrient management perspective based on MFA in a selected city in Thailand [9].

Pak Kret municipality is selected as the study area. It is located in Pak Kret district, Nonthaburi province, the eastern side of Chao Phraya River in Central Thailand (Figure 1). Pak Kret district has total area around 89 km² including 5 urban sub-districts and 7 peri-urban sub-districts. The urban sub-districts or Pak Kret municipality, including Pak Kret, Bang Phud, Ban Mai, Bang Talad and Khlong Kluea, have a total area of 36 km² [10]. The total population of Pak Kret municipality is 242,836, comprising around 80,000 non-registered inhabitants, and 39,746 households (December, 2003).

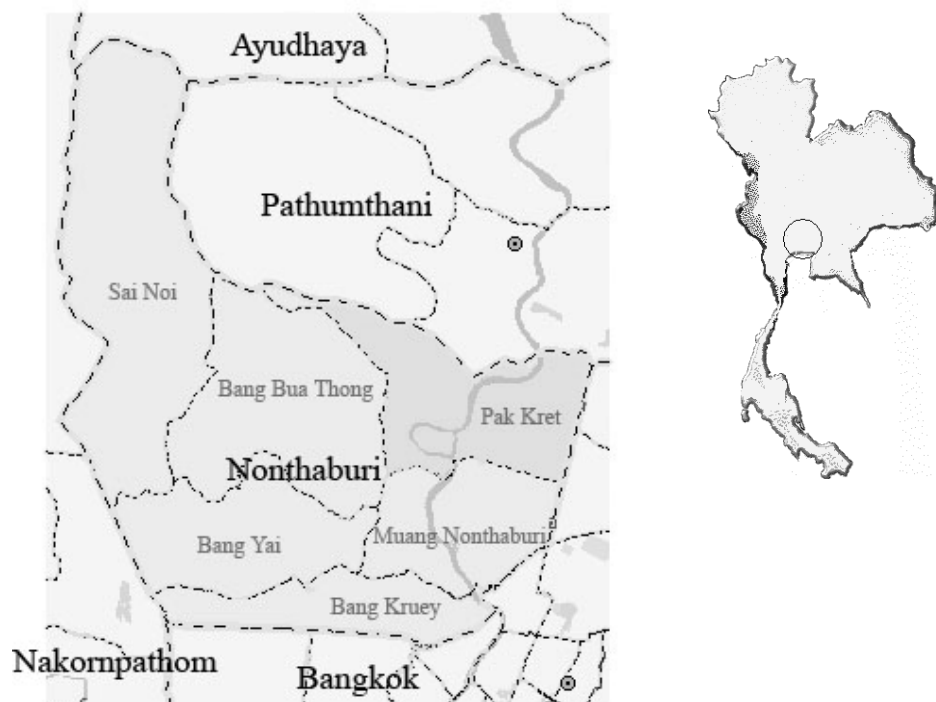


Figure 1 Pak Kret municipality

Current Situation

Most of the peri-urban areas in Pak Kret district are cultivation areas. Most of areas in Pak Kret municipality are changed from agricultural areas to be land development for living and commercial area because of population increasing and economic growth. There are no central wastewater treatment plant, only 2 villages have onsite wastewater treatment

systems. Blackwater is onsite treated by septic tank (90%) and septic tank with anaerobic filter (10%), whereas 20% of total connected to drainage. Most of wastewater, grey water and effluent from septic tank and wastewater treatment plant, is discharged to surface water through drainage. Septage is collected by municipality and discharged onto unused land. Around 80% of municipal solid waste is openly dumped and is left to decompose naturally at an open dumping site in another district, the remainder is disposed of illegally to environment. Agricultural wastes are reused by non-formal composting. There is one composting campaign in Phobsuk village [7].

The focus of the study is on nutrient management related to organic solid waste and wastewater (human excreta and grey water) management. The main objectives are 1) to quantify Nitrogen (N) fluxes related to environmental sanitation and agriculture in Pak Kret municipality including peri-urban agriculture by using Material Flux Analysis (MFA), 2) to identify large waste production processes and 3) to propose improvement measures based on obtained results. The indicator to be analyzed is (N). Other important aspects such as socio-cultural, economic and health aspects have not been considered in order to limit the scope of this study.

Materials and Methods

Material Flux Analysis (MFA) is a systematic assessment of flows and stocks of materials (material balance) within a defined system in space and time. The method of MFA describes the fluxes of resources used and transformed as they flow through a single process or via a combination of various processes)e.g .region, industry.(This allows the identification of weak points, e.g. the large waste production processes in the system and the evaluation of possible solutions. Appropriate management concepts can be adopted by decision makers or planners [6].

A material flux analysis consists of the following steps;

- 1) A system analysis comprising of goods¹, processes², and system boundary
- 2) The measurement of mass fluxes of goods and element (indicator) concentrations of all goods (mass/mass, mass/volume)
- 3) The calculation of the element fluxes
- 4) Schematic presentation and interpretation of results [1].

Mass fluxes of all goods in this study are determined by using information obtained from literature review (scientific publications, official statistics and documents, etc.), field measurement (sampling and laboratory analysis), field survey (questionnaire, interview with key persons and observations), or calculation by mass balance over the processes.

¹ A good is economics entities of matter with a positive or negative economic value. Goods are made up of one or several substances.

² A process is the transformation, transport, or storage of materials. For example, the human body, where food, water, and air are transformed mainly into CO₂, urine and feces.

Results and Discussion

The system border is defined by the area in Pak Kret municipality including peri-urban agriculture area in Pak Kret district. The system includes 7 processes: peri-urban agriculture, market, household, septic tank, solid waste collection and sorting, wastewater treatment plant and composting, and 34 goods. The environmental compartments “Atmosphere”, “Groundwater, surface water and soil”, as well as the process “Open dumping site”, are placed outside the system border and have not been investigated (Figure 2). The MFA results show that the main N fluxes in the environment are caused by septic tank seepage (6.7 g/capita.day) and household grey water (3.9 g/capita.day). The organic waste to open dumping site (2.2 g/capita.day) is the source of pollution (groundwater and surface water contamination) and the cause of nuisance to nearby community. The main N input fluxes into the system were chemical fertilizer (6.9 g/capita.day) and food supply from outside the district (9.1 g/capita.day) (Figure 3).

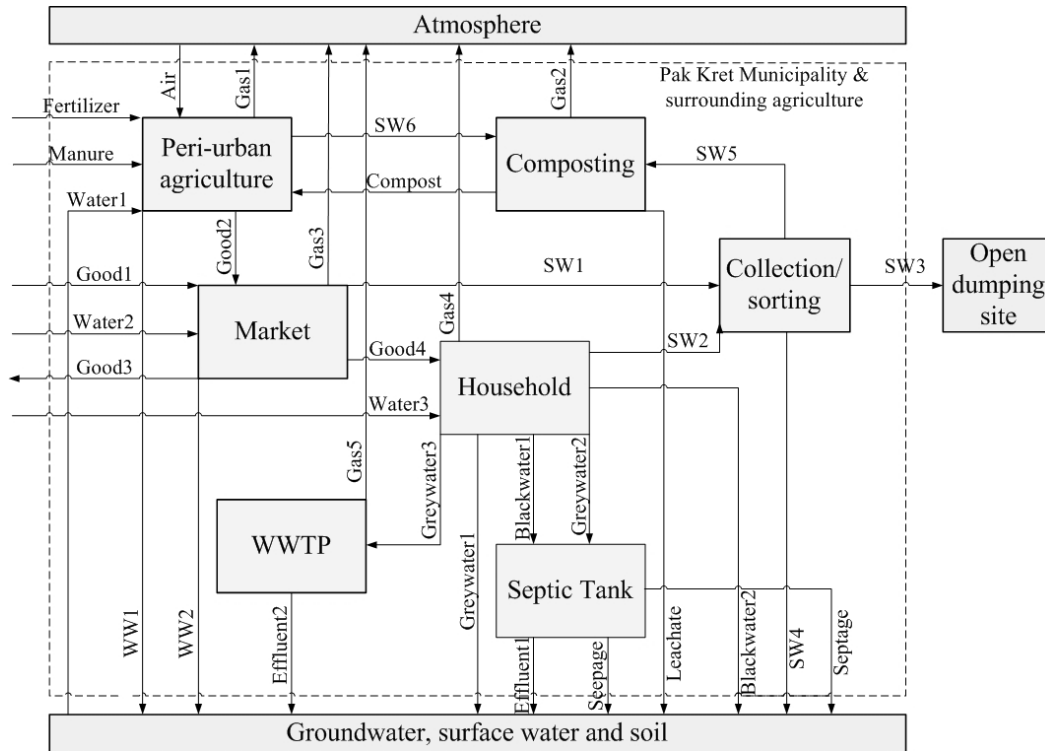


Figure 2 System analysis of Pak Kret municipality and surrounding agriculture

Abbreviations

WW: Wastewater

SW: Solid Waste

Small boxes in processes: stocked or accumulation

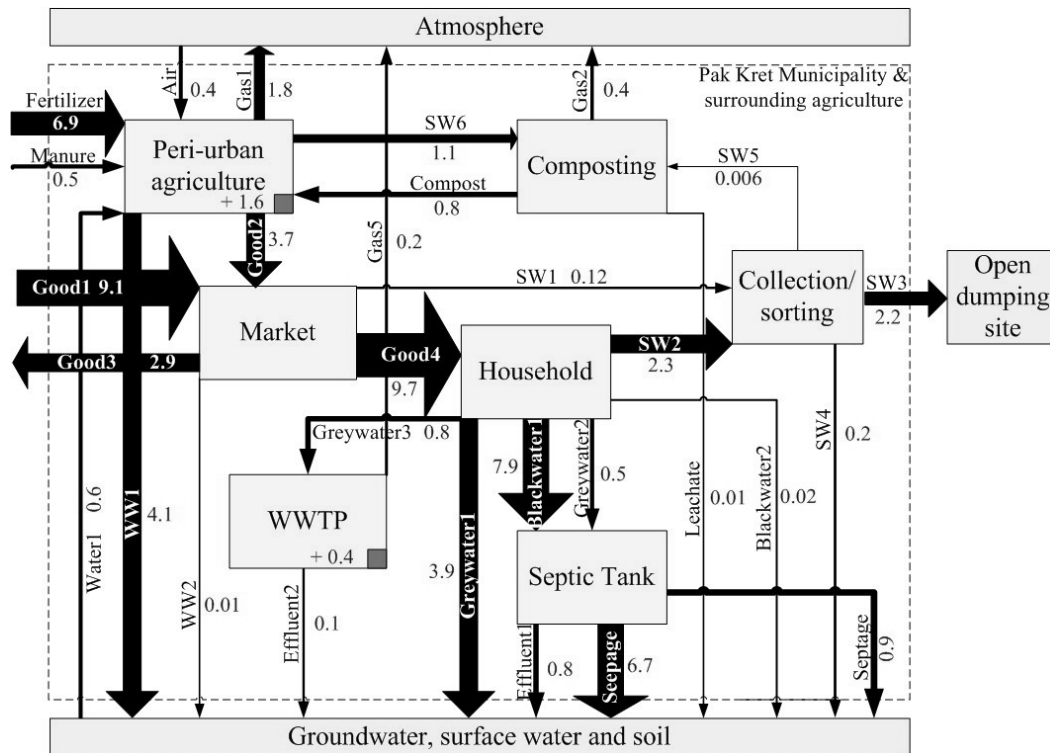


Figure 3 N fluxes (g/capita.day) in the system

According to the results obtained from the study, the weaknesses of this system are analysed as follows; production of N fertilizer consumes lots of energy, besides, using chemical fertilizer for long period causes to soil damage. Chemical fertilizers (unlike organic fertilizers) do not supply micronutrients or organic matter to the soil and do not improve soil quality (structure, etc). Reusing organic solid waste and wastewater as organic fertilizer can replace part of the mineral used, improve soil quality and reduce N load into the environment as well.

As soil in Pak Kret municipality is clay with low permeability and groundwater table is high, the septic tanks do not work properly. There is a possibility of flow exchange between groundwater and septic tank effluent, leading to higher wastewater level in the tank and an increased probability of groundwater contamination which can also render water treatment for drinking water more difficult.

Regarding to the described problems, possible solutions were proposed for identifying the appropriate solutions for environmental sanitation improvements as follow;

1st Scenario: Installation of wastewater treatment plants as well as reuse of treated effluent and sludge to peri-urban agriculture

This scenario can reduce wastewater pollution to the environment. In this case, waste stabilization pond was chosen to treat household grey water, septic tank effluent and wastewater from market due to its effluent remains high N content for agricultural activity and low investment of construction and operation and maintenance. This measure allows the reduction of N requirement for chemical fertilizer around 57 % and also could supply irrigation water to agricultural areas. N loading in wastewater discharging to groundwater could be reduce around 31% (Figure 4).

2nd Scenario: Co-composting of municipal organic wastes from household and market with septage and reuse the compost for peri-urban agriculture

This scenario can reduce the amount of solid wastes dumped at open dumping site and septage discharging onto soil and into surface water. This measure allows the reduction of N requirement for chemical fertilizer around 77%. N loading discharging to environment could be reduced around 6% (Figure 5).

3rd Scenario: Installation of wastewater treatment plant and composting of municipal organic solid wastes

Construction of wastewater treatment plant to treat both blackwater and greywater can reduce surface water and groundwater contamination from high N loading of septic tank, household and market. This measure allows the reduction of N loading to environment around 45%. Moreover, treated sludge from the treatment plant can be reused in peri-urban agriculture which can compensate N requirement for chemical fertilizer around 29%. In addition, composting of municipal organic solid waste of the system could reduce N loading to open dumping site and also can reuse composted product to agricultural activity which can reduce 22% of N requirement for chemical fertilizer. This scenario could totally compensate 51% of N requirement for chemical fertilizer (Figure 6).

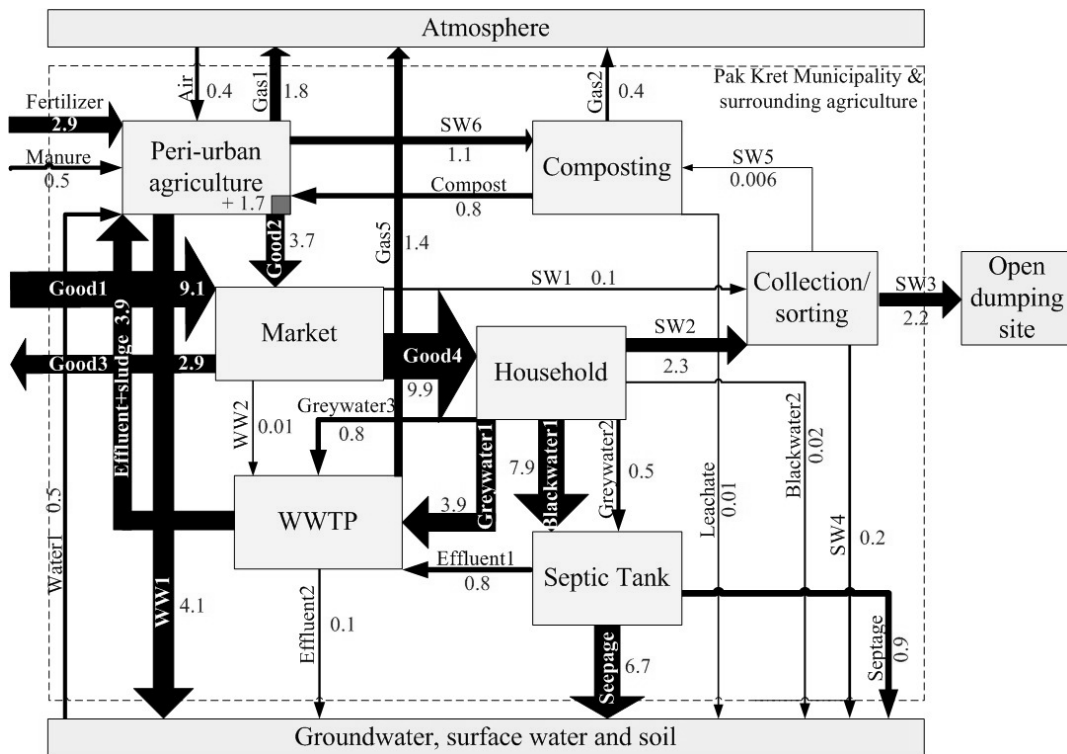


Figure 4 N fluxes (g/capita.day) in the system according to scenario 1

Conclusions and Recommendations

According to the MFA results and discussions, it was found that the major N input fluxes into the system were chemical fertilizer and food supply (6.9 and 9.1 g/capita.day respectively). The major N output fluxes were from septic tank seepage, household grey water and organic waste to open dumping site (6.7, 3.9, and 2.2 g/capita.day respectively). Installation of wastewater treatment plants as well as reuse of treated effluent and sludge to peri-urban agriculture give the reduction of N requirement for chemical fertilizer and N loading in wastewater discharging to the environment 57 % and 31% , respectively. Co-composting of municipal organic wastes from household and market with septage and reuse the compost for peri-urban agriculture should reduce N requirement for chemical fertilizer and N loading to environment 77% and 6%, respectively. Wastewater treatment plant and composting of municipal organic solid wastes give the reduction of N requirement for chemical fertilizer from reuse of treated sludge and composted product and N loading to environment 51% and 45% repectively.

Recommendations

Scenarios should be developed with the different stakeholders in Pak Kret (householders, farmers, municipality, etc.) The scenarios should then be evaluated according to different aspects such as costs, socio-economic benefit, health and environmental impact. This study showed that MFA can be used as a tool to evaluate scenarios based on resource recovery and environmental protection aspects. MFA needs a number of information to calculate the material fluxes in which the insufficient data and reliability are considered as the main problems. In the case of Pak Kret, the accuracy of the estimations and calculations can be improved by measuring of present required fertilizer for agriculture, determining of transfer coefficients³ of nutrients for each crop, and determining of transfer coefficients of septic tanks.

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³ Transfer coefficients (TC) define the fraction of the total inputs into the process transferred to other processes.

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