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Balance Sheet for Phosphorus in Malaysia by SFA

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Abstract: Phosphorus (P) is essential element for plant growth, human and animal nutrition. However, is output has long been recognized as major causes of environmental problem, especially eutrouphication for freshwater. Application of Substance Flow Analysis (SFA) has been used to identify the amounts of P through inputs and outputs of different subsystem (pools) of Malaysia region. In this study, the stocks and flows of P in agriculture, household, industry (CITT), waste management and wastewater management were identified and quantified. The P flow and stock was calculated for the year of 2007. Total inputs to Malaysia region was estimated to be 879 kt P a^{-1}, whereas total output was approximately 1151 kt P a^{-1}. Out of this, it is widely recognized that the highest of P accumulates concentrates at industrial (CITT) subsystem is 286 kt P a^{-1} (38%), followed by agricultural subsystem with 266 kt P a^{-1} (34%). The results obtained reveals that imbalanced of industry trade on export and import of P, as well as input-output balance in Malaysia region is another significant area to be improved.

Key words: Phosphorus; Metabolism; Substance Flow Analysis/Material Flow Analysis, Malaysia.

INTRODUCTION

Phosphorus (P) is non renewable resource and it is essential to plant growth, animal feed and soil flexibility (Cordell, 2006). P inputs has been identified through two source (path) which are non natural sources; fertilizer, animal feeds, organic solid (organic wastes) and wastewater. For natural sources are atmospheric deposition and weathering of natural minerals. However, this area will not be given much attention in this study because of the difficulties in accurate quantification. P was chosen as a case study for the following reasons: (i) It is non renewable resources, (ii) it may cause eutrophication problem to environment (iii) it plays an important role in economic efficiency in each country.

In Malaysia, P problem with eutrophication phenomenon become major consideration since 40 years ago. Many studies also have indicated that, phosphorus concentration in sea, rivers and lake in Malaysia had exceeding the capacity of receiving waters (Radojevic and Bashikin, 1999). Therefore, efforts to limit eutrophication often focus on reducing P inputs to environment with phosphorus has been investigated by using several approaches such as empirical models, simple budget model, nutrients good-web models and other (Carignan and Kalff, 1980). However, the main purpose of this study is to apply and to describe a method of Substance flow analysis (SFA) on Malaysia scenario. According to this approach, a substance of phosphorus is able to be qualification and quantification the link between sources, pathways, intermediates and final sinks of phosphorus flow in different periods (Brunner and Rechberger, 2003). Furthermore, SFA is also regarded as a tool to describe the current situation of phosphorus problem existing and phosphorus metabolism network in some area. For instance, several studies have been conducted focusing on the national, regional or local flows of phosphorus (Isermann, 1990; Forsberg and Rengefors, 1992; Nilsson, 1997; Danube Applied Research Program, 1997; Burström *et al.,* 1998; Günther, 1998; Tangsubkul *et al.,* 2005; Billen *et al.,* 2007; Montangero *et al.,* 2007).

History of P in Malaysia:

The history of P in Malaysia was studied by Chong Foo Shin (1983), revealed that there is no known marine phosphate occurrence in Malaysia. Only based on theories on geological environment for marine phosphate, there is potential phosphate provinces exist in Malaysia. For instance, the analyses of local paleography, paleooceanography, regional tectonics and common lithologic association have identified the following for P investigation:

(a) Rock age: Cambrian (550-515 milion year), Ordovician (515-435 million year) and Permian (290 245milloin year) at Peninsular Malaysia.
(b) Lithologic association with black shale and chert was detected at Mahang Fm (Perak and Kedah), Karak Fm. (Pahang) and Pendawan Fm. (Sarawak).

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Bat guano in Malaysia is mostly in inorganic form as phosphates of calcium, aluminum, iron and partly in organic form. The P content of bat guano in Malaysia was estimated to be values range from 0.47 to 17 percent, about 0.9 percent of which is soluble in 2 percent citric acid. Furthermore, the accuracy of guano reserve and resource in Malaysia was estimated to be 30 thousand metric tons in 1974 with the world production was 50 thousand metric tons (Bureau of Manila, 1968). Most deposits of guano in Malaysia are small, containing a few hundred or a few thousand metric tons, largely contributed of the dried excrement of bats. According to Kalpage (1979), bat guano in Malaysia was found in limestone caves in Kedah, Perlis and Perak and it was popular among Malaysian paddy farmers in Kedah and Perlis at one time.

According to the report of Malaysia Statistics Department (DOS) (2001), only cave rock phosphate deposits are known for phosphate rock in Malaysia. While the potential area of phosphate in Malaysia are Bukit Cuping in Perlis, Gunung Keriang in Kedah, Gua Boma in Pahang and Gua Niah in Sarawak. According to Arsap (1976), the cave phosphate rock is formed by percolating of rainwater through the guano with accompanying leaching of phosphate and other soluble, followed by deposition on suitable rock surfaces and crevices below.

In 1983, there were six processing factories in Kedah and Perlis producing about 12,000 tonnes per year (Chong Foo Shin, 1983). But to date, all the factories were closed due to management and financial problems. Furthermore, in 1978, the phosphate dust is used by the chemical company of Malaysia to produce granulated natural rock phosphate fertilizer. Also, apart from the granular P-fertilizer, the only one company that produced single superphosphate locally has closed down (Von Uexkull, 1975). The phosphate produces in Peninsular Malaysia from 1972 till 1976 are recorded as 20,000 tonnes of P2O5 by 1972, 24300 tonnes by 1973, 25,200 tonnes by 1974, 20,900 tonnes by 1975 and 19,300 by 1976 (FAO, 1979).

Aims of the Study:

This study provides an overview of phosphorus input and output exist in Malaysia. Main issues related to phosphorus flow discussed at this paper were:

(1) What are the major sources of excess phosphorus supply to Malaysia's environment?
(2) What are the input and output of phosphorus in Malaysia?
(3) How much P input and output transfer from one system to another?
(4) How can we assess the recovery of Malaysia system from phosphorus loads?

A brief discussion is provided on each these issues using information available from study results.

Methodology:

Background of Study Area:

The setting of this study is Malaysia with comprises thirteen states plus the Federal Territories of Kuala Lumpur, Federal Territories of Putrajaya and Federal Territories of Labuan. The total land area of this country is 328,550 square kilometers (km^2) with a registered population of 22,036 million people in Peninsular Malaysia, 3114 and 2440 million people from Sabah and Sarawak respectively in 2007 (DOS, 2008). The population in Malaysia is multi-ethnic in all parts of the country, as such Malays, Chinese, Indian, whereas the ethnic group such Iban, Bidayuh, Melanau, Kenyan, Keyan and others in Sabah and Sarawak.

Malaysia encompasses a surface area of approximately 320,000 km^2 with 59% occupied by forested land, 9% rangeland, 12% cropland (row crops, vegetables, citrus, sugarcane and others), 15% pasture, 8% urban and 27% aquatic systems (CIA, 2006). The total land area of Malaysia is 329,847 km^2, the 66th largest country in the world in terms of area, whereas the peninsular Malaysia makes up 131,000 km^2 or 39.7%, while east Malaysia covers 198,847 km^2 or 60.3% of the total land of the country. About half of Peninsular Malaysia soil is covered by granite and other igneous rocks, a third more is covered by stratified rocks older than the granite and the remainder is covered by alluvium (DOM, 2000). While, the terrain can be characterized as coastal plains which rises towards the hills and mountains.

For topography and climate, Malaysia is a tropical country that faces two monsoon winds seasons, which are the Southwest Monsoon from late May to September and the Northeast Monsoon from November to March. The Northeast Monsoon brings in more rainfall compared to the Southwest Monsoon. There was estimated that annual rainfall exceeds 2000 mm a year and the average temperature is 27 degrees celsius (DOS, 2009).

During the 22-year term of Prime Minister Mahathir bin Mohamad (1981-2003), Malaysia was successful in diversifying its economy from dependence on exports of raw materials to expansion in manufacturing, services and tourism. Malaysia has achieved remarkable economic progress over the past two decades and is well on the way to becoming a fully industrialized nation. In 2007, the economy as a whole grew at 9.3 percent and agricultural value added increased by 4 percent (DOS, 2009).

System Analysis:

The P in Malaysia regional was evaluated by Substance Flow Analysis (SFA). In this case study, SFA was used to track all the significant flow of P in five subsystem chosen, which are agriculture, household, industry

(CITT: Commerce, industry, trade and tourism), solid waste management and domestic wastewater management. The results shown in Fig.1 are the quantities represent thousands of tonnes (kt) of phosphorus per annum (annual), while thickness of the arrows represents the amount of P. This quantity relates to the 2007 period and Malaysia was chosen as the spatial boundary, covering some 13 political states. Plus, all figures refer to thousands of tonnes P is rounded to the nearest thousand. Besides, the boxes designate processes and the arrows represent flows. All qualification and quantification of related data and statistic is estimated by using Microsoft Excel Spreadsheet and it is interpreted into a flow diagram and modelling system which enabled in Fig.1.

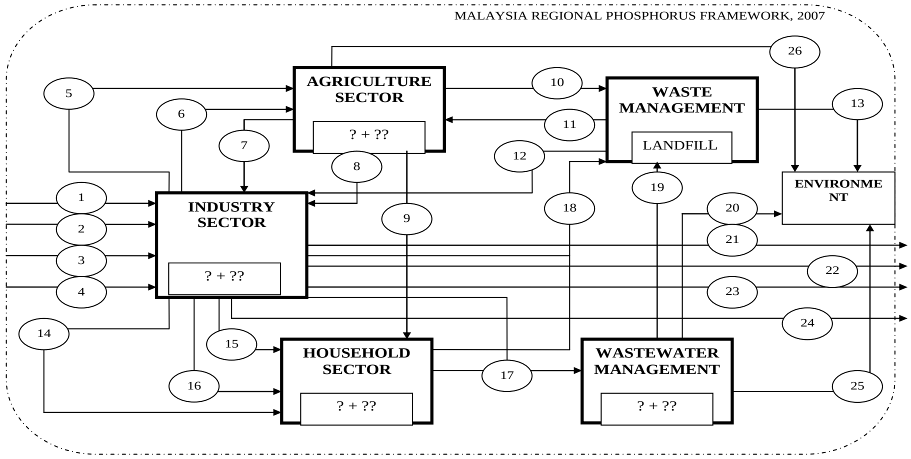

Fig. 1: The system analysis for phosphorus balance in Malaysia.

Here, the all subsystem is defined with P flow (flux) with comprising 26 mutually linked loops with consider the main direction of the substance flows in the system is from the top to the bottom. Fig. 2 shows the whole system under this study, as be expressed as a 'framework model'. The analysis will be simplified with numbering each process and good, in order to make reorganization towards each flows became easy to count. Table 1 illustrates the 26 flow and 5 subsystems involve in this case study which it definition for each term is explained in the 'framework model' below:

Table 1: The numeration of flow used in MFA system.

Code	Name	Meaning
1	Food	Import food
2	P-Raw-F	Phosphorus raw + fertiliser
3	Fodder	Import fodder
4	Others	Import other phosphates
5	Fodder from ind.	Fodder from industry
6	P fertilizer	Phosphorus fertiliser consumption
7	Animal production	Animal production
8	Plant production	Plant production
9	Biomass	Biomass
10	Residue	P-removed
11	Compost	Compost
12	Recyclables	Recyclables
13	Wastes	Waste
14	Others	Other consumption
15	Detergent	Detergent consumption
16	Food cons	Food consumption
17	Do Ww	Domestic Wastewater= Household wastewater + Industrial wastewater (Input)
18	Mun. Waste	Municipal Waste= Household waste + Industrial waste
19	Sludge	Sludge
20	Effluent	Effluent
21	Fodder	Fodder export
22	Others	Other export
23	P fertilizer	Phosphorus fertilizer export
24	Food	Food export
25	Domestic Ww	Domestic Wastewater= Household wastewater + Industrial wastewater (Output)
26	Erosion, leaching	Erosion and leaching

Data Sources and Quantification:

In order to calculate and balancing P in each subsystem, numerous data types are required such as resources, goods (trade and use), process and substances, concentration of selected indicator, geographic region, population, impact of studied system, equivalent equation and others. While, other data sources covering book keeping storage keeping, log sheets of operators, personal information, estimations, online measurements and specific measurement. Moreover, the statistical information in this case is about Malaysia inventory, production, consumption, imports and an export of goods (foreign trade) is available from various literatures. Hence, the specific source will listed as follow below:

***Agriculture*:**

In this study, agriculture subsystem are characterized by 3 pool; (a) animal production, (2) plant production and, (c) agricultural soil. Data for animal production is calculated **according** to Sibbesen and Runge-Metzger (1995) method, which is obtained on the annual number of slaughtered animals and animal products (milk and eggs) (FAO, 2004; Yearbook of Agriculture 2004-2007; DVS, 2007 and MOA, 2007). On other hand, P concentration in manure and products is taken from various local literatures (Devendra, 1975a; MOA, 1993; Sibbesen, 1996; Ng, 1979 and Taiganides, 1996). In plant production, results from the annual amount of P removed of output goods (harvested plants or crop production such as cereals, industrial crops, vegetables and tuber crops, cash crops, spices and fruits) was calculated by multiplying the corresponding yields (amount of crop production) with P concentrations (MARDI, 2006; DOA, 2008); FAO, 2007; FAMA, 2008; MOA, 2004; and, DOS, 2007). While, P concentration is derived solely from (Ng, 1979), (Bolton, 1964), (Thong and Ng, 1978), (Joseph, 1971), (Yaacob, 1983), (Awada and Suehisa, 1971) (Devendra, 1975a, Devendra, 1975b and Devendra, 1979), (Thong and Ng, 1978) and Chen (1985), (MARDI, 1999) and (De Datta, 1986), (Tandom, 1987), (Pierzynski and Logan, 1993).

***Industry*:**

P calculation to CITT subsystem included fertilizer industry, detergent industry, fodder industry, food industry and others industry. The data for all import and export trade was obtained from Ministry of Trade (MITI, 2007), FAO database (2007) and Malaysia Statistic Report (2007). The amount of P in fertilizer industry was determined according to fertilizer import, exports, production and consumption of phosphates in 2007 (FAO, 2008; IFA, 2007; and DOS, 2009). While total amount of P in detergent industry was calculated by multiplying the annual detergent use, import and export in Malaysia by the fraction of STPP content in associated detergent use in 2007 (Ciba, 1977; DOS, 2008; MATRADE, 2001; CICM, 2000; MIDA, 2006). Meanwhile, Malaysia trade of food and fodder industry was calculated using the official statistic data of Malaysia and balance sheets for food commodities produced by FAO (2004). Finally, the P flow in others industry was calculated according Malaysia official statistic report (2007).

Household:

The flow of phosphorus in household subsystem was estimated according to household food intake and food purchased, detergent consumption by household and others use by Malaysia population annually. Total amount of P in food consumption was estimated by multiplying the Malaysia population value with the P content (Refer to Latifah, 2010). Furthermore, there are several formula that were used as decribed in Saeyhan (2004), Zessner *et al.*, (1997) and Baccini and Brunner (1991). Meanwhile, the amount of raw data of food commodities (kg per capita per annum) was obtained from the food balance sheet of FAO (2005) and Malaysia official statistic report (2003, 2004, 2005, 2006, 2007 and 2008). However, the total amount of P in biomass was not estimated because the lack of raw data on the amount of biomass in activities cooking and heating.

***Domestic Wastewater Management*:**

In the wastewater management subsystem, the calculation was based on the distribution of P flow in sludge and effluent in the both of two compartments, which are Individual Septic Tank (IST) and Sewage Treatment Plant (STP) in year of 2007. The P flow in domestic wastewater subsystem was estimated based on the population is connected to wastewater services with daily average water consumption in households and P loads per capita. In this study, the P load discharge limit in domestic wastewater is according to prescribed under Environmental Act Regulation (1974) and sewage Service Act (1993). The data for domestic wastewater generation was obtained from the SPAN (2003-2008), MHLG (2007), IWC (2003, 2004, 2005, 2006, 2007 and 2008) and DOE (2003).

Waste Management:

The P flow in solid waste management subsystem was calculated on the five pool of the most important waste accumulated in Malaysia region like landfill, compost center, incineration recycled area and others center (for examples: dumping, burial and open burning). Meanwhile, the estimation was made according to the amount data of municipal solid waste generation and waste collected by Alam Flora Sdn Bhd. that were obtained from local waste management company and local authorities (Alam Flora, 2007 and MHLG, 2005). While, phosphorus fraction in waste is estimated based on Skutan and Brunner (2004), Schachermayer *et al.*, (1995) and Sokka *et al.*, (2004). However, waste generation data originating from construction workers does not include in the study.

Stock and Environment:

Stock of total available P in studied system was not estimated because of the unavailability of complete data, instead the true scenario in Malaysia that there is no P reserve was recorded till now except in formed in guano, but still not be explored yet. Meanwhile, P losses from environment were not known due to lack of studied regarding this matter.

RESULTS AND DISCUSSION

In this study, Malaysia P stocks and flows were identified and quantified using Substance Flow Analysis (SFA) as the research method.

P Balance in Malaysia:

Table 2: The average amount of P flow per thousand tonnes per year (kt P/a) in Malaysia.

No.	Name	Malaysia (thousands tonnes/year)
1	Food	25
2	P-Raw-F	162
3	Fodder	6
4	Others	26
5	Fodder from industry	48
6	P fertilizer	218
7	Animal production	4
8	Plant production	72
9	Biomass	0
10	Residue	115
11	Compost	0
12	Recyclables	0
13	Wastes	26
14	Others	9
15	Detergent	129
16	Food cons	35
17	Domestic Wastewater	24
18	Municipal Waste	26
19	Sludge	15
20	Effluent	8
21	Fodder	13
22	Others	5
23	P fertilizer	40
24	Food	9
25	Domestic Ww	24
26	Erosion, leaching	132

Table 2 presents per capita P flow is tabulating with origin of flows (number) and associated names of goods. Figure 2 illustrates the results of SFA of metabolism-P in Malaysia in 2007. The results to date are shown in Fig. 2 in which the quantities represent thousands of tonnes (kt) of phosphorus per annum and full description of the sources data.

From the Fig. 2, some part such as wastewater management and waste management are balanced or structured with follow from back to front. The flow of P is quantified as the net sum of input flows, internal flows and output flows. However, there is no accumulation implies to all P flows through the system and the stock of each compartment of agriculture, CITT, household, waste management and wastewater management is not quantified and the proportion of P in forest, biomass, zoo mass, soil storage and ashes is not specified in this model.

From the analysis of the entire system of Malaysia, the results indicate that industry (CITT) subsystem is the most critical sector influencing the amounts of the phosphorus accumulated in Malaysia region. As shown in Fig.2, nearly 45% of the total net phosphorus is accumulated in the region and this was assumed from the amount of the total phosphorus import leave the area is 35%. Therefore, changing the concept of import and export trade by stressing on local product demand may leads to a change of successful economic in Malaysia growth.

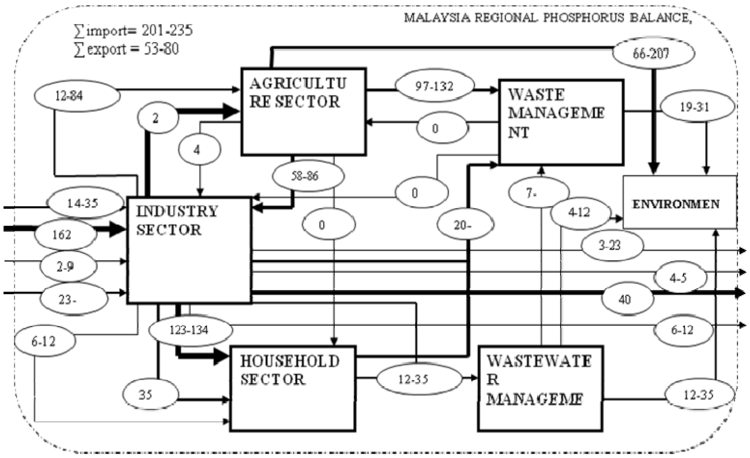

Fig. 2: The regional P Metabolism of Malaysia in 2007.

In Fig. 2, the largest flows-P to and from the system are agriculture and CITT which amount to 23% of the total incoming P and 11% of the total P leaving the system. This largest user of P in the industry and agriculture sector have consumes around 21% of the total P produced. Besides, the second largest input flow-P is the import of P-fertilizer import into industry which constitutes 16% of the total incoming P.

About 15% of the total input P into wastewater system comes from external foodstuff sources with the remaining 70% being drawn from P in household activities within wastewater treatment area, whereas only less than 10% of P have being recycled from households sector. Another interesting fact is about 15% of the incoming P to wastewater and waste management system is released back to surface water (after treated) for the purpose of maintaining environmental flows. Despite that, around 13% of P leaving the system as erosion and leaching process is recorded from agricultural activities.

In Figure 3, exhibits the estimation results of P balance in percentage amount (%) for general flow (item) in Malaysia region. As an illustration, the highest possible of P flow is from the highest P fertilizer consumed for agricultural activities with the fraction of P is about 21 % (218 kt P). Followed by the 15 % of flow 'P raw fertilizer' imported into Malaysia region, equals with 162 kt/a of P.

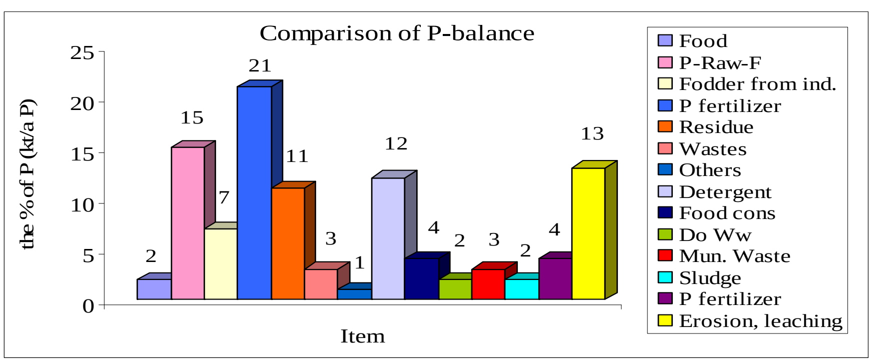

Fig. 3: Estimation of per capita (%) P balance in Malaysia region, 2007.

Meanwhile, the results of the output of flow-P discharges into Malaysia's environment was assumed to be 13% from leaching and erosion with the amount is 132 kt/a. clearly show that Malaysia is a country that the widespread use of P fertilizer in plantations activities on oil palm, rubber, cocoa, coconut, pepper and rice has led to an increased on erosion and leaching action, instead the large disposal of this output which can be a problem to the industry and the environment is the main contributor for this case. Finally, the lowest flow for P accumulates is originating from 1% of 'other' in CITT sector, which equivalent with 9 kt/a.

Phosphorus Flow in Malaysia in 2007:

Fig. 4, Fig. 5, Fig. 6, Fig. 7 and Fig. 8 illustrates the P input flows and output flows of Malaysia whole five subsystem in 2007. All quantities are calculated to tonnes per year. Consider first Fig. 4, which treats the **agriculture** subsystem. Most of the P input is agricultural soil in the region is 54% (200 kt P per year) followed by plant production with 31% (115 kt P per year) and animal production is 15% (57 kt P per year). In total, the region input about 330 kt of P in 2007. Of the P leaving (output) the agriculture, approximately 61% (137 kt P per year) is loss from soil, the remainder enters the crop production, in which this pool produces 32% (72 kt P per year). As remain is animal production with P output is 6% (14 kt P per year).

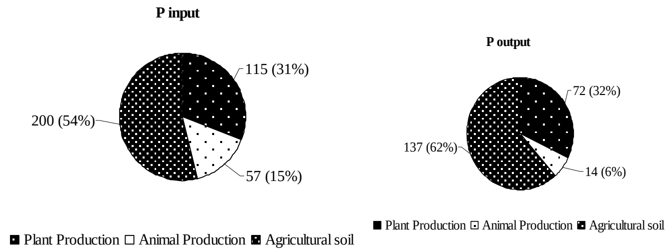

Fig. 4: Input and output of P balance in agriculture subsystem (kt P/a).

In Figure 4, by fertilizer (200 kt P per year) and manure (11 kt P per year), 211 kt per year of P are applied to Malaysia regional soil. While, plant take up 115 kt P per year and 72 kt P per year of plant removed and soil losses passes to the surface waters by leaching and erosion. Therefore, it is a matter on the amount of fertilizer applied in soil need be monitored and controlled in future, regards to avoid environmental pollution. Here, sludge (plus compost) is assumed zero, except for atmospheric deposition and weathering of natural minerals, where it is not known whether and how much it exists.

Other hand, taking into account that the efficiency rate for plant production (including agricultural soil) is 97%, far On greater than animal production, about 3% (See in Figure 4). Clearly revealed that when P is limited, the efficiency of P in dietary intake (food taken) should be changed with low meat consumption, increasing vegetarian foods and animal farming (Brunner, 1996). This efficiency was calculated as followed; as plant production (including agricultural soil) consumes 211 kt P per year to produce 115 kt P per year in crop harvested and animal production (including eggs and dietary products: milks etc.) requires 15 kt P per year to produced 3%.

Fig. 5 displays the P flows in the **industry (CITT)**. The largest input of P in industry subsystem is fertilizer sector, which comprises approximately 45% (162 kt P per year) of the total usage. Overall, the largest amount of P input for fertilizer sector on a Malaysia scale is mainly because of high demand with P fertilizer imports for industrial applications (MIDA, 2004). Since industry P use surplus in the Malaysia has already posed, attention should also be paid to nutrient surplus management in Malaysia with use of free-P product. Meanwhile, detergent sector represent the largest P output in Malaysia capturing about a quarter of the total export trade account for nearly 42% (263 kt P per year) of the total output flow; food sector, fodder sector and other sector (including pharmaceutical industry, metal industry etc.) in make up the rest with total output about 17% (107 kt P per year).

Fig. 5: Input and output of P balance in industry subsystem (kt P/a).

In Fig. 5, the study found that the total average net P import is 79% (219 kt P per year) outweigh the total average net export is 21% (57 kt P per year) by far, resulting in accumulation of 162 kt of P per year). Interestingly, this study reveals that there is huge extent of the accumulation of P in industry (CITT) subsystem, with about one-sixth of the P imported stays ‘forever’ within the region. Perhaps, further researches on SFA will able to investigate the fate of potentially risks P in Malaysia’s environment.

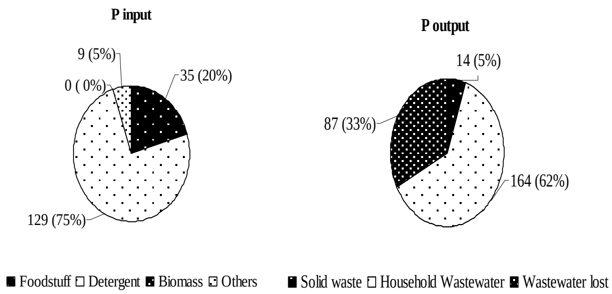

Fig. 6: Input and output of P balance in household subsystem (kt P/a).

Fig. 6 shows detailed P flows into the **household** processes. All of the P input entering household comes from foodstuff (including food intake and or purchased) with 20% (35 kt P per year).The incoming P is used for nourishing activities (detergent) is 75% (129 kt P per year). However, the value of P flows of biomass (including cooking and heating) is not precisely known 0% (0 kt P per year). On the output side (Fig. 6), only 5% (14 kt P per year) of food brought by private household in Malaysia is discarded as municipal solid waste, while 95% (251 kt P per year) being eaten, eventually transformed to urine and faeces, collected with sewage and loss to the environment. Hence, when comparing the P balance of input and output for wastewater management subsystem, it can be concluded that rural life activities play important key towards wastewater discharges rather than solid waste discard for P flow. For P output of household wastewater, intensive use of P from nourishing activities and food consumption (dietary habit), has resulted in a high surplus and this also have a great influence from non-P free in detergent and product in Malaysia daily practices. In Malaysia, the total detergent consumption per capita per man (kg/ man-year) is assumed to be 3 kg/man-year (Mori, 1991).

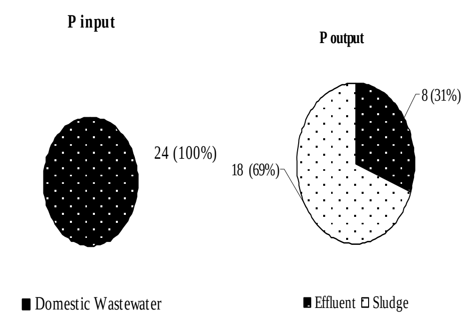

Fig. 7: Input and output of P balance in domestic Wastewater subsystem (kt P/a).

Detailed **domestic wastewater subsystem** P input and output are illustrated in Fig. 7. Total input to Malaysia domestic wastewater was estimated to be 100% (24 kt P per year), whereas total output was approximately 31% (8 kt P per year) for effluent and 69% (18 kt P per year) for sludge. At present, 95% of the sludge waste is reserved without any economic activities and usually was disposed in landfill area since it application in present is low priority to local Malaysia societies (MHLG, 2003). As mentioned above, the result found that there is large P accumulation in wastewater compartment due to the source of detergent phosphates as well as food phosphates because they are sewered in the same way either to septic tanks or sewage treatment plant or will reach rivers or sewage landfills. Therefore, this area is requiring additional attention for developing of a sound phosphorus management practice in Malaysia region.

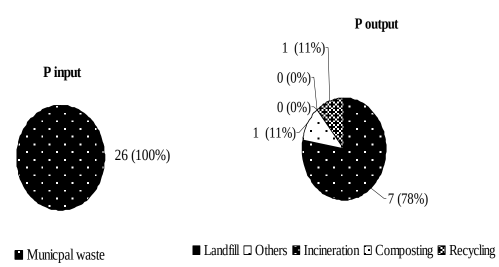

Fig. 8: Input and output of P balance in solid Waste subsystem (kt P/a).

Annual input-output of P from **solid waste subsystem** in Malaysia was approximately 100% (26 kt P per year) of which imports accounted for 36% (Fig. 8). Landfill application and others (open burning, burial, illegal dumping etc.) are found to be the most dominant contributors of P output in waste streams, accounting for 78% (7 kt P per year) and 11% (1 kt P per year and plus with 9 kt P per year for waste not collected) of the total load respectively. Since much of the P product has been landfilled with this approach, it may be lead is leaching into surface and ground waters especially when landfill application without bottom and top liners. Hence, it is recommended that municipal solid waste is applied to other method such as incineration, compost and recycling.

Uncertainties in the Study:

In this study, due to the error in the information from the facilities subjected and the lack of input from the official and unofficial statistic data on the national level in the chosen period, we are not be able to identify more uncertainty for this case study. Especially, with the uncertainty calculation in particular pool. Moreover, this paper is the first attempt on this application of specific approach such as Monte Carlo Simulation and Gauss's Law (Brunner and Rechberzger, 2004).

Conclusions:

Case study of phosphorus in flow in Malaysia exemplifies how MFA can be used to investigate the flows and stocks of phosphorus in Malaysia for the year 2007. The outcome from MFA application may help the researches and related bodies to identify of the areas requiring improvement for developed the sustainable development of regional waste and environment.

The findings of the study reveal several issues and are summarized as follows:

- There is unbalance of P input-output in Malaysia region with the total input is 879 kt P/a and total output is 1151 kt P/a.
- The real amount of P reserves in Malaysia is not known. However, there are potential useful stocks that are not being exploited at this moment like guano.
- In Malaysia, there is no actions have been done for banning phosphates from household detergent, food product, fertilizer and other related goods.
- The level of P-recycling in Malaysia region is very low especially in P-solid waste products and P-domestic wastewater. Only 3 to 7 % of that amount P is successfully be recycled back into the environment.
- In Malaysia scenario, the value of import P is higher than export P.

The final results conclude that, strategies to reduce and to limit the amount of P flow in particular area in this region need to be discussed and developed as well as; Best management Practices (BMPs), control phosphorus imports, implementation on legislative and enforcement action, reducing fertilizer recommendation, on site management strategies (in situ phosphorus management). On other hand, several issues such as population density, lifestyle, type of activities and consumption need to be considered too. Thus, a continue research should be carried out in future.

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REFERENCES

Alam Flora, S.B., 2007. Alam Flora Annually report in 2003-2008. Kuala Lumpur. Malaysia.

Arsap, 1976. Fertilizer marketing, distribution of use in Malaysia. Bangkok, Thailand.

Available online at: http://www.matrade.gov.my/cms/index.jsp Data accessed: 1th April 2007.

Awada, M. and R. Suehisa, 1971. Nutrient removal by papaya fruits. Hort Science, 5: 82.

Baccini, P. and P.H. Brunner, 1991. *The* Metabolism of the Anthroposphere. Springer, Berlin.

Billen, G., J. Garnier, J. Némery, M. Sebilo, A. Sferratore, S. Barles *et al.*, 2007. A long-term view of nutrient transfers through the Seine river continuum. Sci Total Environ, 375(1-3):80-97.

Bolton, J., 1964. The manuring and cultivation of *Hevea brasiliensis*. J. Sci. Fd. Agric., 15: 1-8.

Brunner, P.H. and H. Rechberger, 2003. Handbook of material flow analysis. CRC Press.

Bureau of Minerals, Manila, 1968. Mineral raw material resource for fertilizer industry in the Philippines. In Proc. Seminar "Sources of Mineral raw materials for the fertilizer industry in Asia and Far East". Bangkok, Thailand, pp: 78-80.

Burström, F., N. Brandt and B. Frostell, 1998. Materialräkenskaper och Miljöarbete i Stockholm- kväve och fosfor i storstaden.

Carignan, R. and J. Kalff, 1980. Phosphorus sources for aquatic weeds: Water or sediments? Science, 207: 987-989.

Chen, C.P., 1985. The research and development of pastures in Peninsular Malaysia. In: Pastures in the tropics and subtropics. Proceedings of a symposium. October 2-6, 1984. Tsukuba, Japan. TARC, Ministry of Agriculture, Forestry and Fisheries.

Chong, F.S., 1983. Phosphorus in Malaysia Soil. In report of Malaysia Mineralogy Statistic. Kuala Lumpur, pp: 221.

CIA, 2006. The World Fact Book: Malaysia. Retrieved-12-09.

Ciba, 1977. Soap. World Conference on Soaps and Detergents Convention Centre, Montreux, Switzerland October 9-14, 1977. Journal Oil American society, 54(6): 32-33.

CICM, 2000. Central Industrial Corporation Marketing Monthly Trade report, Kuala Lumpur, Malaysia.

Cordell, 2006. Urine Diversion and Reuse in Australia: A homeless paradigm or sustainable solution for the future?, Masters Thesis, Department of Water and Environmental Studies, Linköping University, Sweden. Available from: http://www.ep.liu.se/undergraduate/abstract.xsql?dbid=8310.

Danube Applied Research Program, 1997. Nutrient Balances for Danube Countries, Final Report, Project EU/AR/ 102A/91.

De Datta, S.K., 1986. Improving fertilizer nitrogen efficiency in lowland rice in tropical Asia. Fertilizer Research, 9: 171-186

Devendra, C., 1975a. Efficient utilization of feedingstuffs in Malaya: Perpestives and potential prospects. Bull No.141. MARDI, pp: 18-32.

Devendra, C., 1975b. Agricultural by-products for animal feeding in Malaysia. MARDI, 31: 14.

Devendra, C., 1979. Malaysian Feedingstuffs. Malaysia Agricultural Research and Development Institute. pp: 106-120.

DOA, 2003-2008. Department of Agricultural: Agricultural statistical data 2003-2008, Malaysia: Kuala Lumpur Statistical Office, 2008.

DOE, 2003-2005. Department of Environment: environmental Quality Report. Kuala Lumpur, 2008.

DOM, 2000. Department of Mineralogy: Mineralogy data, Malaysia. Kuala Lumpur, Malaysia.

DOS, 2001-2009. Statistical data 2003, Malaysia: Kuala Lumpur Statistical Office, 2008.

DVS, 2005-2008. Department of Veterinary Services, Ministry of Agriculture, Malaysia.

FAMA, 2003-2008. Federal Agricultural Marketing Authority report in 2003-2008. Malaysia. Available online at: http://www.famaxchange.org/ Data accessed: 10th April 2007.

FAO, 1979. FAO Annual Review, 1974. Rome. Available online at: http:///www.fao.org Data accessed: 11th May 2007.

FAO, 2004-2007. FAOSTAT, Agriculture Statistics; Food Balance Sheets. 2001. Food and Agriculture Organization of the United Nations. Available online at: http:///www.fao.org. Data accessed: 11th January 2008.

Forsberg, C. and K. Rengefors, 1992. Anrikning av fosfor i stadsregionen- en fosforbuget för Stockholm. Vatten, 49: 305-10.

Günther, F., 1998. Phosphorus management and societal structure - hampered effluent accumulation processes (HEAP) in different areas of the Swedish society. Vatten, 98: 3.

International Fertilizer Industry Association (IFA), 1996-2006. Available online at: http://www.fertilizer.org/ifa/publicat/html/pubman/manual.htm. Data accessed: 18th January 2009.

Isermann, K., 1990. Share of agriculture in nitrogen and phosphorus emissions into the surface waters of Western Europe against the background of eutropication. Fertil Res., 26: 253-69.

IWC, 2003-2008. Indah Water Consortium Annual Report 2003-2009. Kuala Lumpur.

Joseph, K.T., 1971. Nutrient content and nutrient removal in bananas as an initial guide for assessing fertilizer needs. *Planter*, 47: 7-10.

Kalpage, F.S.C.P., 1979. Soils and Fertilizers for Plantations in Malaysia. Kuala Lumpur, pp: 25.

Latifah, G., 2010. An application of Material Flow Analysis (MFA) as a tool for sustainable regional management: Phosphorus as a case study in Malaysia. Master Thesis. University of Malaya, Kuala Lumpur. Malaysia.

MARDI, 1991-2006. Malaysian Agriculture Research and Development Institute. Selangor.

MATRADE, 2001. Malaysian External Trade Development Corporation report (unofficial). Malaysia.

MHLG, 1998. Ministry of housing and local government: Guidelines for developers- sewage treatment plant, Volume IV, second edition. Malaysia.

MITI, 2007. Ministry of International Trade and Industry (MITI) statistic report; 2007. Malaysia.

MOA, 2003-2007. Ministry of Agriculture, Malaysia statistical databases; 2007.

Montangero, A., N.C. Le, V.A. Nguyen, D.T. Vu, T.N. Pham and H. Belevi, 2007. Optimising water and phosphorus management in the urban environmental sanitation system of Hanoi, Vietnam. Sci Total Environ., 384: 55-66.

Ng, S.K., 1979. Review of oil palm nutrient and manuring: Scope for greater economy in fertilizer usage. Oleagineux, 32: 197-209.

Nilsson, J., 1997. Biophysical Indicators and Sustainable Development Records for Improved Environmental Management-Examples from Municipalities and Firms. Ph.D. Thesis. Stockholm University. Stockholm, Sweden.

Pierzyanki, G.M. and T.J. Logan, 1993. Crop, soil and management effects on phosphorus soil test levels. J. Prod. Agric., 6: 513-520.

Radojevic, M. and V.N. Bashkin, 1999. Practical Environmental Analysis. The Royal Society of Chemistry, Cambridge, pp: 466.

Saeyhan, R., 2004. Development of a Method for the Regional Management and Long-Term Use of Non-Renewable Resource: The Case for the Essential Resource Phosphorus. PhD Thesis. University of Technical, Vienna. Austria.

Sibbesen, E. and A. Runge-Metzger, 1995. Phosphorus Balance In European Agriculture Status And Policy Options. In: Phosphorus in the Global Environment. H. Tiessen (Editor), John Wiley and Sons Ltd.

Sibbesen, E., 1996. Nitrogen, phosphorous and potassium in fodder, animal produce and animal manure in Danish agriculture in the 1980ies. Report no. S2054. Danish Institute of Plant and Soil Science, Tjele.

Sokka, L., R. Antikainen and P. Kauppi, 2004. Flows of nitrogen and phosphorus in municipal waste: a substance flow analysis in Finland. Progress in Industrial Ecology, 1: 165-186.

SPAN, 2003-2008. National Water Services Commission Report. Kuala Lumpur. Available online at: http://www.span.gov.my/ Data accessed: 20th January 2007.

Statistics Malaysia, 2003-2008. Statistical Yearbook of Malaysia 2003-2007 (Originally in Malaysia report), Statistic Malaysia, Kuala Lumpur, Malaysia.

Taiganides, E.P., 1996. Animal Wastes, Applied Science Publishers, London, UK.

Tangsubkul, N., S. Morre and T.D. Waite, 2005. Incorporating phosphorus management considerations into wastewater management practice. Environ Sci Policy, (8):1-15.

Thong, K.C. and W.L. Ng., 1978. Growth and Nutrient Composition of Monocrop Cocoa Plants on Inland Malaysian Soils. Preprint: International Conference on Cocoa and Coconut, Malaysia.

Von Uexkull, H.R., 1975. Fertilizer use and future trends in Malaysia. International Potash and Phosphate Inst. East and South Asia Programme, Singapore, pp: 275.

Yaacob, O., 1983. The Growth and Nutrient Uptake in Durian on an Oxisol at Serdang, Malaysia. Comm. in Soil Sci. and Plant Anal., 14(8): 689-698.

Zessner, M., K. Deutsch, W. Schaar and N. Kreuzinger, 1997. Nährstoffbilanzen der Donauanrainerstaaten - Ergebungen für Österreich, Institut für Wassergüte und Abfallwirtschaft, TU Wien, Vienna, Austria.