西 南 交 通 大 学 学 报

第 54 卷 第 3 期
2019 六 3 月

JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY

Vol.54 No.3
June 2019

ISSN - 0258-2724

DOI：10.35741/issn.0258-2724.54.3.29

Research article

Environment

A STUDY OF SOCIETAL FLOW OF PHOSPHORUS AND ITS EFFECT ON ENVIRONMENTAL SUSTAINABILITY IN LANDFILL SITES TERENGGANU, MALAYSIA

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Abstract

Phosphorus (P) in the waste at Terengganu can be identified by the heterogeneity of waste sources present at the waste disposal collected, the technology used, location of disposal and the management depends on microbial waste decomposition operations. The diversion of phosphorus out of the waste disposal sites is associated with the presence of low phosphorus inflows due to reduction, recycling and waste recovery activities outside of the landfill system. This finding motivates the socioeconomic characterization of the actors (players) and the identification of management strategies developed by the stakeholders. Thus, the purpose of this study was to identify the nutrient element of phosphorus in the waste disposal site and investigate whether stakeholders were aware of phosphorus and phosphorus credit related to local economic circulars and to examine possible ways of managing phosphorus in the waste source by small waste players in Terengganu. The design of this study was qualitative, involving face-to-face interviews with the stakeholders and a corresponding analysis of their responses. The findings revealed lack of knowledge and awareness by actors regarding the element phosphorus, the causes and sources of phosphorus generation as well as the effects of phosphorus on environmental sustainability. This study highlights useful factors to guide future management decisions and educational programs as well as further research, to disseminate information concerning phosphorus recovery among actors involved in waste management at Terengganu.

Keywords: phosphorus, landfill, waste management, substance flow analysis (SFA), social network analysis (SNA).

摘要： 丁加奴废物中的磷（P）可以通过收集的废物处理中存在的废物源的异质性，所使用的技术，处置地点和管理依赖于微生物废物分解操作来识别。由于垃圾填埋系统外的还原，再循环和废物回收活动，磷从废物处理场转移出来与低磷流入的存在有关。这一发现激发了行动者（参与者）的社会经济特征，并确定了利益相关者制定的管理战略。因此，本研究的目的是确定废物处理场中磷的营养元素，并调查利益相关者是否了解与当地经济通告相关的磷和磷信用，并研究可能的方法来管理废物源中的磷。在登嘉楼浪费玩家。本研究的设计是定性的，涉及与利益相关者的面对面访谈以及对其反应的相应分析。调查结果显示，行动者对磷元素，磷生成的原因和来源以及磷对环境可持续性的影响缺乏了解和认识。本研究突出了指导未来管理决策和教育计划以及进一步研究的有用因素，以传播有关在登嘉楼参与废物管理的行为者中磷回收的信息。

关键词: 磷，垃圾填埋，废物管理，物质流分析（SFA），社会网络分析（SNA）。

I. Introduction

Phosphorus (P) is a limited resource first described by Thomas Malthus in 1798 and categorized as a restricted element of planet Earth by Donella Meadows in 1972 [1]. The presence of P in the management of a waste system is triggered by leakage of P from food and organic waste, dust, feces, and wastewater that are not separated or burned but disposed of at the waste disposal site [2, 3, 4, 5, 6, 7, 8, 9, 10]. In the 1950s, 25 percent of P was recorded to have ended up in a water body or at a disposal site [11]. In this century, the potential presence of P is similarly observed in waste disposal sites and is considered an economic generator and source for future sustainability in countries such as Europe, China, the United Kingdom, and the United States [12, 13].

A landfill is a lucrative mining resource with stable storage but is at risk globally of causing leakage of leachate to surface and groundwater over an uncertain period [14, 15]. Although many strategies have been developed to manage nutrient recovery, minimizing the entry of organic waste at a disposal site is most effective, depending on the scientific, social, technical, political, economic, and ecological factor roles [7, 8]. In Malaysia, P sources are used in daily routines by households, farmers, and industrial workers involved in the agriculture, textile, food processing, livestock, medicine, and sewage sectors, enough that the concentrations of their contents in a product or body of water are monitored by the Department of Environment (DOE) under the Environmental Quality Act 1974 [16, 17]. Therefore, controlling the imbalance of P flow in waste dumps at disposal sites acting as the final reservoir can be an alternative source for economic profit, but it is difficult and may be impossible if the involvement of the main player is unknown.

II. Research Objectives

This study was conducted to identify the nutrient element of P in a waste disposal site and investigate whether stakeholders are aware of P and related to local economic circulars. We also investigated how P in waste sources could be managed by small waste players in Terengganu.

III. Literature Review

Research on P has received considerable attention due to concerns regarding the aspects of orthophosphate concentrations and the amount of dissolved P in river water in Terengganu [18]. Also, according to [18], P has received attention due to the use of P-based fertilizers in agricultural areas and the inclusion of cattle feces that contain high concentrations of phosphate nutrients [19]. The presence of P in water bodies is identified as the major producer of eutrophication problems in Malaysia also [20]. The P element in the landfill has a unique transformation capable of being transformed into worthy products such as struvite, biosolids, granular and fertilisers product with a large proportion of the amount of Total soluble Phosphorus (TP) in the soil almost entirely dependent on the fraction of soluble, mineral, adsorbed and organic [13]. P is the main core ingredient of nourishing foods such as fruits, vegetables and seafood in Malaysia, and for the culture of modern society, it is the supplements needed for their health care. For example, during the pregnancy process, phosphate supplementation is required for correct bone development and regulate of hereditary traits transfer to the baby [21].

Although environmental pollution caused by serious P eutrophication has never been reported in Terengganu, a management program to monitor and control this P source is still nonexistent. In line with the issue of environmental pollution, Ismail et al. [22] attempted to investigate a better strategy in dealing with the environmental performance between upper-middle and high-income Muslim countries such as Malaysia. The result of the study shows that the choice of strategy should depend on the environmental and political economy of the countries.

Syahril et al. [23] examined the effect of global crude palm oil price and plantations on environmental destruction. Their study found that global crude palm oil price and plantations have a long- and short-run relationships with environmental destruction that is measured by the environmental quality index. Moreover, the size of the palm oil plantation has a significant negative effect on environmental destruction. Therefore, to develop a program or platform that focuses on the reduction and recovery of P in waste in the landfills of Terengganu, at least 80% of key players from various agencies from the government, private sector, academia, NGOs, and neighborhood communities should be involved in managing the solid waste in Terengganu, and identifying and documenting the socioeconomic status of waste players in these areas are necessary [24]. This study attempts to identify the offers and limitations in the P nutrient recovery practices that can assist decision-makers in their transition planning based on the economy and sustainability of Malaysia.

Based on the discussion above, numerous studies do not focus on phosphorus (P) in the waste in Terengganu. The phosphorus (P) can be identified by the heterogeneity of waste sources that are at the waste disposal collected, the technology used, location of disposal and reliance on microbial waste decomposition operations. The present study is conducted to identify the socioeconomic characterization of the actors (players) and management strategies developed by the stakeholders.

IV. RESEARCH METHODS

A. Study population and data collection

This non-probability study was conducted using a mixed methodology involving qualitative and quantitative descriptive analysis during the 12 months of 2018. These methods included face-to-face interviews with 45 samples (informants) consisting of government, private, institutional, village, NGO and public players. The start of the first phase of the study involved gathering information on the socio-economic characteristics of the community, the relationship between waste players and waste-disposal sites, knowledge of waste players regarding phosphorus nutrients and waste-management strategies developed by players so far. Before data is transferred to a symmetric matrix, most data should be recorded as a series of binary reactions. A few questions were asked to respondents, with the answer being recorded as 1 for "yes" and 0 for "no."

B. Data analysis

The data was recorded in three groups: (1) socioeconomic characterization, (2) role of nutrient P for waste players and (3) knowledge level and reaction of waste players regarding recovery activities of P in waste. UCINET software was used for each data group to produce several graphical displays to assess the strength of interaction relationships between responses collected during interviews and the factors associated with the observed social practices among the players involved. Data analysis used three important steps as used by Williamson et al. [25] and Le Compte [26]; that is, data reduction, presentation and conclusion production.

V. RESULT

To achieve the objective of this study, we have collected and interviewed 45 informants comprising important waste-management players in seven waste-disposal sites at Terengganu (Figure 1).

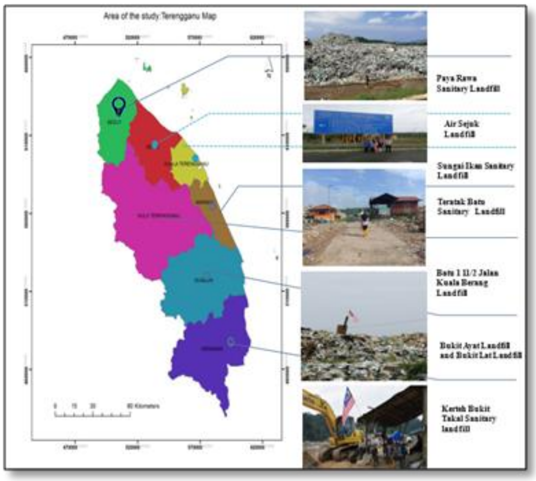

Figure 1. Geographical location of the landfill located in Terengganu which was assessed in this study

A total of 45 respondents interviewed: 39 were male and 6 were women, aged between 15 and 55 with an average age of 43 years (Figure 2a and 2c). Over half (92%) of waste players have formal education, which means they have completed primary, secondary and university levels. Almost every waste player (84%) is a resident who routinely conducts social practice in the segregation of recyclables involved in machinery-handling activities; 35% were white-collar workers and 65% were blue-collar involved top-down in government company operations and private companies.

For 95% of these waste players, their experience working around this disposal site is less than 6 years, since their earnings career is not dependent on government services. Based on the sales figures of recyclables and buyers' opinions from recycling companies, a large proportion of players interviewed (98%) agreed that the mining of good waste products from the disposal site is well received in the market and yields substantial returns depending on the weight (per ton) of waste products and the number of working days (Figure 2D).

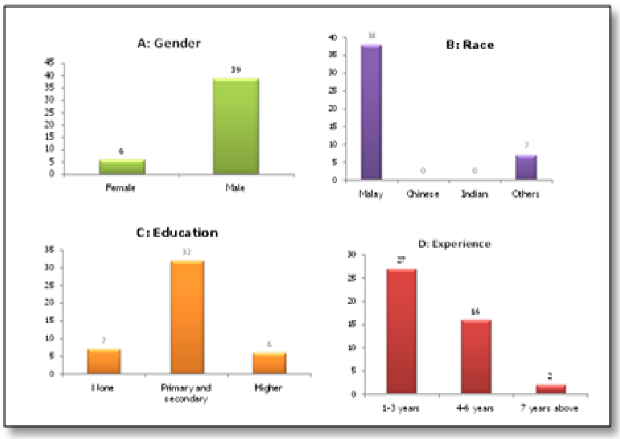

Figure 2. Results from the interview questions regarding waste management by 'players' inside and outside the disposal site in Terengganu

Figure 2 provides a reliable socioeconomic characterization of the interviewed players. The demographic profile of the waste players is reflected in options 2a and 2b; information compiled in 2c on the players' highest level of academic qualification indicates that 71% of waste players have completed the primary and secondary level; finally, 2d shows that only 2% of the players have working experience in the municipal waste-management sector in Terengganu.

Almost half of the respondents retained their job from the phase of garbage collection to the subsequent phases of isolation, transport, and disposal. A participant chooses to collect recyclable items at the disposal site (Figure 3); products such as paper, boxes, plastic bottles, glass, and aluminum material are appropriate for use by recycling companies as opposed to being used in composting activities, isolation outside landfill sites, combustion, grinding, open disposal, or other purposes.

However, no significant advantage exists to improving recycling and product-recovery capabilities when participants are aware that defects are in the upcoming plans for setting up P-based facilities and technologies in their area. The lack and uncertainty of P-nutrient data that is corrosive to garbage products means it is rarely used for state bases. A lack of knowledge has been the most common focus; some 99% of participants are ignorant of the importance of P in their social practices. Most participants (96%) do not know the actual problems with P, do not accept requests for recycling waste products for P fertilizer, and admit they have never experienced a P deficiency in their waste disposal phase (Figure 2).

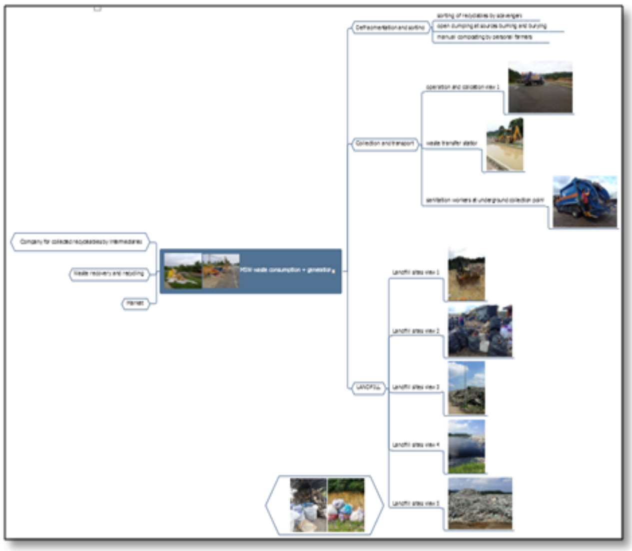

Figure 3. The general flow of the processes of collecting material, recycling items, refilling the waste bin, and sending collected waste to the landfill site

No participants know about P recovery potential from waste sources; however, although they did not know about this nutrient supply opportunity, 43 participants (95%) realized their actions involving the urban solid waste management sector could lead to a healthy environment by stating the need for education programs, raising awareness on common topics, increasing participation in small-scale pioneer projects, and communicating regularly with them along the entire P-chain duration. The largest red line at the right-hand side of Figure 4 indicates that the position of the network of players is not unified and very far apart from each other (Figure 4) [27].

Based on the responses of players and observations in their field, P nutrient recovery action is not correlated with the awareness and knowledge of the players (Action = 1%, awareness = 78%, knowledge = 21%) and is the only factor that has statistical importance in this study (Figure 4).

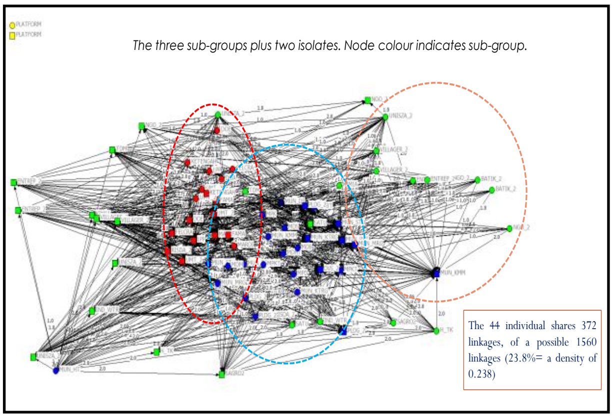

Figure 4. The three sub-groups plus two isolates

Note: the colour indicates sub-group of the player. (Red circle left = private sub-network, middle circle = Sub-member of Municipal Council members, right circle = subregion of the external community).

VI. DISCUSSIONS

P in the waste source, studied from the perspective of the biophysical nutrient pathway (input and output) and the socio-environment at the previously identified waste disposal site, can be caught and recycled [5]. The immediate release of P streams to the water and land can disrupt food safety, which leads to permanent obstacles in the transition of nutrient reductions in the sanitation chain.

The reduction and separation of organic waste at the home and non-household sources is the most common and effective method to ensure nutrients are returned to agricultural land while ensuring human health [2, 28, 29]. However, the eradication of identified nutrient leaks and the use of key indicators that characterize the structure of the nutrient governance network have been explored with moderate success, and it is difficult to survive for a long time [5, 38].

The results of the study show that the addition of detailed information on the basics (i.e.: What is P? Where can P be observed from the waste product?) can help change the player's paradigm substantially and reduce the incidence of P flow into the landfill by holding a workshop and basic awareness program in every municipal community in Terengganu. The main players most likely to develop this system are municipal councilors and private companies that are directly involved in the waste disposal activities at each of the Terengganu landfill sites.

The waste disposal site that is most likely to be used as a pilot test is the Teratak Batu, Marang, and Kemaman sanitary landfill (considering the potential of a new sub-facility of sanitary facilities and the location of a nearby sewage plant) [30]. The focus of P recovery from wastewater, like gathering urine with centralized development, shows the successful recovery of organic solid waste such as compost and struvite [31]. The need for financial support from upper-level players, namely federal, state, and district governments can assist in the development of investment-related decision-support programs and tools in nutrient recovery technology, commercialization of research, and reuse and recycling of CRM resources in regional, state, country, and global markets [32].

However, the commitment of involvement of industry partners from different sectors such as the textile industry, detergent industry, fertilizer industry, food processing industry, livestock slaughter industry, feedstuff, fodder, and feed additives industry and others (pharmaceutical and metal industries) is the most effective key change for recovery of P that is rich and available in the future waste sector [33, 34]. Previous research focused on the general context of waste management. It showed that players from this sector assist in the transfer knowledge, creating player network platforms, and developing detailed mapping of information on their best-performing technology management solutions, in contrast to the final goal of focusing on developing nutrient recovery solutions, which can deal with evolving environmental engineering techniques and environments [35, 36].

Future studies to determine the sustainable management capabilities P from local perspectives are needed to fully understand the complex interaction of governance systems from multi-faceted perspectives in the regions, including social, economic, and political. Such studies should identify players' practices and strategies (actors comprising municipalities, individuals, and organizations of key organizations) for the planning and development of the conceptual framework of P in the region. For example, the main influential players, the members of the municipal councils in each district in Terengganu, have full control over landfill sites in their district. For example, the Kuala Terengganu District Council has a major landfill site at Sungai Ikan, Kuala Nerus, receiving 50,190 tonnes of waste per year from

Kuala Terengganu District and Kuala Nerus District [30]. Thus, the preparation of a comprehensive social system of understanding and interaction, such as a legal, cultural, or economic system, with agents able to make decisions helps ensure that identifying options, constraints, weaknesses, and disruptions for nutrient management strategies is more efficient.

In addition, the lack of capacity, motivation, interest, incentives and joint action controls by players from the first subgroup (politicians, urban workers and representatives of private companies), second subgroups (workers from field management of agricultural management, farming, water and land) third (private individuals and local communities) support the presence of potential external players to restore communication within the range of these subgroups and widen the network out of this structure [30]. However, in the study by researchers, the lack of a more realistic and comprehensive assessment of P nutrient management in solid waste is not a priority factor in the development of waste management network in the state of Terengganu, suggesting that the focus of the P issue as a single nutrient is not very strong in community communities this is. The environmental pollution triggered by waste from P is not a major local environmental issue compared with other environmental issues such as global warming, open burning, water crises, and others. The availability of abundant P sources from the waste sector (food digestion, compost, etc.) and wastewater (sewage remnants, biogas residues, etc.) in the study region can improve the recovery and recycling of this P. However, based on our face-to-face interviews, most local stakeholders do not know where this P source allocation is available, while others remain confused about who the real owner of the P source is and who can give them financial incentives from the restoration of P resource allocation.

These players' lack of knowledge (bottom-up) on the basic definition of P and ways to identify its presence (100% unaware of what P as a nutrient is). Therefore, there is a real need to develop a simple strategy for knowledge transfer that is easy for players to understand and promote the benefits of P nutrients in their life routines. However, in the absence of a P nutrient platform at the state and national levels, the reconciliation of P recovery projects at a large or small scale is difficult to implement. Additionally, the absence of nongovernmental organizations (NGOs) for waste management, and the distance of membership of unincorporated and non-research institutes and research far from each other, undermines the structure of nutrient governance networks in the region.

At the grassroots level, there is no dialogue among players (<1% incentives to encourage free use of P from waste products) about the implications of P deficiency or nutrient management on a family parish (district and state do not apply). Basic education to local communities about utilizing the diversity of P resources and developing entrepreneurial ventures regarding P in waste sources will be successful if it begins with the establishment of a group of smallholders responsible for P in the state of Terengganu.

Interestingly, though players do not understand that waste products are associated with P nutrient recovery, they always provide an alternative explanation for the potential value added to the aspects they observe. One of these answers is that the diversion of waste from the disposal site is a wise act. However, it can be detrimental to the health of their environment in the event of a cash income per day incentive. Other problematic aspects are taxes (minimum payment is imposed on some landfills only), high demands by waste producers (private or individual companies), and the ambiguity of the legal system for the regulatory aspects of nutrients and rules that are unclear on the routine of players in landfills. The relationship between the factors mentioned by the player and the presence of the growing amount of rubbish means there is room for developing new projects for the improvement of the reduction and recovery of waste in small communities in the Terengganu.

Despite the lack of scientific knowledge and short-term employment duration (average length of work is 1-5 years), almost all respondents quickly assimilated new information on P management requirements presented during face-to-face meetings in the field. In response, a short briefing session was developed to improve the player's knowledge of the basic understanding of P. The briefing session informed players on how to identify the presence of P nutrient in waste products, as well as stock flow and P process and the necessary prerequisites to improve the management strategy of P that is sustainable in the small waste management community on their scale (Figure 4). In the briefing, players are also encouraged to separate most of their organic waste and their non-household waste first. Undoubtedly, an interviewed urban officer acknowledges that Terengganu state does not apply Act 672 [39] that contributes to the failure of the above situation [37]. According to a record released by DOE-TRG [17], absence of any collection and processing (food waste) companies operating privately or otherwise in the state will inhibit the potential of recycling and reducing this nutrient shortly. Understanding and implementing P management sustainability issues should begin at a regulatory level that recognizes the need for P recovery in waste products. Subsequently this conducts continuous dissemination of knowledge to other major 'players'.

Nutritional imbalances in inefficient waste management have resulted in significant worldwide economic losses, including the potential loss of nearly 90% P to meet the global food safety guarantee [35]. The study by Metson et al. [5] reports the loss rate of P in waste management in Switzerland was estimated at 90%, equivalent to the net import of P by 14,700 tons P per year. The same scenario affects the player's economy and environment continuously and unknowingly for an uncertain period given the current absence of research on P stocks in the region. Recently, the Terengganu government has been proactive in implementing several programs to support this "sustainable waste management". These programs help to protect the economy of valuable waste products, but also help to reduce the allocation of National money for waste disposal. We convinced that the socio-economic study in the context of micro and macro analysis of the final waste management sub-network (at the disposal site) has the power to highlight the needs of the players (known as workers and government officials, communities, NGOs and private companies and civilians) and can reach the attention and actions of decision makers in the government.

VII. CONCLUSION

In conclusion, this study suggests the first step in the implementation of the policy to manage the imbalance of P flow and proposes P recovery and recycling measures in the waste disposal sites of the Terengganu state. The results of this study not only reflect the socio-economic aspects of the involved actors but also explore the understanding and practice of the rules and instructions by the actors to complement the advanced management strategies for moving toward the preservation of the economic circular of P in Malaysia. A positive step in the diversion of P to waste disposal sites consists of (i) the identification of the requirements for the actors from different organizations to join, and (ii) developing a formal nutrient platform at the national and international levels, which is a "network connector" ensuring scientific validation, legitimacy, and good practices that can be mobilized at the initial stage of P pilot project in waste disposal.

VIII. SUGGESTIONS

Another critical long-term goal of the project is to develop a continuous educational strategy for the introduction of micro P to stakeholders, such as municipal employees, local communities, and network members of other waste governance authorities, across multiple scales. Some key initiatives include finding a funding project to set up an advanced study to analyze the aspects of facilitation, regulation, education and the role of core players in the recovery and reuse of P from sources of waste, based on the information gathered in the current study.

ACKNOWLEDGEMENT

The authors thank the local enforcement officers and employees of the district municipal council, SATU, IWK and KPKT, village chiefs and related individual for their support and cooperation. Thank you to UMT for TAPE 2018-2020 (VOTE: 55123) research fund. The author thanked Prof. Noor Zalina Mahmood for reading and revising this manuscript. Thanks to commentators for their comments to improve the quality of this publication.

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