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GREENING FOOD PROCESSING INDUSTRIES IN VIETNAM: OPPORTUNITIES AND CONSTRAINTS

TRAN THI MY DIEU
Department of Environmental Technology and Management, Van Lang University, 45, Nguyen Khac Nhu, District 1, Hi Chi Minh City, Vietnam (e-mail: dieuhung67@yahoo.com)

Abstract. The food processing sector in Vietnam plays a vital role in its economic development, but its rapid growth seems to go hand-in-hand with environmental deterioration. Several decades of applying the conventional end-of-pipe approach made clear that it only deals with treating the symptoms. It is necessary to combine technological (end-of-pipe) solutions to overcome urgent pollution problems with ways to prevent wastes from being generated or to reuse their valuable material. This article presents a methodology for analyzing the possibilities for waste prevention in food processing industry in Vietnam.

Key words: industrial ecology, industrial zone, pollution prevention, SMEs, sustainable development, Vietnam.

Abbreviations: BOD_5: – Biological oxygen demand after 5 days; COD: – Chemical oxygen demand; CP: – Cleaner production; DONRE: – Department of Natural Resources and the Environment; EMS: – Environmental management system; ISO: – International Organization for Standardization; IZ: – Industrial zone; IZID: – Industrial zone infrastructure development; JV: – Joint venture; MONRE: – Ministry of Natural Resource and Environment; NGO: – Non-governmental organization; SME: – Small and medium-sized enterprise; VCPC: – Vietnam Cleaner Production Center; WWTS: – Waste water treatment system

1. Introduction

The food processing industry is very important for Vietnam's economic development but is also responsible for significant contributions to environmental deterioration (Dieu, 2003). These environmental problems may affect also the future prospects for industrial growth of the country. Several pollution prevention approaches have been developed and practiced in developed and developing countries but all of them require particular circumstances for success. Combining various approaches may solve several weaknesses. Thus, the question is how to make use of the strong points of existing pollution prevention approaches to 'green' the food processing industry in Vietnam. This article explores options for transforming food processing in Vietnam into more sustainable (and ultimately zero-waste) industrial ecosystems. More specifically, this article addresses the following questions:

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– To what extent and how can industrial ecosystem practices developed in highly industrialized Western countries be adapted and applied to Vietnam's food processing sector?
– Is it possible to apply the concept of industrial ecosystems to large as well as small and medium-sized companies?
– What would be core features of a zero-waste industrial ecosystem model for the food processing industry in Vietnam?
– Which actors, institutions and relations are crucial for introducing the proposed model in practice? What are their roles and contributions?

In order to answer these questions, the strong points of the existing pollution prevention approaches were investigated and integrated in the development of a methodology for moving towards a zero-waste industrial ecosystem. Taking into account the diversity of industrial systems and contexts in Vietnam, as well as the differences in comparison with highly industrialized countries, this methodology was tested in three different settings: (1) *household-scale* tapioca processing in a village, (2) *large-scale corporate* tapioca processing industry, and (3) several types of food processing companies, other than tapioca, in an *industrial zone* (IZ).

The following section introduces the methodology developed for greening food processing industries, as well as the three case studies. Subsequent sections discuss similarities and differences between the three case studies; constraints and opportunities in implementing a zero-waste industrial ecosystem of food processing industry in Vietnam; and general conclusions about the applicability of the methodology and approaches for greening food processing and other industrial sectors.

2. Pollution prevention methodology

There are many different ways to get rid of wastes and achieve zero- (or close to zero) waste industrial systems. Each approach has its own strengths and weaknesses, while their application often demands specific conditions and time-space constellations. Integration of different approaches can overcome the weaknesses and shortcomings of individual approaches. This section aims at creating a methodology for developing an integrated model of pollution prevention for industrial systems, using the various theoretical ideas, especially focusing on cleaner production (CP), waste exchange and industrial ecology. The starting point to develop such a methodology is found in the analysis of those material and energy flows of industrial systems, which cannot be used, therefore causing emissions, waste and exhaustion of natural resources. Next, possibilities for reducing emissions, waste and natural resource use from these industrial systems are examined.

A systematic approach for analyzing options for a zero-waste industrial ecosystem may include four steps:

1. Analysis of material and energy flows resulting in waste;
2. Prevention or reduction of waste generation;
3. Designing options for internal and external waste recovery, recycling and reuse; and
4. Identification of wastes needing to be properly treated prior to discharge.

Applying this physical–technological model in practice may face severe difficulties and barriers, however, since the industrial system as a whole and its various constituting subsystems may have conflicts of interest. Moreover these systems often lack coordination, meet financial problems, and are not isolated entities but related to and embedded in larger and complex social-economic networks. No matter how innovative, original and closed the designed industrial system is in terms of its substance flows, this does not guarantee successful application and implementation of the whole model or even some of its parts.

To translate the developed physical–technological model for an industrial system from the design table to reality, it is essential to analyze the complex social, economic and political relations and institutions between the industrial system and outside actors. Only through understanding the existing relations of the industrial systems with, among others, government agencies, other economic entities and social actors, we are able to (i) identify barriers hampering the implementation and introduction of some or all of the alternatives of the physical–technological model, and (ii) design changes in social, political and economic relations and institutions necessary to facilitate, support and enhance possibilities for implementing some or all of the physical–technological options. In other words, we are in need of adequate concepts to analyze the interactions and relations between actors within and outside the industrial system, as well as the institutions that govern and structure these interactions and relations. Network analyses and models that relate industrial firms to the societal, economic, and policy environment are useful for this purpose:

> 'Network models have the advantage of combining both the structural properties of institutions and the interactions between actors constructing a network. Networks can be characterized as social systems in which actors engage in more or less permanent, institutionalized interactions' (Van Koppen and Mol, 2002, p. 142).

There is a broad and well-established literature on network analysis, to which various disciplines have contributed. Most environment-related network studies construct their concepts and analytical tools on an *ad hoc* basis, following directly from one or a limited number of empirical studies. Consequently, these network models and concepts often have a limited use in empirical studies. The triad-network model, as developed by Mol (1995), is a more theory-based conceptualization. It encompasses a policy, an economic and a societal network and is suitable for analyzing the roles of actors and institutions in the construction and functioning of industrial systems from different perspectives (political, economic, and social). As such, the triad-network model helps us to understand and analyze the relation between the developed physical–technological models on the one hand, and institutions and actors constituting the economic, social and policy environments on the other hand. Each of these three networks constitutes a combination of a specific analytical perspective, distinctive institutional arrangements, and a restricted number of interacting (collective) actors:

Policy networks. Policy networks concentrate on industry–government relations from a politico-administrative perspective (Mol, 1995). All policy incentives and arrangements in supporting or regulating industrial sectors belong to the rules and resources, which are structured and negotiated within this network. It is therefore important to identify the relevant actors and institutions, which determine industrial and environmental policy, including their positions, strategies, resources and interactions (Vliet and Frijns, 1995). Applied to this research, policy network studies should clarify the relationships and interactions between the industrial enterprise(s) and the local and central environmental management authorities. The legislation related to environment, which can, should and sometimes have influenced environmental innovation in firms and industrial systems, is part of the formal policy network. So are the resources available for local environmental authorities such as their monitoring equipment and manpower for control and enforcement. Analyzing the formal structure and relations between environmental authorities and industrial actors is often less informative than analyzing the actual practices, interdependencies, and institutional arrangements that are at work in greening (or failing to green) industrial production locations and products.

Economic networks. Economic networks entail interactions based on economic rules and resources between economic agents in and around industrial parks, industrial chains, or industrial sectors that form the object and unit of analysis (Van Koppen and Mol, 2002). Economic network studies analyze: (i) the relationships between firms in a product chain by looking at the vertical interactions from input suppliers to producers and final consumers; (ii) the relationships between competing firms in the same (sub-) sector and interaction, among others via branch organization; (iii) the interactions between firms and other economic agents (such as banks, insurance companies, infrastructure companies) and research institutes and (iv) regional relations and interactions in restricted geographical areas.

Societal networks. Societal networks focus on the relationships between the industrial enterprise(s) on one hand, and local communities and local and national social organizations such as Youth Unions, Women's Associations, mass media and NGOs on the other. The nature of these relationships is analyzed, as well as the interdependencies between the actors, and the resources applied in interactions. If environmental considerations play any role in these interactions, the analytical focal point is how the existing relations can give environmental interest a better position 'on board' and how this integration can subsequently influence, stimulate, and support the adaptation of options from the physical–technological model. The studies of O'Rourke (1999), Woltjer (2001) and Phuong (2002) provide good examples of Vietnamese social network studies on the greening of industry.

The usefulness of this network-based methodology is assessed in this study by applying it to three different cases from Vietnam's food sector. The first two case studies consist of tapioca producing enterprises and they were selected to better understand the possibilities and problems in developing, applying and implementing the model of zero-waste industrial ecosystem in the same industrial sector but with different scales. The first case study includes households in Tra Co Village, Dong Nai Province, representing the characteristic sector of (small) scale household enterprises. The second case study consists of a large-scale tapioca producing plant called Tan Chau-Singapore Company in Tay Ninh Province. The third case study focuses on a group of six different food processing enterprises located in Bien Hoa 1 industrial zone, Dong Nai Province. It is comparable to the case study in Tra Co Village because a group of companies is studied, but different because of the scale and the industrial sector concerned. This case study also allows the exploration of the potentials for environmental improvements in industrial zones, compared to enterprises located outside industrial zones. The following section provides brief overviews of the case-studies sites.

2.1. Case Study at Tra Co Tapioca Processing Village

In Vietnam, tapioca producing units vary between small-scale (household) with only 3 employees, medium-scale factories with about 15 employees, or large-scale factories with more than 30 employees. As household- and large-scale units are the most prominent categories, the cases of Tra Co Village and Tan Chau-Singapore Company were selected.

In the South Key Economic Regions of Vietnam, Tra Co Village is a typical traditional tapioca producing village. The environmental problems caused by tapioca production are serious, but interestingly Tra Co Village is the only place where part of the tapioca wastewater is successfully reused in fish culture. At the time of conducting the case study, there were 65 tapioca producing households in Tra Co Village. In the selected village, 15 households were selected to observe the processing technologies and the waste handling methods that have similarities as well as differences. These households' processing methods may differ in fresh roots' handling, roots' rinsing methods, starch extraction (different settling steps), final products (wet or dry starch) and the machines used. It becomes possible to compare and analyze the causes of differences in production efficiency and environmental performance and to identify options for prevention and minimization of wastes.

2.2. Case Study at Tan Chau-Singapore Company

Several large-scale tapioca companies have been established in the Southern part of Vietnam since 1990 to satisfy the growing demand for raw material inputs for the monosodium glutamate, textile, and paper industries, etc. Among the currently operating five large-scale companies, Tan Chau-Singapore Company was selected for in-depth study.

2.3. Case Study of the Food Processing Companies in Bien Hoa 1 Industrial Zone

Bien Hoa 1, Dong Nai Province, is the oldest among the 68 industrial and export processing zones in Vietnam (Nhan, 2001). This zone represents a 'bad practice industrial zone' and contributes significantly to environmental deterioration, especially of the surface water of Dong Nai River and the air quality in Bien Hoa City. It occupies an area of 551 ha and is located at 6 km from the city center of Bien Hoa City and 30 km from Ho Chi Minh City. The food processing enterprises in Bien Hoa 1 IZ are typical for Vietnam as they produce refined sugar, milk products, coffee, soft-drinks, cakes, candies, and ice. These companies clearly illustrate the current practices that make it difficult for industrial enterprises in Vietnam to apply advanced technological options to solve environmental problems: the use of less advanced technology, the strong emphasis on end-of-pipe treatment, poor environmental awareness, absence of environmental management systems, etc. A group of six food processing companies in Bien Hoa 1 IZ has been selected for this case study. All data related to production processes and environmental implications of these enterprises were collected through site observations, direct interviews and inventory sheets.

3. Learning from the case studies

3.1. Similarities

At present, food processing in Vietnam consumes unprocessed agricultural products, fresh water, and electrical and thermal energy for its operation, but does little to compensate for the energy consumed, fresh water used, and soil nutrients utilized. In addition, its production activities contribute to the deterioration of the environment due to improper discharge, disposal and emission of the generated wastes. The three case studies showed that excessive generation of byproducts arises due to inefficient technology, inadequate processing, inadequate reuse and recycling of materials, underpriced natural resources, lack of knowledge about waste treatment and recovery, inadequate finances, poor environmental regulation and enforcement, and limited civil society involvement in environmental protection. The case studies indicated furthermore that cleaner production (CP), waste exchanges and ideas of industrial ecology can be valuable options for the future greening of food processing in Vietnam, although the most feasible technical options and organizational schemes differ between the three cases as we will see in the next section.

Food processing leads characteristically to the generation of three types of byproducts, mainly organic in nature: (i) wastewater, resulting from process cooling and heating, and domestic sources; (ii) solid byproducts, including rejected raw materials (such as cassava hard roots and wood shells, unqualified vegetable and fruits, etc.), process residues (cassava fibrous residues and pulp, spent coffee grounds, molasses, etc.), and rejected packaging materials; and (iii) air pollutants and surplus heat generated from boilers and heaters.

It is difficult to avoid the production of organic byproducts due to the importance of maintaining sufficient standards for hygiene and quality. However, the case studies revealed that for perishable and biodegradable byproducts, the logical solutions for waste reduction include:

- Prevention and minimization at source;
- Using rejected organic materials as livestock feed (for instance fish feed from tapioca wastewater, swine feed from cassava fibrous residues and pulp);
- Converting organic waste materials (such as cassava hard roots and wood shell, residues from fruits and vegetable, spent coffee grounds, etc.) to soil conditioners and fertilizers through composting;
- Recovering biogas for energy generation through anaerobic processing;
- Treating byproducts for reuse, e.g., using treated wastewater for irrigation; and
- Proper treatment of wastes before discharge.

All three case studies suggest possibilities for transforming the currently existing industrial food processing systems (closer) to a zero-waste industrial ecosystem, in which the food processing industry, other related industries, and agriculture are integrated.

Experiences from the three case studies made clear that failures in environmental management can be indicated in five areas:

- State environmental management authorities, especially provincial departments of natural resources and the environment (DONREs) face difficulties of high workload, limited expertise, and scarce resources for monitoring and enforcement;
- Regulations and incentives for producers are lacking to make their production processes more ecologically sound, and to reuse and recycle wastes;
- Economic agencies do not encourage producers to improve their production efficiencies and environmental performances;
- Research for improvements in production processes and environmental protection is inadequate; and
- Civil society is not actively involved in environmental issues.

Beside similarities found in the case studies, several dissimilarities can also be indicated.

3.2. Dissimilarities

Any general or national approach to greening food processing industry in Vietnam must take into account a great diversity of industrial systems in terms of scale, size, industrial sector and location. This section reviews some of these dissimilarities.

3.2.1. Scale

To compare household-scale and large-scale companies in the tapioca industry, case studies were conducted at Tra Co Village and Tan Chau-Singapore Company. Though these case studies were conducted for one industrial sector, the proposed options and implementations to approaching a zero-waste industrial ecosystem are not the same.

First, the proposed technological options for household-scale units differ from those for a large-scale company. The traditional tapioca production technology applied by the households in Tra Co Village is not as suitable for the proposed CP measures as the more modern production technology applied in Tan Chau-Singapore Company. At the latter, with respect to reuse and recycling, it is feasible to install a livestock feed production, composting, or biogas plant or establish fishponds within the boundaries of the corporation to reduce transportation costs. It is, however, impossible to do the same for individual tapioca producing households. This does not mean that it is impossible to improve the households' environmental performance, however. The case study at Tra Co Village revealed that the limitations of individual households in implementing waste exchange can be overcome by co-operation between the households. Installation of a central composting plant, a central biogas plant, or a central wastewater treatment system (WWTS) to process and reuse the byproducts from all tapioca producing households would help to solve the existing environmental problems in an economically and environmental friendly way. By doing so, the group of tapioca producing households can benefit from the collective off-site reuse and recycling of wastes and from the available environmental services.

Second, differences in the size of production units lead to differences in the organization of a CP program. For a large-scale firm like Tan Chau-Singapore Company, it is possible to organize a study team itself to conduct a CP program, but this is not feasible for each household in Tra Co Village, who has only 3–5 workers. Again, one CP study team could be organized for all tapioca producing households in the whole village. But, without economic incentives, it is not easy to get all 65 households in Tra Co Village to participate in a CP program on voluntary basis. In addition, the company has better skilled staff for specific tasks, for instance production technology, machine repair, administration, etc., so it is easier to train workers to get acquainted with new technologies or installations.

Third, differences in the existing organizational structure of the industrial systems also lead to differences in the organizational structure of the proposed industrial ecosystem. While Tan Chau-Singapore Company is responsible for the installation and operation of its own WWTS, the households can only pay the (public or private) owner of a central WWTS to treat tapioca wastewater generated from their production process after it has been installed and put into operation. In other words, in the case of household-scale producers, it is necessary to have a third actor, who is responsible for treatment of un-reusable byproducts.

Finally, relations between these industrial systems and the different social actors and institutions are also different to a certain extent. For a large-scale company like

Tan Chau-Singapore Company, Ministry of Natural Resource and Environment (MONRE) played a role in the initial stage of the company by appraising the environmental impact assessment report. So far, MONRE has however, not directly influenced the environmental improvement at Tra Co Village. While Tay Ninh DONRE has monitored the environmental situation of Tan Chau-Singapore Company from its initial stage (1996), environmental problems at Tra Co Village have just started to receive attention from Dong Nai DONRE in 2001. By applying regulations in compliance with environmental discharge standards, Tay Ninh DONRE has at least succeeded in forcing Tan Chau-Company to store tapioca wastewater in ponds without discharging it into Tha La River. However, it is very difficult for Dong Nai DONRE to use strong enforcement instruments such as fines, administrative punishments or closure for all 65 tapioca producing households that violate environmental regulations, because this will create significant social problems. Furthermore, the potential role of customers in pushing producers to take environmental as well as quality considerations into account when buying a product only seems relevant in the case of large-scale companies that participate in international markets.

3.2.2. Industrial clusters versus single enterprises

Compared with the situation with a group of enterprises (65 tapioca producing households in Tra Co Village), it is much easier to design and implement a zero-waste industrial ecosystem for one company (Tan Chau-Singapore Company), for several reasons. First, the collection of byproducts from a group of enterprises is certainly more difficult than for one company only. In order to collect tapioca wastewater from Tan Chau-Singapore Company, we only have to design a sewer network within the company, but in case of Tra Co Village, this has to be done for the whole village. Second, convincing one company to participate as an anchor in the model is certainly easier than to get agreement from all 65 tapioca producing households. Third, the implementation of a CP program for one company is much easier than in case of a number of tapioca producing households. CP training in one company is surely less difficult compared to a whole village.

3.2.3. Sub-sectors

The case studies at Tra Co Village and Bien Hoa 1 IZ have revealed that the operationalization of the methodology developed for a group of enterprises from one food processing sector also differs from a group involved in different industrial food processing sub-sectors. A group of enterprises from one industrial food processing, sub-sector will generate almost the same byproducts. This leads to two main advantages:

- Benchmarking can be done by these enterprises themselves. It is possible to compare the production efficiency and environmental performance between these enterprises. This is not only helpful in selecting feasible solutions to reduce the generation of byproducts but also in convincing producers to mutually learn from each other's experiences.

– A group of enterprise may generate the same kinds of byproducts in larger amounts making it worthwhile to reuse, recycle or treat them. It is possible to gather the byproducts from the different enterprises and handle it by the same method. Additionally, it is easier and more economic to handle large amounts of one byproduct by one method than to handle small amounts of different byproducts using different methods.

The disadvantage of having a group of enterprises from only one food processing industrial sub-sector is that these enterprises cannot use each other's products and reuse byproducts. In other words, the material flow network, which is often essential to reach a zero-waste industrial ecosystem, can only be created by including enterprises that use and produce different inputs and outputs. However, because food processing industry manufactures food for human beings, it is usually only possible to use each other products as raw materials and not to reuse their byproducts. Except for some byproducts (like wrapping materials), most organic byproducts from food processing industry are only suitable for producing non-food products like livestock feed, fish feed, industrial grade alcohol, biogas, compost and irrigation water. Organic byproducts (usually the majority of all byproducts in the food processing industry) generated from different food processing enterprises, are of course not uniform though they are all organic in nature. For instance, molasses of Bien Hoa Sugar Company contain different organic compounds and contents than the fruits waste from the Dona Newtower JV Company or spent coffee grounds from the Bien Hoa Coffee Factory. Wastewater from all food processing companies in Bien Hoa 1 IZ certainly contains biodegradable organic contaminants. However, the organic composition of wastewater from these companies is totally different in terms of COD or BOD_5. This makes reuse and recycling processes more complicated than in the case of uniform byproducts from one industrial food processing sub-sector.

3.2.4. Location

Beside the several dissimilarities discussed above, the industrial ecosystem model developed for enterprises located within an IZ also differs from one intended for those located outside the IZ on several points.

First, enterprises located within an IZ can benefit from collective environmental services (such as a common wastewater treatment system (WWTS), composting, collection and handling of other wastes, etc.) by the Industrial Zone Infrastructure Development (IZID) Company.

Second, they can reduce the costs for transporting byproducts to recyclers located within the IZ. Because agriculture provides raw materials for these food processing enterprises and can also serve as an environmentally friendly receiving body for wasted materials, short physical distance between the enterprises and the agricultural fields can be an important condition for successful implementation of the industrial ecosystem model. These advantages include (i) reduction in costs and time to transport raw materials from the fields to the enterprises; (ii) minimizing the loss of the quantity and quality of raw materials caused by transport from the agricultural fields to enterprises; (iii) reduction in costs of wastewater treatment, because only pretreatment of wastewater for reuse is needed instead of complete treatment; (iv) water resource conservation thanks to the possibility of reusing wastewater for irrigation, instead of using (surface or ground) water; and (v) providing a clear life-cycle benefit by returning composted organic solid wastes to the soil.

Finally, actors and institutions involved in the policy network of enterprises located within an IZ are different compared to those located outside. Enterprises located within an IZ are normally under an administrative management of the IZID Company and District IZ Authority. These institutional and policy actors can play a significant role in creating the conditions that support the development of the proposed industrial ecosystem model, educating and advising (potential) participants on the opportunities to improve their production efficiency and environmental performance as well, and closely monitoring the environmental performance. These actors can also cooperate intensively with environmental authorities on various levels.

4. Constraints and opportunities

The case studies have revealed several constraints hampering the implementation of CP, waste exchange and even end-of-pipe treatment approaches in the food processing industry in Vietnam. However, there are also opportunities to support a more sustainable development of the food processing industry in Vietnam. Discussions on these constraints and opportunities, which are not the same in all situations, will focus on the following main aspects: (1) technical, (2) environmental policy, (3) economy and (4) public participation.

4.1. Technical

Technical constraints refer to the absence of (knowledge about the availability of) adequate technology and problems of implementation. The case studies have revealed that producers often do not know how to implement CP measures, to apply reuse and recycling options, and to treat waste properly. It has been hard to find any plan or even idea about implementing CP programs in the studied companies. Implementation of CP does not seem to have much urgency in their development strategy. Several economic and technological possibilities feasible for on-site and off-site reuse and recycling of byproducts have not been practiced. For instance, Bien Hoa Coffee Factory has not considered on-site reuse of spent coffee grounds to establish self-sufficiency in thermal energy. BIBICA Company does not seem to know that it is wasting an excellent source of calcium for livestock feed production. The Dona Newtower JV Company does not seem to realize that waste fruits are raw materials to produce bio-fuel. Recovery of biogas from anaerobic treatment of tapioca wastewater to generate energy is a new idea for Tan Chau-Singapore Company. Concentrations of substances in the effluent from the existing WWTS of the studied companies, which are often higher than allowed according to Vietnamese discharge standards, give evidence that these companies do not pay attention nor know how to treat it properly. In addition, technical constraints also refer to lack of willingness from producers to change the current techniques. They all consider their current production practices efficient and do not want to modify their operational habits. They have the prejudice that implementing any change in the processes takes too long and may affect the product quality; what, especially in case of food, may be a strong barrier. Additionally, the required extra investment adds to their unwillingness to any change. The lack of information dissemination also contributes to the technical constraint because not all producers are informed about the available technological possibilities to improve their efficiency and environmental performance. Reuse of tapioca wastewater, as fish feed is one of the examples for this constraint. Though this technique is applied successfully in Tra Co Village, it is unknown in Tay Ninh Province. In general, all case studies showed that it is hard to find enduring or even incidental collaboration between research institutes and producers. This limits the opportunities for producers to access new techniques to improve their production efficiency and environmental performance. In addition, due to the limited number of practical demonstrations and full-scale applications of laboratory studies, it is difficult to convince producers to carry out waste reduction and minimization activities. Finally, the lack of advanced equipment for use in the production process, such as in the case of tapioca processing households in Tra Co Village is causing high quantities of generated byproducts and wastes. The lack of facilities for monitoring and continuous assessment of environmental performance is another constraint, leading to improper implementation of environmental protection activities by several producers. All three case studies show that none of the producers have data on material flows of their production processes, though these data could be very important to judge whether their processes are operated efficiently.

On the other hand there are several opportunities to overcome these constraints and to further implement CP options for greening food processing industries in Vietnam. First, CP and waste exchange are actually not completely unknown in Vietnam. Successful demonstration projects on CP in Hanoi and Ho Chi Minh City do not only illustrate the potentials and possibilities to implement CP in Vietnam, but provide also the availability of know-how on CP. The experiences from these projects can serve as a foundation for further multiplying them to other enterprises. The case studies also illustrate the existence of waste exchange activities in Vietnam such as selling byproducts to other producers in stead of discharging them (tapioca producers sell for example fibrous residues, other food processing companies sell broken cardboard boxes, plastic bags, etc.), or reusing byproducts in agriculture (Tra Co Villagers reuse tapioca wastewater as fish feed). In other words, there are good opportunities for waste exchange and reuse or recycling in Vietnam in the future, provided that precaution is taken to avoid secondary pollution. Successful CP demonstration projects can convince producers that it is not too difficult to improve their production efficiency in terms of technical modification and costs. The establishment and the recent (from 1998 to now) achievements from the Vietnam Cleaner Production Center (VCPC) can also contribute to overcome the lack of dissemination of technical information and increase awareness on the importance of CP. Several activities carried out by VCPC such as organizing trainings and awareness-raising seminars; editing guides and manuals on cleaner assessment; preparing reports, video tapes, brochures and leaflets; conducting CP assessment within companies; etc., have been efficient ways to expand and disseminate CP technologies to producers. It is necessary to have intermediary organizations as a bridge to transfer information from VCPC to the companies. Such intermediary organizations may be branches of the VCPC in each key economic region of Vietnam, the provincial Division of Science and Technology (DONRE), environmental centers, general cooperation, branch associations, etc. Provincial DONREs in collaboration with environmental centers or research institutes can also develop and disseminate CP measures for household production units, which currently do not belong to the target groups of VCPC. Similarly, the limits to the availability of technical information about waste exchange could be overcome by either integrating this program in the activities of VCPC and its branches[1] or establishing waste information exchange centers as sub-sections of the Division of Science, Technology and Information belonging to provincial DONREs and IZID Companies. Furthermore, Vietnam can learn from experiences on production technologies, CP, waste reuse and recycling in other countries and adapt them to the particular conditions of the country. Openness to trade and investment alongside with industrialization might offer opportunities for enterprises to take advantage of newer and cleaner technologies developed in other countries (Rock, 2000, 2001). Growing foreign investments in industrial development might help Vietnam to modernize the industrial system and achieve more sustainable development. Finally, in order to encourage producers to conduct auditing programs, provincial DONREs or IZ authorities need to give clear and specific guidance for environmental reports and material manifests so that producers can carry out measurements and provide more detailed data on their production process and waste generation. By doing so, environmental management authorities can compare and establish whether these production processes are operated efficiently and environmentally friendly and advise them in conducting a CP program.

4.2. Environmental Policy

Implementing CP in Vietnam also encounters several constraints in the domain of environmental policy. First, the existing environmental legislation strongly emphasizes end-of-pipe solutions, while CP and waste reuse and recycling are only briefly mentioned without concrete incentives or guidelines for their implementation. This is shown in all three case studies. For instance, to overcome the environmental pollution due to tapioca processing in Tra Co Village, Dong Nai DONRE and the People Committee planned to install a new sewer system,[2] in stead of seeking solutions to reduce the generation of wastes. In case of Tan Chau-Singapore Company, in the initial stage the focus was on waste treatment rather than orienting them to optimize their material flow within the production process and paying attention to on-site and off-site reuse and recycling of byproducts. This is also the case for the food processing companies in Bien Hoa 1 IZ, who installed WWTSs just to fulfill the requirements from the environmental authorities without paying proper attention to treatment efficiencies. This is why effluent concentrations from these plants usually remain above the Vietnamese standards and contribute to the deterioration of surface water. Second, there is no incentive for investing in and implementing CP and waste exchange options. The disposal of industrial waste (such as waste fruits from the Dona Newtower JV Company, eggshells from BIBICA Company, etc.) mixed with domestic solid waste constitute an example of this. Third, low resource pricing and absent pollution treatment fees are among the major regulatory constraints in encouraging the implementation of option for CP and waste exchange. This is illustrated by the case of Tra Co Village, where the producers can use ground water free of charge for their production activities and consequently they are not interested in minimizing water losses. Moreover, they do not have to pay for discharging their wastewater. Finally, most producers do not have a separate environmental management section. Therefore, so far, except for the operation of WWTSs and the selling of byproducts for recycling, hardly any other environmental improvement activity is carried out by producers themselves.

To promote the implementation of CP and pollution prevention as well as further approaching a zero-waste industrial ecosystem for food processing industry in Vietnam, the following measures should be taken into account. First, it is important to establish financial incentives in the environmental regulation system to encourage the implementation of CP and waste exchange practices. By setting a waste treatment and disposal fee based on the unit of generated waste, higher fees will encourage producers to minimize the generation of waste. Second, appropriate pricing of natural resources and materials and the removal of subsidies for water and electricity supply as well as for the waste collection and disposal service is essential. It is of course of great importance to determine the correct charging rates. Too high charging rates will affect the economic performance and competitiveness of a business, while a rate too low will discourage producers to pay attention to environmental protection. The Government Pricing Committee in collaboration with Electricity of Vietnam and Water Supply Companies has to carry out studies to propose appropriate prices of electricity and water supply for industrial producers. Similarly, in the case of treatment and disposal fees for waste, MONRE and DONREs should establish proper prices in collaboration with environmental centers and waste treatment companies. Finally, without continuous maintenance of environmental protection activities by the companies, all attempts towards more sustainable development are meaningless. In addition, because 'cleaner' is a relative expression and 'cleaner' today may not be 'cleaner' tomorrow (Sakurai, 1995: 2) and because industrial development is a dynamic process, establishment of a permanent system or institutions to facilitate and implement proper environmental pollution prevention activities is necessary. This can be done in different ways at different levels. For companies above a certain size (such as medium- and large-scale companies) it is suggested to establish a separate environmental management section, to monitor, audit, and design CP measures as well as to properly operate the waste treatment systems. For small-scale or household-scale production units, where it is difficult and impossible to establish separate environmental management sections for each unit, Environmental Management Sections of District Urban Management Divisions will remain important.

4.3. Economic

The first economic constraints identified in all three case studies is the nearly complete absence of incentives from economic agencies such as banks, tax agencies and insurance companies to apply CP and pollution prevention measures. No tax exemption or tax reduction is applied for environmental investment by companies. Insurance companies have only emerged recently in Vietnam and are mainly involved in health insurance. Second, the case studies also show that consumers play no role yet in pushing food processing companies in Vietnam to improve the quality of product and environment nor do they trigger companies to acquire ISO certification. None of the studied companies produces a product with an eco-label or is working towards a labeling system while at the same time Vietnamese consumers are generally unfamiliar with eco-labeling. Alcohol produced from reused by-products (such as high quality molasses from sugar companies) is not differentiated, in terms of environmental protection, from the alcohol processed on the basis of original raw materials (such as wood). Finally, lack of capital or financial assistance for investment in environmental measures remains a barrier for the implementation of CP measures and also for end-of-pipe treatment, especially in the case of household-scale units.

There are several possible ways to overcome these economic constraints. First, CP demonstration projects that have recently been established in Ho Chi Minh City and Hanoi show that environmental funds with a preferential interest rate could facilitate the implementation of CP (Nhan, 2001). Thus, companies are willing to borrow money from credit institutions for environmental investments. Vietnam can also learn from experiences in other Asian countries in applying soft loans and tax benefits (Chandak et al., 1995; Roestamsjah and Cahyaningsih, 1995; Rock, 1996) to make CP and environmental pollution prevention measures more attractive. Second, foreign customers and consumers may push companies that export part of their products (as the cases of food processing companies in Bien Hoa 1 IZ and Tan Chau-Singapore Company) to pay more attention to their environmental performance. Producing for European and US markets may be instrumental in acquiring ISO 9000 certification (such as shown in the cases of Bien Hoa Sugar Company, Bien Hoa Coffee Factory, and DIELAC Powder Milk Factory). Moreover, ISO 9000 accreditation may be considered a good start to further implementation of proper environmental management systems (EMS). Introducing an EMS according to ISO

14000 from this basis, may be a rather smooth process as these companies already have experience with the internal organization and reporting requirements and the accreditation procedures (Magno, 2001). Finally, the companies confronted with financial limitations, could start with cost-effective low and no-cost CP measures that are easy to implement. The savings from these low- or no-cost solutions could be used to subsequently fund the application of more costly options.

4.4. Public Participation

A strong involvement from the public is considered a key catalyst for adoption of environmental-friendly production practices. In several cases in Vietnam, environmental reforms are triggered by complaints from the local community (O'Rourke, 1999; Woltjer, 2001; Phuong, 2002). However, the case studies indicate the existence of several constraints that hamper community action. First, the overall level of environmental awareness of local residents remains low, in particular regarding the long-term impacts caused by (industrial) wastes. Especially in the case of the community industries only very limited attention is paid to the problem of waste disposal. For instance in Tra Co Village, where villagers earn income through the use of wastewater from tapioca production as fish feed or from recovered fibrous residues and pulp, the inhabitants do not complain about the discharge of wastewater. Farmers living in the surroundings of Tan Chau-Singapore Company sell cassava roots to the company and buy wet fibrous residues, hard roots and wood shells against attractive prices. In addition, the company employs some members from the neighboring households. So it remains rather unattractive to complain about environmental problems caused by this local production unit. Second, difficult access to environmental agencies is also limiting the role of the community. Sometimes community members do not know DONRE or its responsibilities. Therefore, they sometimes call upon social organizations such as the Retired Civil Servants' group, the Veterans' Association, the Women's Association, or the media to transfer their complaints to higher authorities. Finally, the absence of local and national independent non-governmental organizations (NGOs) working on pollution issues deprives citizens in Vietnam from a powerful source of support. In other countries, domestic environmental NGOs may link to international environmental NGOs to mobilize concerned citizens to participate in policy-making and to push state organizations and industrial polluters towards environmental reform (Phuong, 2002).

In order to strengthen the role of communities in detecting environmental pollution and changing behavior of the polluters, the communities should become more aware and better informed about the environment and environmental quality in their neighborhood. The Government can help by including environmental issues in the curriculum of primary schools and by broadcasting information about the environment on television, radio and through newspapers. The government could also widen the opportunities for establishing local, national as well as international environmental NGOs. Finally, in order to facilitate community action, the state environmental authorities have to provide specific guidelines for citizens' complaints.

5. Discussion

The results of the three case studies clearly indicate the need for taking drastic steps towards greater environmental sustainability as well as for a coherent model to achieve (close to) zero-waste ecosystems. The next section will discuss the applicability of the introduced pollution prevention methodology in guiding the further development of the existing industrial system. This is followed by a brief presentation of a physical–technological model for a zero-waste industrial ecosystem in industrial food processing industries.

5.1. Developing Zero-Waste Industrial Ecosystems

Despite several differences between the three case studies, some general conclusions can be drawn about the proposed methodology for developing a zero-waste industrial ecosystem. First, designing a physical–technological model of a zero-waste industrial ecosystem following the four basic steps proved feasible and applicable in different industrial systems. No matter how large or small the industrial system, its location, the kind of production processes used, how homogenous or heterogeneous, the logic of analyzing the process flow data, waste generation and solutions to prevent, minimize, and treat wastes, remains the same.

Second, the case studies clearly showed that without proper understanding of the relationships between the industries, the governmental organizations, other economic entities and social actors, it is not possible to identify the barriers that hamper the implementation of the options developed in the physical–technological model. An analysis of actors and institutions following a triad-network model proved useful in all case studies.

5.2. A Proposed Physical–Technological Model for Zero-Waste Ecosystems

Based on the case studies the possibilities and approaches for greening food processing industries in Vietnam are presented in a general physical–technological model (See Figure 1). Though its operationalization will vary due to the diversity of the particular industrial (food processing) systems, this generalized model provides a foundation for governmental authorities, planners, policy makers and environmentalists in reforming existing and establishing new industrial systems. Following this model, the agricultural sector will supply inputs for the food processing industries and the livestock sector, such as sugarcane, green coffee beans and cassava. The industrial sector subsequently provides products to the market and other enterprises, and will return biomass to the agricultural sector after a composting process and wastewater to the aquaculture sector. The livestock sector can also supply manure to the composting or biogas production plant. Other related industries can process products or byproducts from the food processing enterprise (for instance enterprise A in the model). Byproducts of the food processing industry are mostly organic and can be reused as inputs for livestock and fish feed, composting, biogas production,

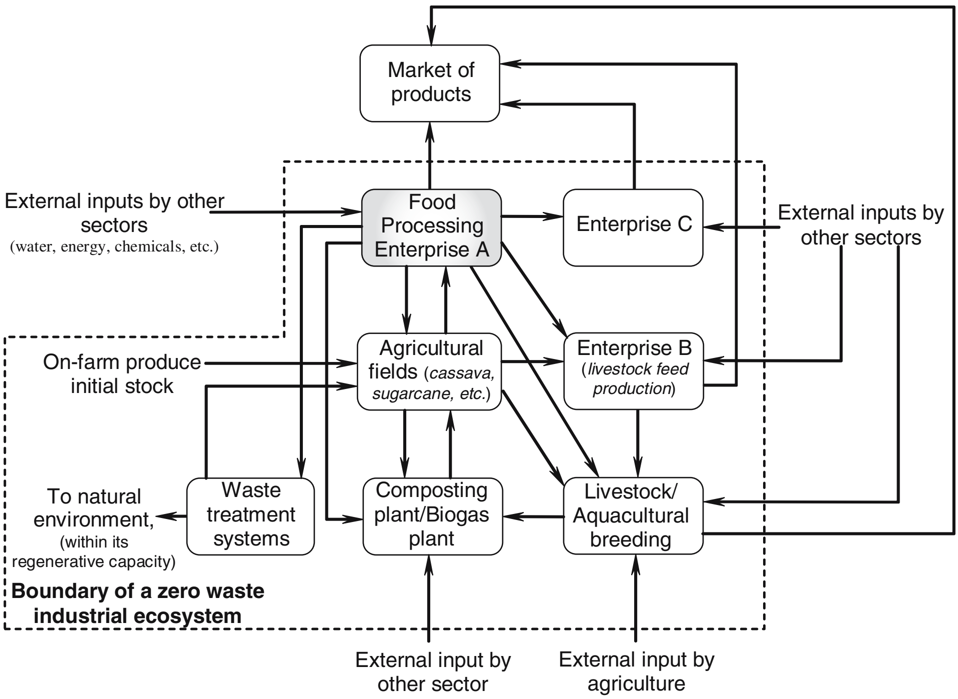

Figure 1. General recommended physical model of a zero-waste industrial ecosystem for food processing industry.

and some other products such as industrial alcohol. Thus, transfers of energy and materials exist between agricultural fields, industrial enterprises, and livestock and fish farming.

From the case studies we can conclude that this physical–technological model can be applied for industrial food processing systems of different scales and structures in Vietnam that use agricultural products as raw material inputs. Although the relations between the proposed elements of the model zero-waste industrial ecosystem of a food processing industry may differ from one system to the other, the main elements essential for establishing cooperation between industry and agriculture remain largely similar (See Figure 2).

6. Conclusions

Though not only similarities but also dissimilarities arose from the three case studies, it is possible to draw several conclusions in answering the questions formulated in the introduction of this article.

The industrial ecosystem's approach developed in highly industrialized countries can be applied to the food processing sector of Vietnam. The methodology to design a physical–technological model of a zero-waste industrial ecosystem following the

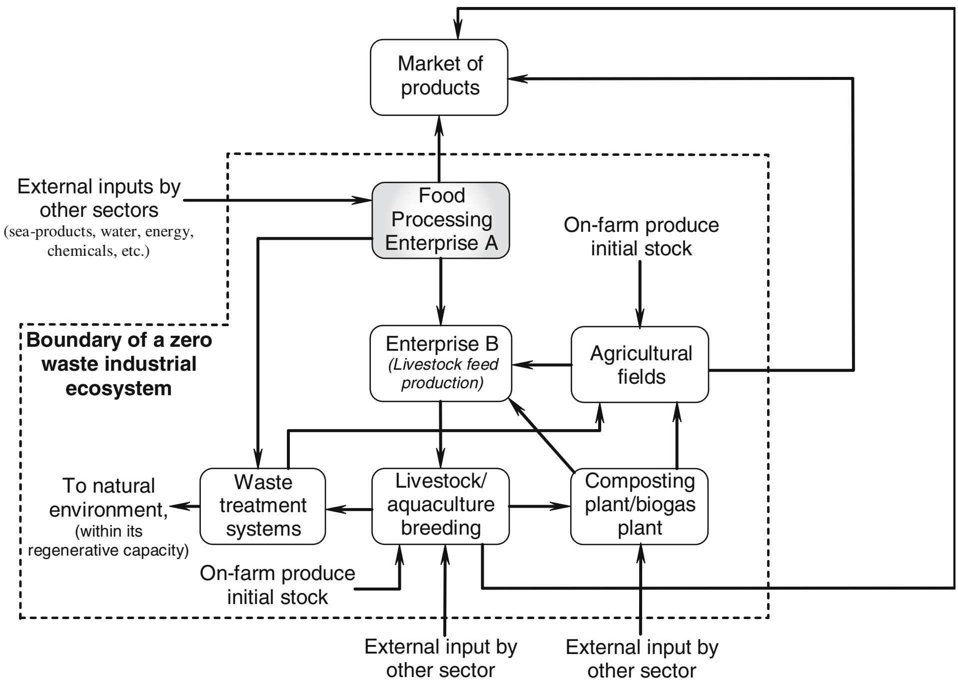

Figure 2. A proposed physical model of a zero-waste industrial ecosystem of food processing industrial sub-sectors, which do not use agricultural products as raw materials.

four basic steps proved feasible for different industrial systems in Vietnam. However, the case studies showed that without an analysis of actors and institutions, any physical–technological model remains a theoretical possibility at best. Available technological and management options to improve the industrial environmental performance are often not implemented because the triad network, the networks of political, economic and societal actors, does not provide sufficient pressure for doing this.

The concept of industrial ecosystems can in principle be applied to large as well as to small- and medium-sized companies. In practice there are, however, several key differences as the technological options vary widely between different scales of operation. In addition, smaller companies obviously dispose of more limited financial and human resources than larger firms available for environmental improvements. Finally, government institutions pay limited attention to the environmental performance of smaller industries and are more closely observing large-scale enterprises.

Bringing the food processing industrial sector in Vietnam together in industrial zones offers several advantages. As these industries produce similar by-products, there are substantial quantities on offer for recycling or further processing and the common interests of these firms provide a push for the installation of collective services close to the IZ thereby reducing transport costs. Another important benefit of IZ is the presence of government institutions with clearly defined responsibilities, notably IZID and IZ authority. These institutions play a crucial role in the introduction of the model of a zero-waste industrial ecosystem in the food processing industries in Vietnam, because they can oblige corporations to introduce this approach and also develop collective services to deal with waste and by-products.

The experiences from the case studies regarding the possibilities for greening the food processing industry in Vietnam can be generalized in a physical–technological model, in which the (food processing) industry and agriculture cooperate. This model consists of food processing enterprises and some or all of the following components: other enterprises that use products from food processing enterprises as raw materials, livestock feed production enterprises, fish culture households, livestock breeding households, composting plants, biogas production plants, agricultural fields and wastewater treatment plants. Though operationalization of this physical–technological model will vary due to the diversity of (food processing) industrial systems, this generalized model can provide the foundation for governmental authorities, planners, policymakers and environmentalists in reforming existing industrial systems and establishing new industrial systems as well.

Notes

[1] Burnside Cleaner Production Center plays an important role in providing information on waste reduction and prevention, and cleaner production to existing industrial estates (Smolenaars, 1996).

[2] This includes a sewer network and a wastewater treatment plant.

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