CHAPTER IV

RADIOGRAPHIC MEDICAL WASTE MANAGEMENT IN THAILAND

4.1 Introduction

Up till now, there have been few articles on the cycles of silver (Johnson et al., 2005; Lanzano et al., 2006). These articles have described the stock and flow of the silver cycle in an overall depiction focused on the industrial usage of silver from its ore extraction to its final disposal. Therefore, an investigation on the flow patterns of silver that originated from radiographic waste was undertaken in this study in order to improve the radiographic waste management system in Thailand.

There is little information on how radiographic waste is manipulated in Thailand. Most Thai researchers (Tameerak 1979; Seelsaen 2001; Songkroah 2004) focused on the technology for silver recovery from the waste rather than on management policy. This chapter aims to report on the present situation of radiographic waste in Thailand with an emphasis on a material flow analysis of silver and to propose future prospects for its management.

4.2 Objectives

The specific purposes are as followed.

1) To formulate a material flow analysis of radiographic medical film.

2) To investigate the current roles and responsibilities of key stakeholders, viz. waste generators, waste dealers, waste processors, and waste regulators, in the radiographic medical waste cycle in Thailand.

3) To evaluate deficiencies in the radiographic medical waste cycle.

4) To establish a fact sheet to assist the development of radiographic medical film management system.

4.3 Literature reviews

In California state, the Office of Pollution Prevention and Technology Development developed a pollution prevention guide to assist general medical and surgical hospitals in evaluating their operations for waste minimization opportunities. In the radiology-related part, which includes radiographic waste, the hospitals are recommended to store spent fixer (regarding as hazardous waste) and to haul it away by a licensed transporter. Used film could be sold to a recycler. Prior to selling used film, it was recommended that the jacket be removed for a better price. In addition, the hospitals were encouraged to only solicit the services of commercial recovery units with the necessary permits before evacuating their wastes (Wilson et al., 1998).

In Colorado state, the hospital chemicals project was carried out by Colorado Hospitals for a Healthy Environment (CHHE). Silver from used photographic film was one of the chemicals in this project. It was recovered by on-site recycling and off-site recycling as concluded in **Table 4-1**. Many recycling services that reclaimed silver from the used fixer also collected used films and papers. The recovered silver was sold to a metal reclaimer and the treated fixer was disposed of into the drain with prior permission of the public wastewater treatment authority. Moreover, this project suggested guidelines for choosing an off-site company for photographic waste, as summarized and prepared by the Water Quality Control Division and the Laboratory and Radiation Services Division of the Colorado Department of Public Health and Environment (CDPHE). Of importance was the selection on photographic waste management companies because liability did not end when the waste was discharged from the facility. The guidelines suggested questions to ask a photochemical recycler during the selection process, a potential silver recovery company, and additional potential services (McClearn, 2000).

In Minnesota state, the Minnesota Technical Assistance Program, MnTAP (1995), proposed a fact sheet for the management of hazardous waste from dental clinics. In fact, dental clinics produced a few hazardous wastes and these wastes could be recycled. This fact sheet described the sources of hazardous wastes generated by dental clinics, listed management and disposal options for these facilities, and names of silver recycling services. In 2003, the Minnesota Pollution Control Agency

proposed a management of photographic and radiographic waste fact sheet for businesses that produced the waste. This fact sheet laid out a management procedure for used photographic solution and film from waste generators to waste processors. The waste processors, in particular, had to ensure the maximum amount of silver removal and that the unit was maintained regularly and working properly. Finally they had to contact their sewer authority before discharging wastewater into the local waste water treatment plant.

Table 4-1 Silver recovery alternatives.

Considerations	Off-site Treatment	On-site Treatment
Volume of fixer	Recommended when fixer volume generated is less than 25 gallons per month	Recommended when fixer volume generated is more than 25 gallons per month
Cost	May be free, though a pickup fee may be charged	Costs vary for equipment and maintenance contracts
Regulatory	By collecting fixer for off-site recovery there is no discharge into the sanitary sewer; therefore, the local discharge limits will not be exceeded.	Treatment does not guarantee 100% removal of silver before discharge into the sanitary sewer. That local discharge limit may be exceeded. A discharge permit may be required.
Labor/maintenance	Fixer will need to be stored until the service provider picks it up	Treatment equipment should be inspected routinely. By sampling the treated fixer, the adequate removal treatment can be verified.

Remarks: 1 gallon is equivalent to ca. 3.8 liters

4.4 Methodology

4.4.1 Collection of Data from Stakeholders

An investigation has been performed among different stakeholders: suppliers, waste generators, waste dealers (waste transporters), waste processors and waste regulators. **Table 4-2** summarizes the data collected from the stakeholders and the data collection method. Questionnaires, interviews, site-visits, literature research and internet sources were the types of techniques and tools used for collection of data and relevant information about radiographic medical waste management. The numbers of participants from each group of the stakeholders are shown in **Table 4-3**.

4.4.2 Formulation of Material Flow of Radiographic Medical Film at Present

All of the information obtained from the collected data and literature reviews has been used to formulate the material flow of silver from the radiographic medical waste production phase to silver recovery phase.

4.4.3 Evaluation of the Deficiencies of the Present Radiographic Medical Waste Management System

The data obtained from the previous step was combined with those of related studies in the areas of radiographic waste management and available technology for the silver recovery from radiographic waste. The deficiencies of radiographic medical waste management system through out the material flow were eventually evaluated.

Table 4-2 Areas of investigation for each stakeholder.

Stakeholders	Areas of investigation	Method for data collection
Suppliers	• X-ray film import and distribution	Questionnaire as in Appendix C
Waste generators (hospitals)	• Consumption quantities • Film developing methodology • Procedures to manage radiographic medical waste • Criteria to select waste processor • Names of waste dealers and waste processors	Questionnaire as in Appendix C and interview
Waste dealers	• Operating licenses • Names of waste processors	Interview
Waste processors	• Radiographic waste treatment technology • Procedures to recover silver from used X-ray film and used radiographic solution • Operating licenses	Interview and site visit
Waste regulators		
Ministry of Industry	• Licensed silver waste recovery factories • Present measurements, roles and actions to manage radiographic waste • Related law and regulations	Internet and interview
Ministry of Public Health	• Present measures, roles and actions to manage radiographic waste • Related laws and regulations.	Internet and interview

Remark: Quantities of imported X-ray film/radiographic solution and names of importers obtained from the Customs Department, Ministry of Finance via the internet were important data used in the study of this part.

Table 4-3 Stakeholders involved in the data collection phase.

Stakeholder	Total	Sampling group
Suppliers	20	20
Hospitals	1,454*	100
Waste dealers	-	15
Waste processors	-	10

Remark: * Data from Jeaskul, 2002.

4.4.4 Establishment of a Fact Sheet to Support the Development Radiographic Waste Management System

The information derived from collected data and, of importance, the content of the technology part in this study were used in developing suggestions in the form of a fact sheet. The fact sheet was designed to support the concerned parties in radiographic waste to understand necessary issues about the waste and how to manage the waste in a systematic way.

Methodology of the management part is summarized and shown in **Figure 4-1.**

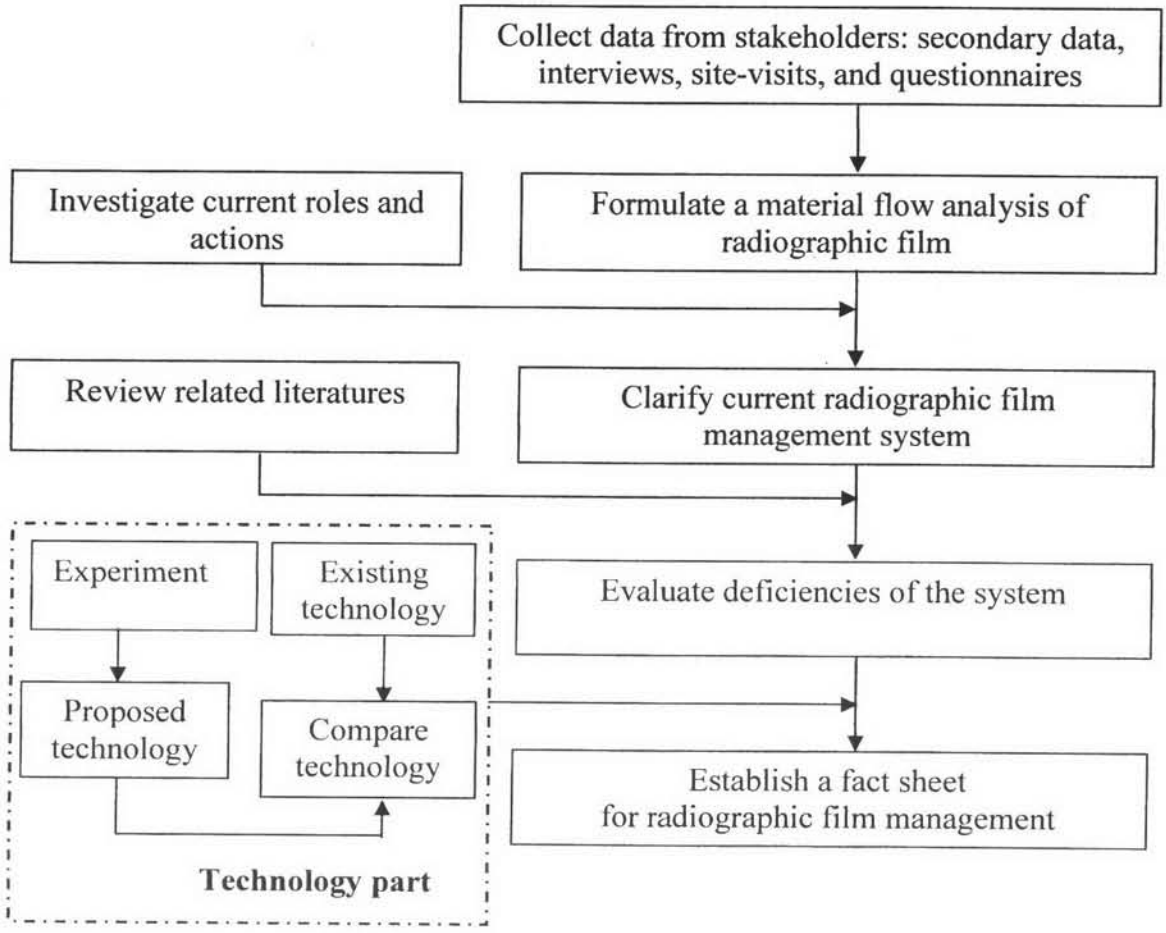


Figure 4-1 Summary of the methodology.

4.5 Results and Discussions

4.5.1 Present Situation of Radiographic Waste Management in Thailand

One important tool of industrial ecology based upon the law of conservation of mass to monitor the flow of specific substances is a Substance Flow Analysis (SFA) or a material flow analysis. A SFA is used for identifying environmental problems and proposing remedial/prevention strategies (Kapur, 2006). In this study, the existing situation of radiographic medical waste management in Thailand was explained through a SFA to determine how much silver was disposed of into the environment. The flow of silver normally consists of 4 stages: (i) production, (ii) fabrication and manufacturing (F&M), (iii) use, and (iv) waste management (WM). In this analysis, the system boundary limited only the flow of silver in the production and F&M stages. A flow diagram of the silver waste life cycle is presented in **Figure 4-2**.

A mass balance equation was formulated to access the flow patterns of the silver waste cycle. It determined the recovered and lost amounts and established the amount entering the material reservoirs. The mass balance equation is as followed.

$$dF/dt = \Sigma F_{input} - \Sigma F_{output} + \Sigma (S_t - S_{t-1}), \quad (1)$$

where F represents the material flow into and out of each hospital inside the control volume and S represents the stock of material retained or depleted from the reservoir over a time period.

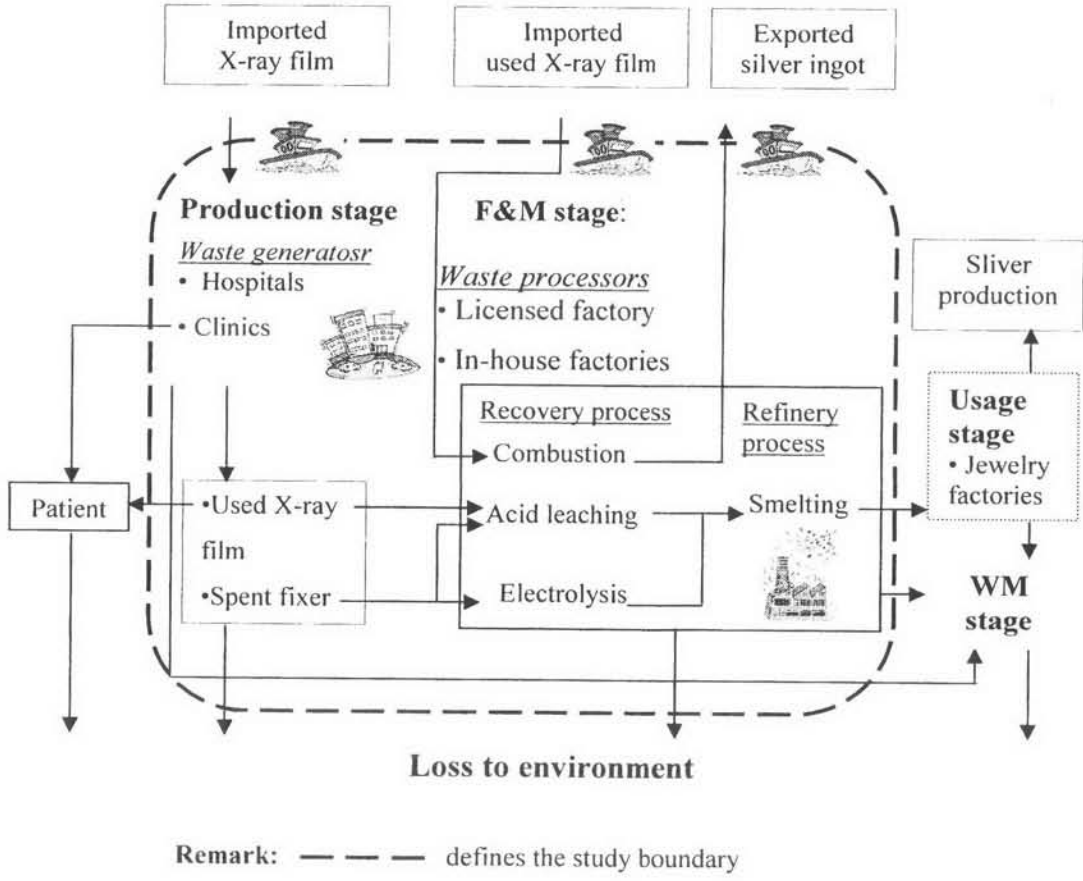


Figure 4-2 Material flow analysis of silver in radiographic waste.

4.5.1.1 Production of Radiographic Medical Waste

At present, there is no film manufacturer in Thailand. All kinds of X-ray film products are imported. Silver flows in an active form (AgX), coated on the X-ray film,

into the study boundary. The application of the film has been mainly used for medical purposes. It was found that 93.5% of imported film was distributed to hospitals and ca. 5% to clinics. These utilizers produce wastes at their premise and become the primary waste generators (PWG).

The stocks of silver do not change from year to year; this is due to the fact that a procurement amount of new X-ray film is carried out on annual basis and the amount of used film i.e., retained silver, primarily depends upon the space of storage area for used film in each hospital. For example, for the year 2003-2004, the accumulation term shall approach zero under steady-state conditions. The net accumulation of material equals to the summation of silver influx minus silver outflow in a defined control volume. Hence, Eq.(2) can be written as followed.

$$F_{silver} = \Sigma F_{input\,(2004)} - \Sigma F_{output\,(2004)} + \Sigma S_{(2004)} - \Sigma S_{(2003)}. \quad \textbf{(2)}$$

X-ray film is imported by the suppliers; the monthly and yearly quantities are recorded by the Department of Customs (Ministry of Finance). **Figure 4-3** indicates the amount of imported film from 2001-2005. The annual imported amount of film increased in 2002 and remained stable at a range of 630-640 metric tons up to 2005. The fact that there is ca. 2% silver content (by weight) in X-ray film; this amounts to 12.5 tons of silver as the main material input in the defined system as shown in **Table 4-4**.

In addition to domestic supply, used film is imported by a waste processor. The price of imported used films is apparently cheaper than the domestic used film. At present, the amount of imported used film is legally limited; it only allows for a test-run operation of a factory. On average, approximately 1% silver content (by weight) is found in the used X-ray film, this amounts to 0.1 ton of silver as the extra material input in our defined system besides the new imported film.

After film being used for internal effect diagnosis assistance in hospitals, silver becomes (primary) waste as spent photographic solution and solid sheet material. It was found that, silver, in its metallic and compound forms, remains on the film after being developed and in the spent fixer at 55-65% and 35-45%, respectively. Finally,

these wastes are generally sold to waste dealers (WD) rather than directly to waste processors (WP) for the further recovery of silver.

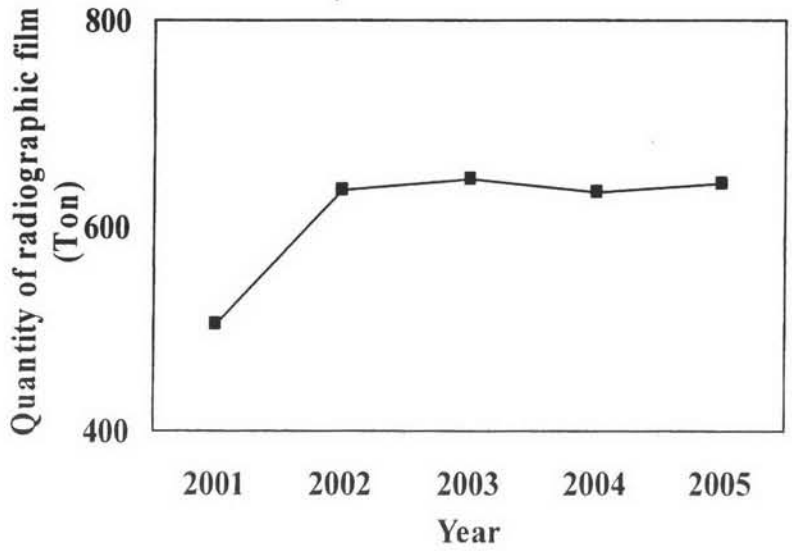


Figure 4-3 Quantities of imported X-ray film from 2001 – 2005 (Thai Customs Department, 2005).

Table 4-4 Silver content in materials.

Material	Silver content per unit material (g Ag/m^2)	Total silver (kg Ag)
Original X-ray film	4-6[a]	12,700[c]
Used X-ray film	3.0-3.5 [a]	6,980-8,320[d]
Solution (fixer+developer)	around 2,000~6,000 mg/l[b]	

[a] Material samples were digested with HNO_3 and determined by AAS.

[b] Solution sample was directly measured by AAS.

[c] Total silver was estimated to ca. 2% of the amount of imported film in 2004.

[d] Total silver was estimated to ca. 1.1-1.3% of the amount of imported film in 2004.

Of importance, the amount of used radiographic film ca. 5% (estimated from the amount of new film sold to the clinics) was returned to patients. This is a normal practice of the clinics. In addition, some hospitals also return the used film to their patients who would like to keep it as their personal records. The hospitals normally notify the film owners notify prior to selling the film. Some hospitals adopt the used film for glasses to protect the eyes of the neonates during photo therapy. The latter returned amount is arbitrarily estimated to be about 5% (equal to the amount of the used film returned by the clinics). It seems that ca. 0.98 ton of silver flows out of waste management system from waste generator, and it ends up as household hazardous waste (municipal waste).

However, a portion of the silver sinks into the environment through rinse water and used developer solution in the developing process. These solutions are usually drained directly into the sewerage system with silver concentrations in the range of 12-100 mg/l, which is, to our best estimation, ca. 0.04 ton of silver.

4.5.1.2 F&M of radiographic waste

The used X-ray film and spent fixer enter silver recovery factories as a secondary raw material. In Thailand, this kind of factory is categorized as a 106-type factory as it engages in the recycling or recovery of materials from industrial wastes and/or discarded industrial products. With the defined number of workers or horse powers, the 106-type activity becomes a "Factory" by the Factory Act B.E. 2535 (1992). The Factory is controlled under a number of regulations promulgated by the Factory Act.

Table 4-5 shows the number of waste processors for silver recovery i.e., silver recyclers. To date, only a single silver recovery factory has been officially registered with the Department of Industrial Works (Ministry of Industry - MOI). This factory imported used X-ray films from Japan and used them as a raw material in a combustion recovery process. Approximately, 0.09 ton of silver was recoverable by this process. For other recyclers, information was obtained from the interviews with the hospitals.

Table 4-5 Recyclers of silver from radiographic wastes in Thailand.

Process	Number of recyclers	Remark
Combustion/ Burning	1	Legal factory
Electrolysis	17	House factories
Acid leaching	8	House factories

Most of the silver recovered from used X-ray film and spent fixer solution is processed by so-called "house" factories. These small-scale waste processors conduct their businesses without facilities for treating their wastes and become a large group of secondary waste generators (SWG). Factories with the electrolysis process recover silver from developing agent waste; while factories with acid leaching operations recover silver from used film. However, they lack of a proper management system of their wastes. **Figure 4-4** shows the accessible areas of several "In-house" waste processors.

Electrolysis and acid-leaching are the most commonly used silver recovery techniques. Electrolysis is an effective method for extracting silver from solution, whereas combustion and acid leaching are suitable for retrieving silver from used film. Approximately, 95-96% of the silver contained in the used film and fixer solution, which is equivalent to 11 tons, is recoverable.

Silver ash produced by the combustion treatment and sludge generated from the chemical leaching process is smelted and refined to make silver ingots, while other silver-contaminated chemicals cross the boundary into the environment or enter a waste treatment plant before being released into the environment. The silver ingots are sold to domestic jewelry and silverware manufacturers.

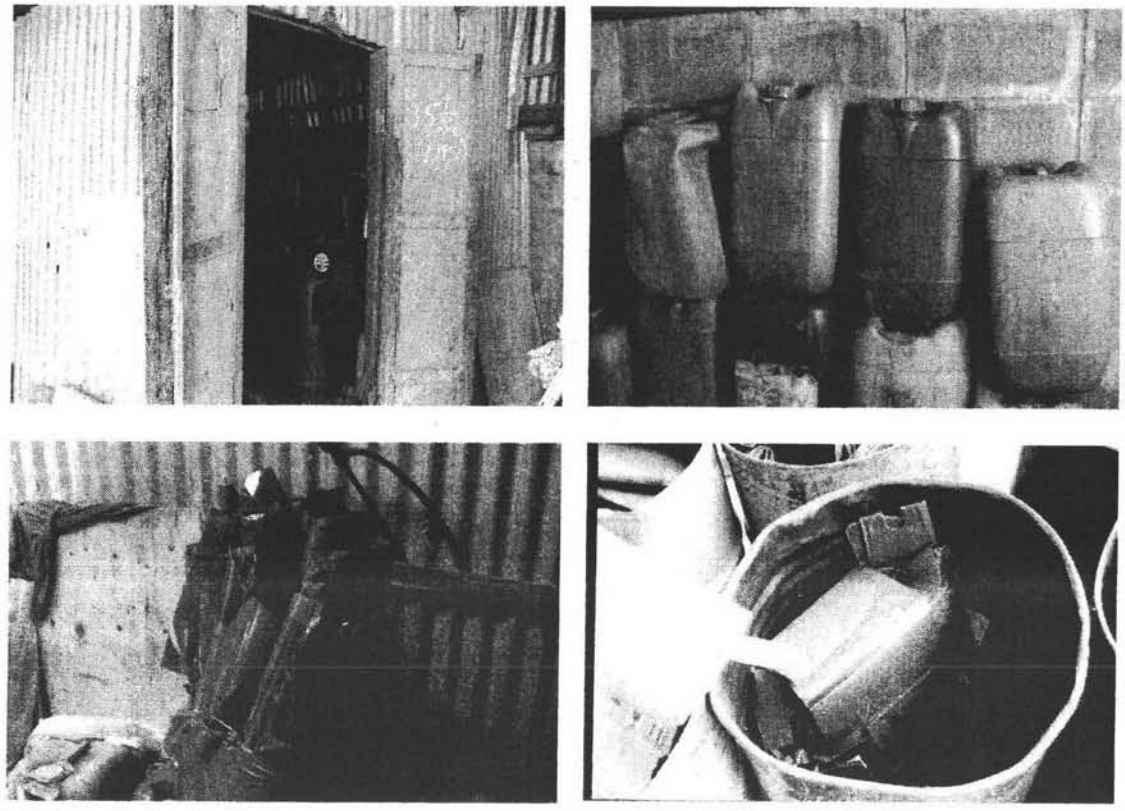


Figure 4-4 In-house waste processor for silver recovery.

The residual wastes, including wastewater and leached plastic sheets, which are contaminated by traces of silver, are sent for external waste management outside the system boundary. Only 40% of the wastewater has been treated on site by neutralization or dilution prior to discharge into the environment. The amount of silver loss in the effluent is approximately 0.52 ton. Furthermore, the analysis of leached film showed that an average of 0.08% of silver by weight still retains on the film sheet.

The silver flow of radiographic waste throughout the production and F&M stages is illustrated in **Figure 4-5**. Even the total loss of 1.5 ton of silver through the biosphere in our system boundary is not comparable to the material available in the system outside. The wastes, especially the emissions from the "in-house" waste processors, have been classified into hazardous material categories (U.S.EPA, 2006).

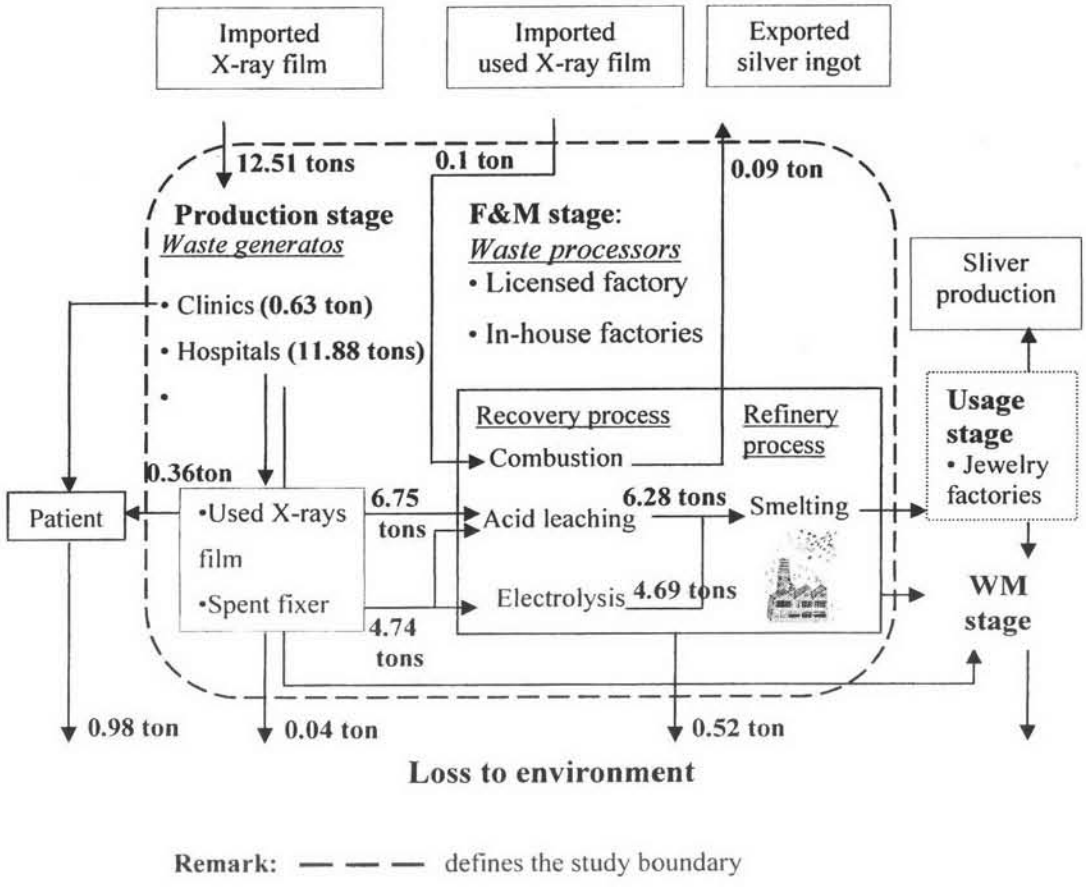


Figure 4-5 Silver flow of radiographic waste in production and F&M stages. The unit is tons of Ag (from 2003-2004).

4.5.2 Waste Management

4.5.2.1 Handling Waste between Waste Generators and Waste Processors

100 out of the entire 1,454 hospitals in the country, including private and public hospitals, were selected as the sample group The data obtained from our integrated questionnaires, which focused on how the hospital manage their radiographic waste, indicated that management practices differ among the hospitals. This was mainly due to these hospitals, clinics and medical centers are affiliates of different authorities.

Only 44 out of 100 sample hospitals replied and returned the questionnaires. These hospitals were classified by number of beds into 3 groups, small hospitals

(<150 beds), medium hospitals (150-500 beds) and large hospital (> 500 beds), as shown in **Table 4-6.**

Table 4-6 Classified sample hospitals by number of beds

Hospital sizes	Sample hospitals	Percentage of data
<150 Beds	8	18.18
150-500 Beds	20	45.45
>500 Beds	16	36.36
Total	44	100.00

The questionnaire results were concluded as followed.

1) Film Consumption

From the survey data, it was found that radiographic film consumption in 2002 and 2003 of small, medium, and large hospitals were 277 versus 242, 1,051 versus 1,200, and 3,163 versus 3,437 kilograms per year, respectively. **Figure 4-6** shows film consumption by sample hospitals with respect to their size.

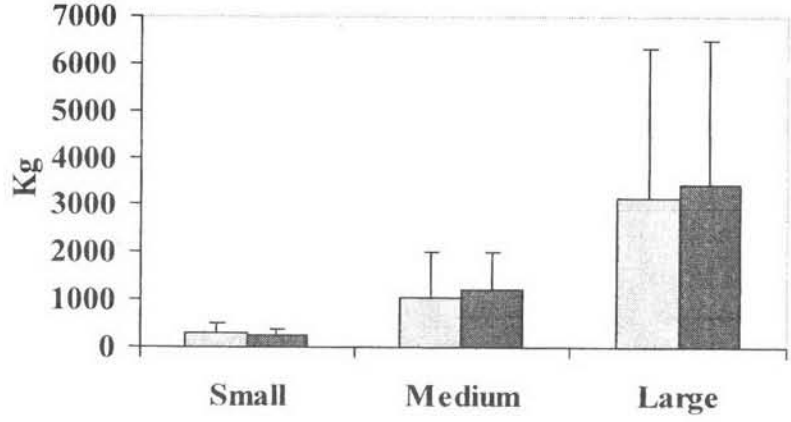


Figure 4-6 Radiographic film consumption classified by the size of hospitals in the year (▪) 2002 and (■) 2003.

2) Storage Period of Processed Film

All the sample hospitals developed their own radiographic film using an on-site automatic machine. Approximately 76.5% of the hospitals kept their used (processed) X-rays film up to 5-10 years for their medical records, as illustrated in **Figure 4-7.**

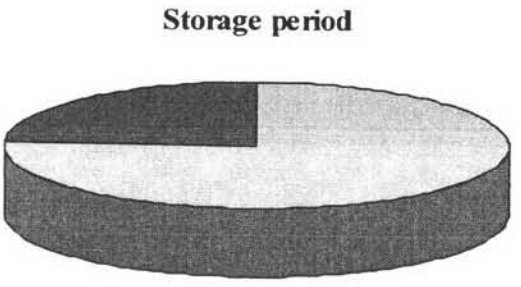


Figure 4-7 Storage period of processed film: (■) 0-5 years and (▩) more than 5 years.

3) Radiographic Waste Management

After the on-site developing process, radiographic wastes i.e., processed film, spent developer and spent fixer, were generated in the radiology department. 85.4% of the sample hospitals sold the used film to the waste dealers; the rest reused the film in other purpose (e.g. as protective glasses to protect the eyes of the neonates during phototherapy etc.). **Figure 4-8** shows the management of processed (used) radiographic film methods. Used X-ray film was sold at a price of approximately 839 and 777 US dollars per metric ton in 2002 and 2003, respectively. The price of spent fixer was approximately 680 US dollars per cubic meter.

All of the spent developer was drained into the wastewater treatment plant. It was found that 90.2% of the sample hospitals drained spent developer into their treatment plant, as shown in **Figure 4-9**.

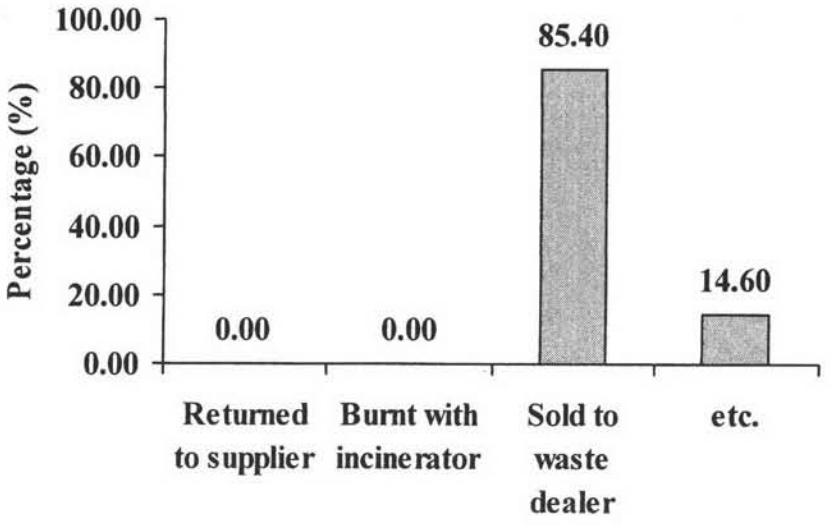


Figure 4-8 Management of used radiographic waste by sample hospitals.

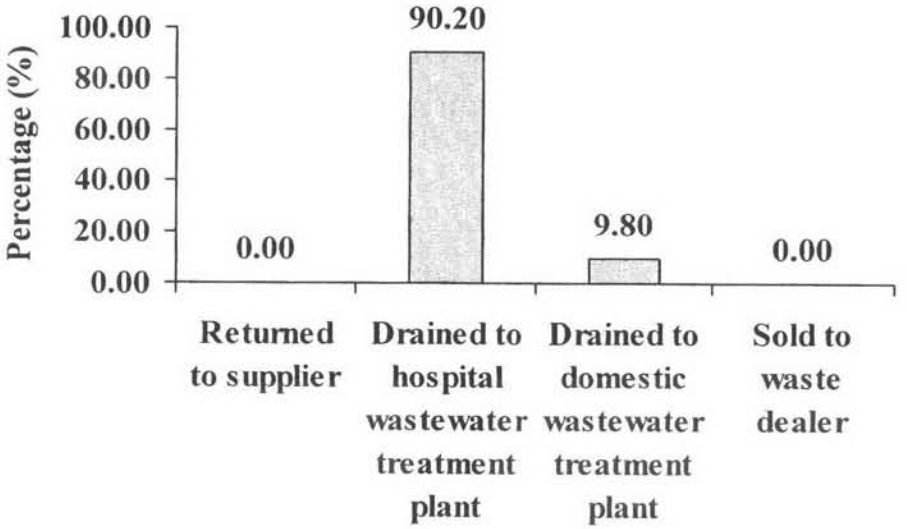


Figure 4-9 Management of spent developer by sample hospitals.

Spent fixer was reused twice at minimal and collected for a number of years until it accumulated to a certain amount to be sold. It was found that 82.5% of sample hospitals sold the spent fixer to the waste dealers; whereas, 17.5% of them drained it into wastewater treatment plant as shown in **Figure 4-10**. The price of the spent fixer sold was approximately 680 dollars per cubic meter.

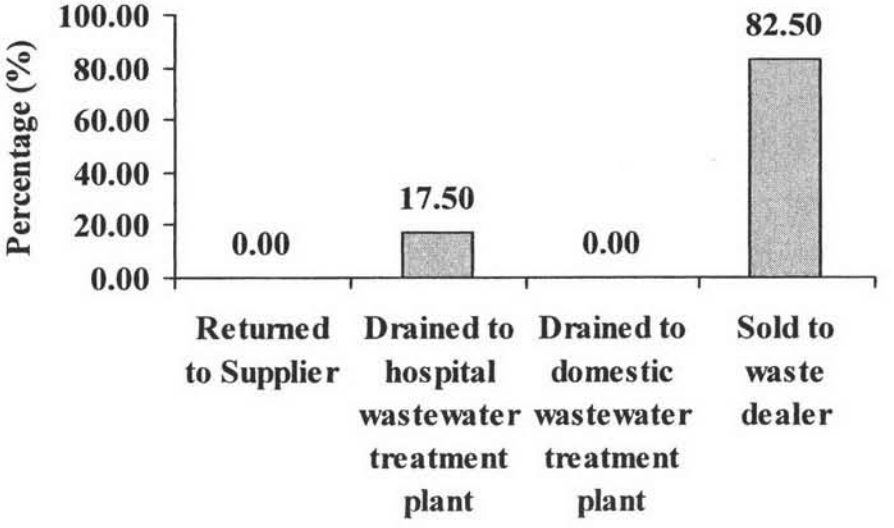


Figure 4-10 Management of spent fixer by sample hospitals.

Radiographic waste dealers were either individuals or juristic persons. The dealer who offer the highest price, get the used X-ray films and the spent fixer solution. In general, a bidding process took place at a hospital where an enormous amount of radiographic waste was produced to gain maximum income. These waste dealers were not required to provide information on their recovery processes and how the waste they generated was managed. **Figure 4-11** reveals the percentages of document requirements, which were a national identification card, a business establishment certificate, a resident registration certificate, and combinations of the fore-mentioned documents. The data showed that 44% of the sample hospitals merely required a national identification card, 9% of them required a business establishment certificate, and 4% of them required a resident registration certificate. While 39% of the samples required a national identification card and a business establishment certificate. Yet, only 4% of them required all of the documents.

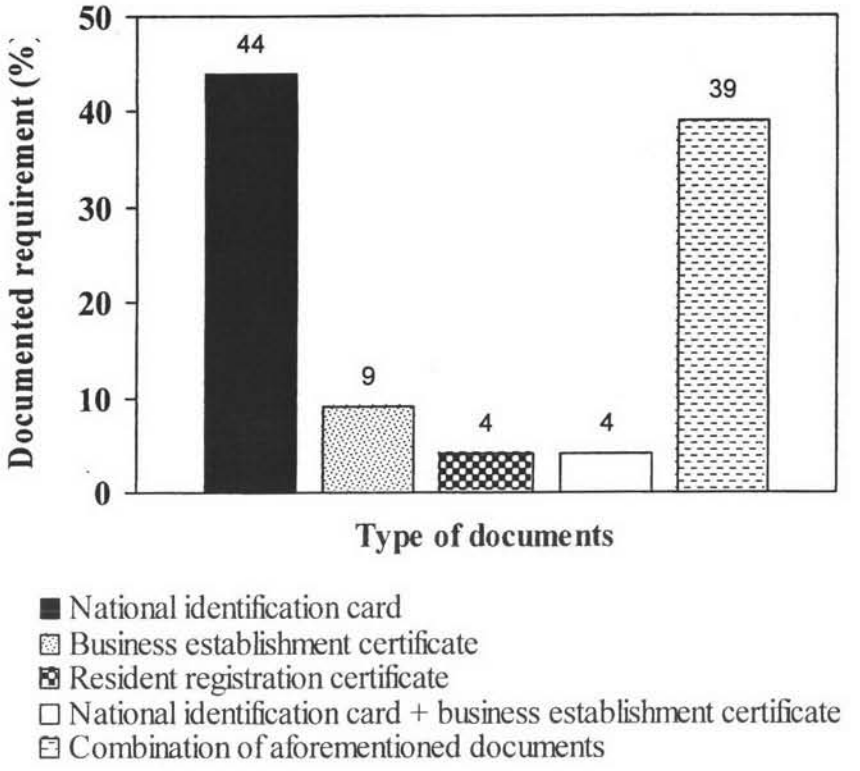


Figure 4-11 Percentages of required documents.

According to the survey data, some waste dealers did not even have a business establishment issued by the Ministry of Commerce (MOC). For those who were registered with the MOC for the radiographic waste recycling business, it was not possible to search the information on how many waste dealers were actually registered with MOC database.

In addition to the missing information of the waste dealers, the information of about the waste processors was rarely disclosed to the hospitals. The names of the waste processors present in this study were obtained from the direct interviews with some waste dealers.

Table 4-7 provides a summary of the present measurements and problems of the management the radiographic waste of the sample hospitals. At present, there has been no specific legal measure for the management of radiographic waste. As a result, the hospitals set up their own requirements and most of the hospitals had a concern for the price of wastes they sold, not how proper their waste was managed.

Table 4-7 Present measurements and problems of the radiographic waste management of the sample hospitals.

Type of Hospitals	Regulator	Process	Problem
1. Public hospitals	Ministry of Public Health	Transferring an administrative duty to finish in each hospital. The hospitals set up their regulations for the management radiographic waste.	- Lack of standard measure to manage radiographic waste. - Lack of direct authority to control. - The waste manage policies enacted to manage this waste are different.
	Bangkok Metropolitan Administration (BMA)	Hospitals set up their regulations for the management radiographic waste. They report to the BMA, after finishing the process.	
	Ministry of University Affairs	Hospitals set up their own rules but do not report to anyone.	
	Other authorities	NA	
2. Private hospitals	-	The hospitals set up their own regulations for the management radiographic waste.	

In the prequalification process for selection of the waste dealers, the hospitals neither took into consideration the reliability of the waste processor (who actually processed the waste), nor required the waste dealers to disclose their waste processors or the operating permits of the processors. Information about the waste processors was practically unavailable. Therefore, a concern of hospitals for their radiographic waste

seemed to end after the bidding process finished, as they had no clue where their radiographic waste was transported to and how the waste was subsequently processed.

4.5.2.2 Laws and Regulations

The Factory Act 1992 (B.E. 2535) and the Public Health Act 1992 (B.E. 2535) are involved in a control of radiographic medical waste in Thailand. **Table 4-8** shows the regulatory roles and jurisdictions of the Factory Act and the Public Health Act.

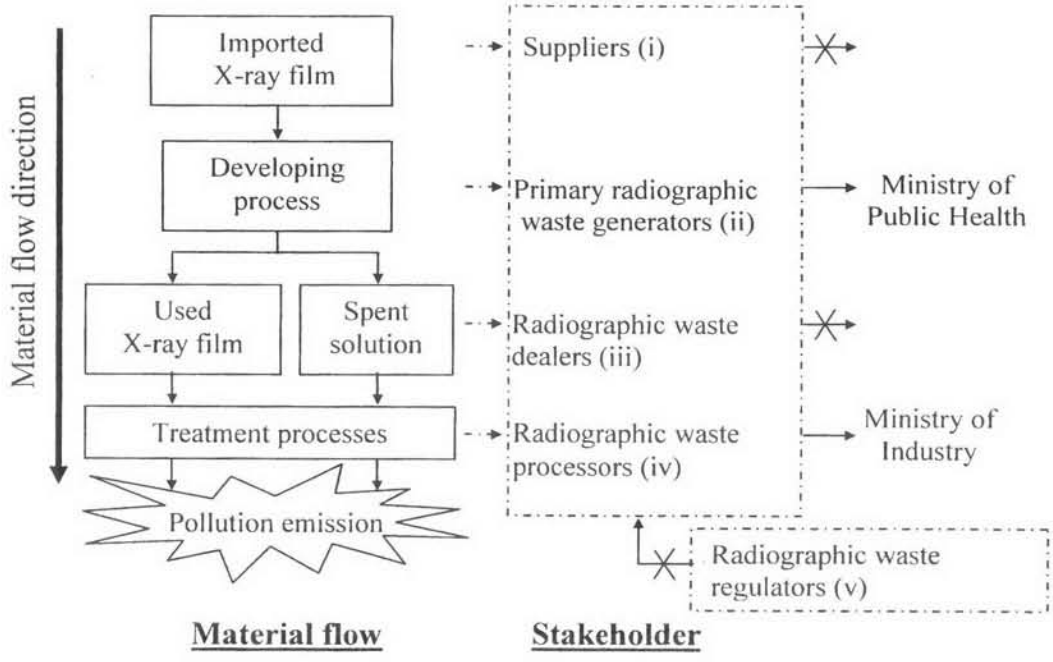
Table 4-8 The regulatory roles and jurisdictions of the Factory Act 1992 (B.E. 2535) and the Public Health Act 1992 (B.E. 2535)

Roles and Jurisdictions	The Factory Act	The Public Health Act
Regulated activities	Regulate the engagement in a factory business - Prevention the dangers injuries or troubles that may cause to the persons or property - Controlling the discharge of waste, pollutants or anything that may effect the environment - Protection of safety in the operation	Regulates activities or operations e.g. disposal of sewage and solid waste, business detrimental to health and source of nuisance etc.
Responsible Authorities	Ministry of Industry and Department of Industrial Works	Ministry of Public Health and Local Administration Organization
Limitation	Enforcement only factories	Factories, hospitals, clinics, small business etc.
Classification - Size - Type of the waste processor	Factory business When uses ≥ 5 Hp machine or employs ≥ 7 workers" - Type 101: Waste Water Treatment and Specific Incineration/Co Incineration - Type 105: Sorting and Landfilling - Type 106: Recycling or Recovery	Business detrimental to health All size - Melting, founding, and smelting metal - Collecting used material or waste

As the Factory Act limits its jurisdiction on the waste processor that uses ≥ 5 Hp machine or employs ≥ 7 workers; while the Public Health Act can control a wider range of waste processing business, it apparently resulted in a gap of regulating measures of the 2 Acts. The Factory Act imposes severe measures to protect human life and the environment from the factory operations by issuing a number of environmental emission standards as well as factory safety standards. The Public Health Act has no rigid measures in controlling environmental impacts or safety for regulating their detrimental-to-health business, this Act is set up to control and relieve complaints or nuisance issues.

4.5.2.3 Problems of Radiographic Waste Management

Based on our analysis, intrinsic problems have occurred in the system. **Figure 4-12** shows the relationship between the X-ray material flow and key stakeholders. The figure depicts five major stakeholders: (i) X-ray film and fixer suppliers, (ii) primary radiographic waste generators, (iii) radiographic waste dealers/vendors, (iv) radiographic waste processors or secondary radiographic waste generators, and (v) radiographic waste regulators.



Note: ⊣→ Unclear control unit.

Figure 4-12 Relationship between the X-ray material flow and stakeholders.

First of all, on the supply side, there were adequate statistics from the Department of Customs (Ministry of Finance) that the materials were all imported into the country. The mass quantity and the names of importing firms were well-documented and the information was available for the public.

Secondly, there were the primary waste generators (PWG). They could be divided into 2 groups: large PWG and small PWG. Large PWG, i.e., hospitals and medical services, accounted for a large portion of the radiographic waste quantity. In general, they were subjected to some regulations endorsed by the Public Health Act B.E. 2535 (1992) issued by the Ministry of Public Health (MOPH). Nevertheless, there was no any specific rule for the control of radiographic waste from Large PWG issued by MOPH.

Small PWGs i.e., factories and some photo shops that used new X-ray film in the production process or business were classified as small radiographic waste producers. Radiographic waste from these factories was currently under the control of MOI under the Factory Act B.E. 2535 (1992). Yet, there was no controls set in place for photo shops.

Thirdly, on the other hand, there were radiographic waste processors i.e., used film and spent fixer recycling factories, which were secondary waste generators (SWG). As previously described, only a single waste processor was registered and controlled by MOI via the enforcement of the Factory Act B.E. 2535 (1992); while the number of "house" factories remained unknown.

It could be assumed that the major feed raw materials for a silver recovery factory would be from the medical services within the country. But, actually, the domestic radiographic waste was hardly processed at the only licensed factory in Thailand. This factory had to import used X-ray films for its recycling operation. It was obvious that a loophole existed in the state control system.

The radiographic waste from industrial operations, as PWG and SWG (or waste processors) is legally defined as "industrial hazardous waste" according to the Ministerial Notification B.E. 2548 (2005) issued pursuant to the Factory Act B.E.

2535 (1992). This Act requires a factory that produces and/or recycles its radiographic waste to apply for an operating permit for their factories and a waste evacuation license from MOI. However, this law can only be enforced on a factory. It is not applicable to the other major waste generators i.e., hospitals (which are regulated by the Public Health Act) and the small waste generators i.e., "house" factories. The "house" factory is not considered as a " factory" under the Factory Act, unless it utilizes power at a rate of 5 or more horse powers and/or employs 7 or more workers.

Fourthly, there were the radiographic waste dealers, who actually transferred the waste from the generators to the processors. These free waste traders were not regulated by any government body. As a result, it was very difficult to identify where the waste commodity was distributed. Thus, it was not possible to locate where the waste was delivered to and to specify who managed it.

Finally, the hospitals as large PWGs lacked of close cooperation among themselves to set up measures to control their radiographic wastes such as defining of waste type (to be hazardous or non-hazardous); separation and collection procedures; criteria to select the waste dealer and waste processor; monitoring measures etc.

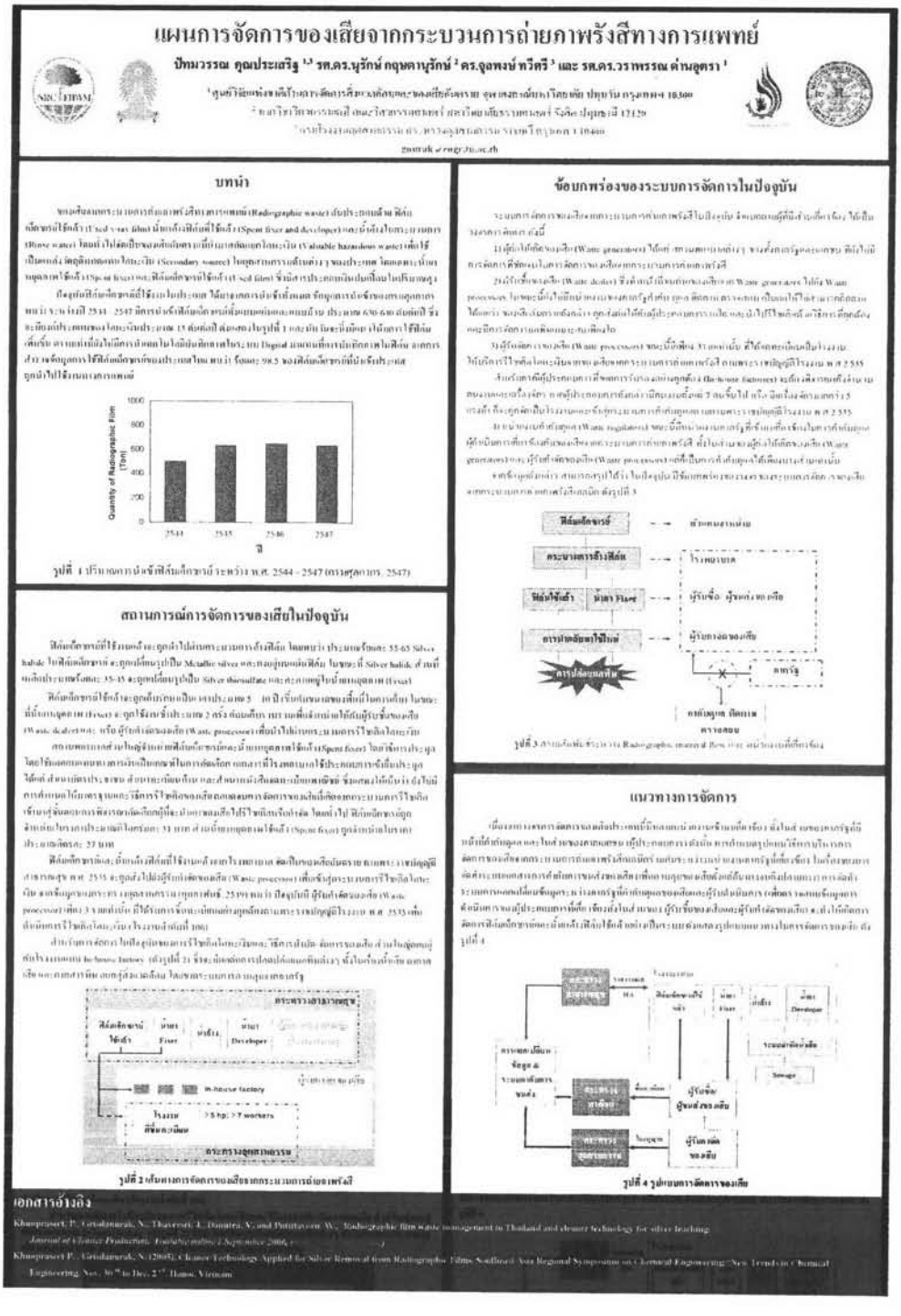
All the above-mentioned problems resulted in a non-systematic management of X-ray waste in Thailand. At present, there seems to be a one-directional flow of material waste without any monitoring system. Pollution from silver recovery processes continues to be released into the environment without awareness or proper treatment. Official records of the radiographic waste are not sufficient for creating a proper management system for the waste.

4.5.2.4 Emerged Problems about Radiographic Waste Management in Thailand from Hospital and Health Officials

The radiographic waste management part of this research was presented in the 4th National HA Hospitals Conference, 15-16 February, 2007 at Rama Garden Hotel, Bangkok and the 8th HA National Forum: Humanized Healthcare, 13-16 March, 2007 at Impact Exhibition Hall, Muang Tong Thani, Bangkok. The aims of these conferences were to propose a new vision for the quality development of hospital, to

serve as a common place for exchanging experiences and knowledge among the public hospital personnel in order to improve hospital quality and hospital standards. About 1,200 participants were officials from health care unit and health-related staff that attended in each conference. **Figure 4-13** shows a poster that was presented in the two events.

Figure 4-13 Presented poster of Radiographic waste management in Thailand.



During the presentations, ca. 20 hospital and health officials who worked in a radiology department or related duties gave some comments and questioned about the existing radiographic waste management system in Thailand. The emerged problems were summarized as shown in **Table 4-9**. This information would be useful for improving a fact sheet of the radiographic waste management in our study.

From the emerged problems, it was found that the information the attended officials concerned were a proper method of management/treatment/disposal of the radiographic waste, waste characteristics and health impacts, and health protection, Of importance was the question about the waste dealer and the waste processor (who they are and how to select them). This information was adopted in our fact sheet after the conferences.

Table 4-9 Emerged problems from hospital and health officials.

Waste type	Problem
Developer	1. How to dispose of a spent developer? 2. Can a spent developer be drained either into an existing wastewater treatment plant or a sewer? 3. If not, what should it be done? 4. Would a developer deteriorate wastewater treatment efficiency? 5. Is a developer harmful to bacteria in a wastewater treatment plant? 6. Is there any valuable metals remain in a developer? 7. Is there any health effect if "a direct contact to a developer" occurs? 8. Does a developer contain with toxic chemicals? 9. Does an odor (vapor) of a developer affect human health? 10. How to protect when a direct contact with a developer is unavoidable?

Table 4-9 Emerged problems from hospital and health officials (cont.).

Waste type	Problem
Fixer	1. How to manage a spent fixer and rinse water contaminated with a fixer? 2. Can a spent fixer be drained either into an existing wastewater treatment plant or a sewer? 3. Is there any health effect if "a direct contact to a fixer" occurs? 4. Does a fixer contain with toxic chemicals? 5. Does an odor (vapor) of a fixer affect human health? 6. How to protect when a direct contact with a fixer is unavoidable? 7. Who is the waste dealer? 8. Who is the waste processor? 9. What are criteria to select waste dealer or waste processor? 10. What is a reason why a spent fixer is considered as HZW 11. How to recover silver from a spent fixer? Existing available technology
X-ray film	1. How to properly manage used X-ray film? 2. Can used X-ray film be reused for other purposes such as material for making 3D glasses? 3. Is there any fixer still stained on used X-ray film? 4. Is there any health effect if "a direct contact to a developer" occurs e.g., from stained fixer on the film? 5. Who is the waste dealer? 6. Who is the waste processor? 7. What are criteria to select waste dealer or waste processor? 8. What is a reason why X-ray film is considered as HZW? 9. How to recover silver from X-ray film? Existing available technology?

4.5.3 Future Prospects for Radiographic Waste Management

In Thailand, the existing measures were found to be insufficient for controlling radiographic waste in terms of environmental concerns. In order to achieve the goal of complete waste management, silver as a hazardous element should be strictly monitored and tracked from its generation points to ultimate disposal sites as proposed in **Figure 4-14**. Pollution prevention guidelines in the form of a fact sheet were developed in this study to manage silver-contaminated wastes for businesses that produce the wastes. The main subjects covered in the fact sheet are the types of radiographic waste, lists of management and disposal options, a manifest system, and a list of waste dealers and silver waste processors in Thailand.

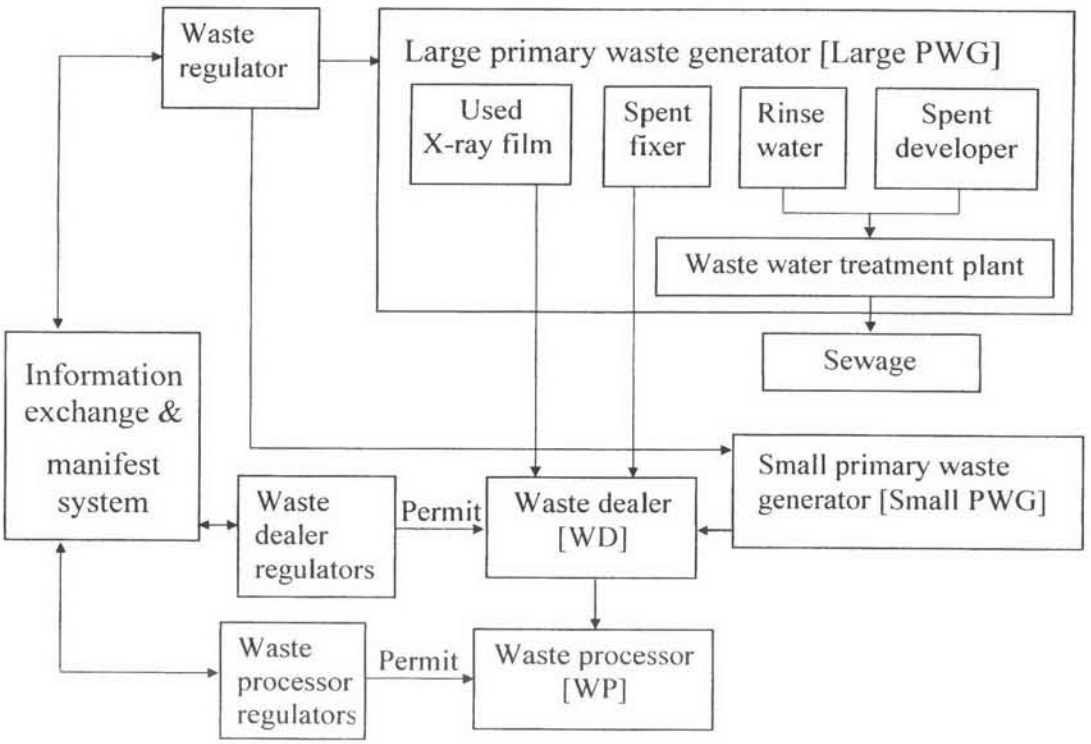


Figure 4-14 Proposed radiographic waste management system.

4.5.3.1 Types of Radiographic Waste

Radiographic waste consists of used X-ray films, spent fixer, spent developer, rinse water and chemical vapors. The wastes are considered as hazardous wastes depending on their characteristics as the followings.

- Fixer (contain silver, D001).
- Used X-ray film (contain silver, D001).
- Used X-ray films and spent fixer are considered as hazardous wastes due to their high silver contents.
- Unused developer can be classified as hazardous because when pH is higher 12.5.

4.5.3.2 Lists of Management and Disposal Options for Spent Photographic Solution and Used Films from Waste Generators to Waste Processors

1) **Safe Handling**

- Store the waste properly.
- Minimize spills and leaks.
- Used the "first-in, first-out" practice to reduce the possibility of exceeding a shelf life of products.
- Pay careful attention to the storage specifications of photosensitive films and papers.
- Should handle the wastes separately from other wastes.
- The fixer should not be mixed with the spent developer.
- The fixer should be collected in a closed plastic container and labeled the container "Hazardous Waste - Used Fixer" and the beginning date when the waste is first added to the container.
- When enough spent fixer has been stored, it should be picked up by a waste dealer or a waste processor.
- The spent developer should be handled with care because it is still very caustic.

2) **Management Options**

Developer can be discharged into a sanitary system; however, it can not be drained to a septic system because it is harmful bacteria in the system. Because the silver content in both spent fixer and used film can be recycled, waste generators

should handle these wastes separately from other wastes. Assuring that the waste dealers and the waste processors are actually recovering the silver, not merely dumping the wastes, and they are familiar with existing laws and regulations.

Of importance is the selection of a radiographic waste management company because the liability of the waste generator should not end when the waste is evacuated from the hospital facility. Guidelines have been created for choosing a company for the off-site disposal of radiographic waste. For example, the recyclers have to apply for an operating permit from the MOI. In addition, they have to treat the wastes generated from the recycling process prior to releasing it into the environment.

4.5.3.3 Manifest System for Radiographic Waste

A manifest system for radiographic waste is needed to control and monitor the waste. A manifest paper is a management tool to keep track on the silver-contaminated hazardous waste during transportation. Hazardous wastes may not be shipped off-site without a manifest and each manifest serves as a legal document. In general, this manifest does not cover the waste generated in hospitals. The waste regulators should establish linkages with each other to jointly and uniformly monitor the waste.

A single manifest typically consists of 6 copies, each designated for specific destinations. This distribution of copies ensures that all parties involved (i.e., the hospital as the waste generator, the waste dealer, the waste processor, and the waste regulator) receive identical copies confirming the proper transport and disposition of the hazardous waste. The flow of material and the manifest is shown in **Figure 4-15** and can be explained as followed.

The hospital, as the waste generator, keeps Copy 3 (to be rechecked with the manifest Copy 6 after the wastes are delivered) and sends Copy 2 to its regulator. The waste transporter (or dealer) carries Copy 1, Copy 4, Copy 5, and Copy 6 along with the shipment. Upon arrival at the treatment, storage, and disposal facilities (TSDF), the transporter retains Copy 4 and submits Copy 1, Copy 5, and Copy 6 to the waste processor (or recycler). The waste processor keeps Copy 5 and submits Copy 6 to the waste generator (hospital) and Copy 1 to the waste regulator.

With the manifest system, the waste regulator would then be able to verify the amount of waste generated by the hospitals and the waste processors by manifest Copy 2 and Copy 6. The waste regulators (if more than 1) should create the linkage among them in order to monitor the waste flow together. Moreover, the waste transporter and the waste processor should be legally registered under any of the existing laws

The uniform hazardous waste manifest is shown in Appendix D. The uniform divided into 3 sections, which are completed by the waste generator, the waste transporter, and the waste processor. In the first section (the waste generator section), information about the name of waste transporter, the name of waste processor, and the quantity and description of the waste are required. In the second section (the waste transporter section), the name of transporter and the details about the vehicle are necessary. The last section, (the waste processor section) signs and fills in the amount and type of waste to confirm that the reception is correct.

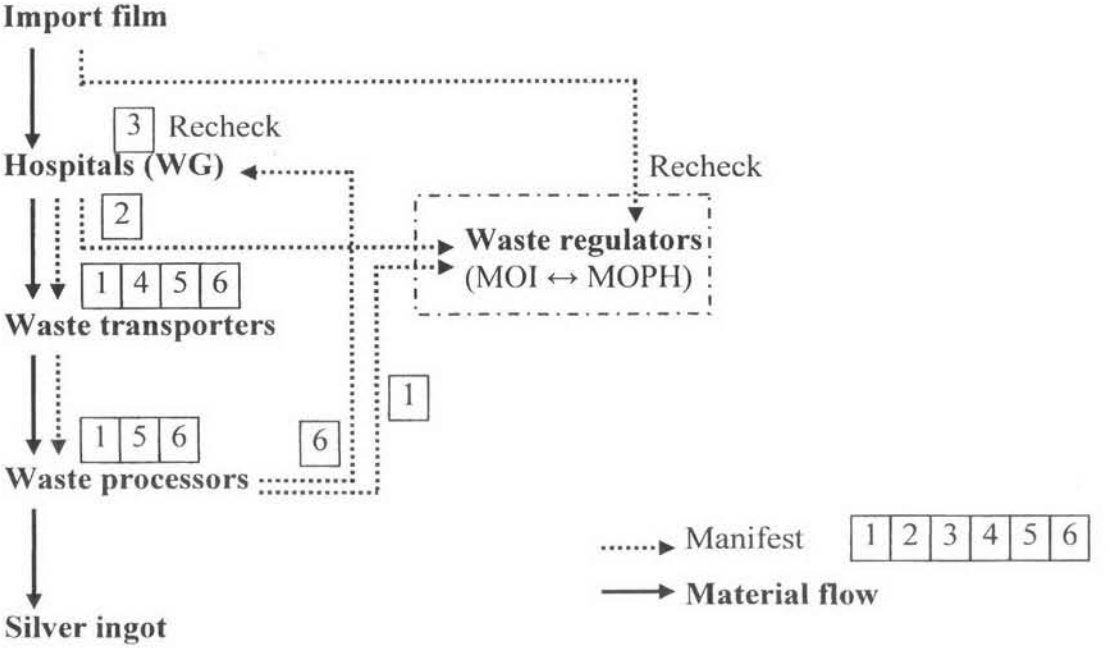


Figure 4-15 The use of a manifest to track hospital radiographic waste flow.

4.5.3.4 Name Lists of Waste Dealers and Waste Processors in Thailand

Registrations of waste dealers and waste processors should be required within the regulatory bodies. Fundamental information, such as the dealer's name, address, silver recycling method and waste treatment process, should be publicized in order to facilitate and to normalize the selection waste dealers. Only a dealer associated with a licensed silver recycler should be allowed to enter the bidding process of the waste generator.

The waste regulators should use the Hospital Accreditation (HA) standard as an incentive tool to help with the control of radiographic waste by adopting the fact sheet created in this study as a guideline for radiographic waste management. The HA certification system plays a key role in the improvement of hospital quality by increasing both its efficiency and competitiveness. Waste management is mentioned as one aspect of this standard; yet, its specifications have not been set up.

4.6 Summary

Radiographic waste management in Thailand involved with a number of parties: the waste generators, the waste dealers, the waste processors, and the waste regulators. At present, inadequate regulatory attention has been paid on the management of radiographic waste. A material flow analysis was used for investigating the amount of silver loss to the environment. It was found that a considerable amount of silver was released into the environment. The discharge of pollutants mostly came from the small waste processors; those were not registered or licensed by any authorities. These "house" factories were exempt from environmental rules and regulations. Concrete rules for the waste processors have yet to be formulated. The proposed fact sheet for the management radiographic waste includes necessary measures to prevent radiographic waste from contributing to environmental deterioration.