The Costs of Industrial Water Pollution on Rice Production in Vietnam

Huynh Viet Khai

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Can Tho industrial parks pollute environment

Can Tho City now has eight industrial parks covering more than 2,300ha but none of them have adequate wastewater treatment systems.

An inspection of 26 factories at the Tra Noc 1 and Tra Noc 2 Industrial Parks in Can Tho by members of the National Assembly's Standing Committee on Monday found that only 11 factories had wastewater treatment facilities that meet required standards. Three businesses were discovered seriously polluting the environment.

The inspection team was headed by Nguyen Duc Kien, National Assembly vice chairman.

Nguoi Lao Dong (The Labourer)

Source: Viet Nam News (May 18, 2011)

Người lao động

C.T GROUP
Nhà phát triển Đô thị toàn diện

Thứ 6, 27/5/2011 02:59

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8 KCN ở Cần Thơ chưa có hệ thống xử lý nước thải tập trung

Thứ Hai, 16/05/2011 22:56

(NLĐ) - Phó Chủ tịch Quốc hội Nguyễn Đức Kiên ngày 16-5 đã dẫn đầu đoàn giám sát của Ủy ban Thường vụ Quốc hội đến TP Cần Thơ khảo sát việc thực hiện chính sách pháp luật về môi trường tại các KCN, làng nghề trên địa bàn TP.

Hiện nay, TP Cần Thơ có 8 KCN tập trung với tổng diện tích hơn 2.300 ha nhưng chưa có hệ thống xử lý nước thải tập trung. Cụ thể, KCN Trà Nóc 1 và 2 có 34 doanh nghiệp (DN) phát sinh nước thải. Tuy nhiên vừa qua, kết quả kiểm tra 26 DN, chỉ có 11 đơn vị xử lý nước thải đạt quy chuẩn. Số DN còn lại không đạt quy chuẩn, trong đó có 3 đơn vị gây ô nhiễm môi trường nghiêm trọng. Phó Chủ tịch Quốc hội Nguyễn Đức Kiên đề nghị TP Cần Thơ tiếp tục đẩy mạnh đầu tư cơ sở vật chất, khắc phục tình trạng ô nhiễm môi trường ở các KCN…

C.Linh

Source: Nguoilao dong (May 16, 2011)

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Huynh Viet Khai

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES AND FIGURES

THE COSTS OF WATER POLLUTION ON RICE PRODUCTION IN VIETNAM

Huynh Viet Khai

EXECUTIVE SUMMARY

The study surveyed rice farmers in two areas with the assumptions of the same natural condition and social characteristics. One is considered as the polluted area near and directly receiving wastewater from the industrial parks, while the other is assumed to be the non-polluted area far from and having no effect of industrial pollutants. The productivity loss of rice production caused by water pollution was estimated by the difference in rice yield between the two regions. The similar calculation was applied for cost increase and profit loss for using wastewater irrigation. The results showed that the yield loss of rice was about 0.67 tons per hectare per crop, VND 0.97 million for cost increase and totally 26 percent of profit loss due to water pollution.Moreover, the study also estimated that total cost increase of the whole interviewed households in the polluted area was about VND 144 million and approximately VND 474 million per crop for their total net economic loss because of water pollution.

1. INTRODUCTION

1.1. Description of the Problem

Vietnam has achieved the average GDP growth rate of 6.71 per year. The industrial sector has mainly contributed economic development in Vietnam, with annual growth of 12 percent during the period of 200-2009. In line with its industrialization and modernization policies, Vietnam has rapidly changed economic structure from agriculture base to industrial economy. The industrial and construction sector only contributed 26 percent of national GDP in 1986, but it rapidly increases to 40.3 percent in 2009.

Economic development has brought many benefits to Vietnam. Income, public transportation and, in general, quality of life have gradually been improved while the percentage of people below the poverty threshold has been decreased. However, there have also been many negative consequences of rapid industrialization, particularly on agriculture and ecosystem health, because of the exploitation of natural resources and pollution.

The two biggest cities in Vietnam, Hanoi and Ho Chi Minh City, have been ranked as the worst cities in Asia for dust pollution. Within Vietnam, Ho Chi Minh City, the largest city, is at the top of the national pollution list(The World Bank 2008). This pollutionin the air, water and land is released by various large industries. For instance, footwear manufacturing releases 11% of the air pollution load, 10% of the land pollution load and 6% of the water pollution load, while the plastic products manufacturing industry produces 10%, 13% and 9% of the air, land and water pollution load, respectively. The main pollution sources do not necessarily come from the large industries. The cement industry, which only has 12 factories and employs 0.5% of the provincial workforces, releases 24% of the air pollution load.Similarly, the 160 paper factories employ only 0.8% of the provincial workers but contribute 14% of the water pollution load.

Since almost all industrial zones have not installed wastewater treatment systems in Vietnam,the existence of industrial wastewater contamination appears almost everywhere[1].Wastewater from thousands of industrial facilities in 30 industrial areas and from small factories and businesses in the basin is the main source of pollution in the Dong Nairiver of Ho Chi Minh City[2]. The untreated wastewater contaminating oil from Hai Au concrete factory has been released directly into paddy fields approximately200m^3/day and 1,500 m^3/day forPhuoc Long textile firm. However, it is difficult to know the actual damage and loss due to the contamination of untreated wastewater from industrial activities in Vietnam(Quang 2001).

There has been some research in recent years on industrial pollution in Vietnam. Thong and Ngoc(2004) presented a descriptive analysis of data collected from 32 industrial estates in southern Vietnam to determine the factors affecting investment on wastewater treatment plants. They found that water pollution was a serious problem in the big industrial

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[1]According to the Department of Science, Technology, and Environment of TayNinh.
[2]The speech of Dr. Trinh Le, the Institute of Tropical Technologyand Environmental Protection.

estates of Ho Chi Minh City, Binh Duong, Dong Nai and Ba Ria-Vung Tau Provinces, and that financial constraints and lack of space were the main reasons why many small and medium-sized enterprises did not invest in wastewater treatment systems. Hung *et al.*(2008) studied the effects of trade liberalization on the environment, using data from the Viet Enterprise Survey of 2002 and the World Bank's Industrial Pollution Projection System. They found that trade liberalization led to greater pollution and environmental degradation but that the Vietnamese people have gradually recognized the importance of environmental protection.

1.2. Literature Review

There have been a number of empirical agricultural studies concerning environmental problems, such as soil degradation, wind and water erosion; however, few have specifically examined the impact of industrial pollution. Bai(1988)conducted field experiments in wheat lands irrigated with wastewater from the Liangshui River, the Tonghui River and the Wanquan River. He reported that wastewater irrigation caused a reduction in wheat yield by 8–17.1%. Similar studies in the Geobeidian area of the Tonghui River and the Yizhuang area of the Lianghe River reported that yields of wheat and rice cultivated in unpolluted soils in the sewage-irrigated area decrease by about 10% of the yields obtained in clean water-irrigated areas. In the sewage-irrigated area with polluted soils, yields of wheat and rice grown reduce by 40.6% and 39% of those in clean irrigation areas.

Chang *et al.*(2001) analyzed the impact of industrial pollution on agriculture, human health and industrial activities in Chongqing. To determine the effect of sewage-irrigation, they proposed expressing yield reductions as a function of the comprehensive water pollution index. Using this approach, reductions in yield due to sewage irrigation were about 10% for wheat and 30% for rice and vegetables.

To evaluate the effects of polluted water irrigation, Lindhjem(2007) compared crop quality and quantity between a wastewater-irrigated area and a clean water-irrigated area. The total loss of corn and wheat production was estimated to be RMB 360 per mu, of which RMB 285 was caused by reduction in quantity, and RMB 75 was the reduction in quality. This paper also cites the study of Song (2004) that used dose-response functions to estimate the reductions in quantity and quality of crops from polluted water irrigation. Water pollution decreased rice production by 20% and quality by about 4%.

A study by The World Bank (2007) also used dose-response functions to calculate the economic losses from crop damage caused by water pollution, in terms of both reductions in crop quantity and quality (excess pollutant levels and substandard nutritional value). The economic cost of wastewater irrigation in China was estimated to be about 7 billion RMB annually for the four major crops (wheat, corn, rice, and vegetables).

Reddy and Behera(2006) evaluated the impact of water pollution on rural communities in India, in terms of agricultural production, human heath, and livestock, using the effects on production, replacement costs and human capital approaches. The study estimated that the total loss per household per annum due to water pollution was $282.5, of which $213.2 was from agriculture, $16.3 from livestock and $53 from human health.

1.3. Research Objectives

Agricultural effects of using wastewater irrigation include yield reduction, low quality crops, and even crops that fail to meet allowable pollution level standards. There are also wider implications for the agroecosystem, such as soil pollution leading to destruction of the soil structure and changes in the soil microbial community. Recovery is a very slow and difficult process once the land has been degraded (The World Bank 2007). For simplicity, we do not include agroecosystem degradation and instead focus on the economic loss of rice production arising from reduced crop quantity and quality, and increased input costs. The total economic losses of rice production in terms of reduced quantity, reduced quality and increase in input costsare estimated by comparing rice productivities, costs and profits between two selected areas, a polluted and non-polluted area. The differencesin rice productivity, cost and profit between these two areas are considered to reflect the economic damage, caused by industrial pollution, to rice production.

The specific objectives are:

- To evaluate the reduced quantityof rice production due to water pollution.
- To estimate the increaseinrice input costs due to water pollution.
- To determine the total loss of net economic return because of water pollution.
- To discuss some policy implications.

1.4. Scope of the Study

Because of a lack of information on the costs of pollution, national and local authorities in Vietnam have not paid much attention to pollution control measures. In this study, we estimate reduced quantity, cost increase and the profit loss of rice production due to water pollution. Our findings could help governmental bodies enforce existing water pollution regulations, for example, TCVN 5945 on water pollution standards or Decree 67 on wastewater pollution charges, also help recognize and understand the failure of some of the current environmental policies in Vietnam. Our study could also provide useful information to authorities, such as the Natural Resources and Environment, and industries to manage water pollution and data for cost-benefit analyses of treatment projects in the industrial zones of Vietnam.

2. EVALUATION CONCEPT AND EMPIRICAL MODEL

2.1. Concept for Economic Valuation of Water Pollution

The total economic loss of rice production includes three factors. First, a reduction in crop quantity assumes that water pollution decreases rice yield. Second, a reduction in rice quality, which is measured as price, assumes that the lower price of ricein a particular region could reflect reduced rice quality due to water pollution. Third, an increase in input costs assumes that farms may attempt to compensate for the possible productivity losses by implementing activities that are capable of offsetting this possible loss but are more costly to implement. The expectation of the profit loss is summarized by the following formula:

$$
\begin{aligned}
\pi_p &= \left(\bar{P}-\Delta P\right)\left(\bar{Q}-\Delta Q\right)-\left(\bar{C}+\Delta C\right)\\
&= \bar{P}\bar{Q}-\bar{P}\times\Delta Q-\Delta P\times\bar{Q}+\Delta P\times\Delta Q-\bar{C}-\Delta C\\
&= \left(\bar{P}\bar{Q}-\bar{C}\right)-\left(\bar{P}\times\Delta Q+\Delta P\times\bar{Q}+\Delta\bar{C}\right)+\Delta P\times\Delta Q \qquad (1)\\
&= \quad \pi_n \quad - \quad \text{Profit loss}
\end{aligned}
$$

$$
\begin{aligned}
\Rightarrow \text{Profit loss} &= \bar{P}\times\Delta Q \quad + \quad \Delta P\times\bar{Q} \quad + \quad \Delta\bar{C} \qquad (2)\\
&= \text{Quantity loss} + \text{Quality loss} + \text{Cost increase}
\end{aligned}
$$

where π_n and π_p are the rice profits in the non-polluted and polluted areas. Because $\Delta P\times\Delta Q$ is small compared with the other parts of the equation, it can be ignored and assumed to be 0.

However, it is complicated to estimate quality loss through the proxy of price because there are many other unobservable factors, excepting water pollution, which affect the price of rice. Thus, the study only calculates the three elements affected by water pollution:

- *Quantity loss:*Water pollution makes rice yield decrease. Production function approach will be used to estimate the loss of rice yield.

- *Cost increase:*Since farms may aim and indeed be able to compensate for the possible productivity losses by implementing activities which are capable of offsetting this possible loss but are more costly to implement. In such circumstances, because it is not productivity which will be impacted, but production costs, cost function approach as "replacement cost" methodology will be applied to assess the impacts of pollution in economic terms.

- *Profit loss:* It is defined as total loss of net economic return estimated by the comparison of profit functions between two selected areas (one is considered as the polluted, other is the non-polluted area). The difference in rice profits of two regions is considered as total loss of net economic return due to industrial pollution.

2.2. EmpiricalModel

2.2.1. Production Function Approach

The principle of production function approach is that industrial activities possibly have a negative impact on the outputs, cost and profit of producers through the effect of environment. Environment affects goods or services existing in the market through the value change of their outputs, for instance, the reduced value of fish caught because of river pollution. Production function approach is often used to estimate the effect of environment change on soil erosion, deforestation, fisheries, the impact of air and water pollution on agriculture and so on (Bateman *et al.* 2003)

A literature search on the production function approach in rice production Vietnam is conducted to make sure that relevant variables will be included in the farm survey questionnaire and to examine the suitability of existing rice production models for the research. There are a number of studies related to rice production in Vietnam. Kompas(2004) and Linh(2007) used stochastic production frontier to estimate technical efficiency of rice production in Vietnam. Do and Bennett (2007) used production function approach with flood duration and relative location of upstream and downstream farmers variables to estimate the cost of changing wetland management, representing the reduced income of rice production in the Mekong River Delta. The loss of rice productivity was estimated based on the differences in rice yield between upper and lower of the Tram Chim park dyke. The results showed that the rice productivity in the lowering of park dyke decreased 0.06 tons per hectare per annum, which led to the profit loss of VND 0.07 million per hectare per annum. These three studies used the Cobb-Douglas functional form of rice production function approach. This study uses a Translog functional form and does test for checking the existence of Cobb-Douglass. The model takes the basic form:

$$Y = f(L, K, I, Z, E, F) \qquad (3)$$

where Y is the rice yield of a farmer in the studied year (tones/ha), L is the number of labors for rice cultivation (man-days/ha), K is capital input (VND/ha), I is a vector of material inputs as seeds (kg/ha), fertilizers (kg/ha), herbicide (ml/ha) and pesticides (ml/ha), Z is a vector of social-economic characteristics of farmers, and E is a vector of farming conditions, and F is the relative location of farms (polluted site = 1, non-polluted site = 0)

Test for the existence of quantity loss due to water pollution:

$$\begin{aligned} &H_0: \text{Quantity loss} = 0 \text{ or Coef. of F} = 0 \\ &H_1: \text{Quantity loss} > 0 \text{ or Coef. of F} < 0 \end{aligned} \qquad (4)$$

The reduced yield of rice is defined as the difference in the average rice yieldbetween thenon-polluted and polluted site. It is estimated by following equation:

$$\Delta Y = f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, F = 0) - f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, F = 1) \qquad (5)$$

where ΔY is the average yield loss caused by water pollution (kg/ha); $\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}$ are the average of labor, capital input, material inputs, social-economic characteristics, and farming conditions, respectively.

As mentioned earlier, a translog functional form is used in the study. The production functional form in the polluted and non-polluted areas is written as followed (Tim and Battese 2005):

$$\begin{aligned} \ln(Y) = {} & \alpha_0 + \alpha_1 \ln(L) + \alpha_2 \ln(K) + \alpha_3 \ln(I) + \frac{1}{2}\alpha_{11}\left(\ln(L)\right)^2 + \alpha_{12}\ln(L)\ln(K) + \alpha_{13}\ln(L)\ln(I) + \\ & + \frac{1}{2}\alpha_{22}\left(\ln(K)\right)^2 + \alpha_{23}\ln(K)\ln(I) + \frac{1}{2}\alpha_{33}\left(\ln(I)\right)^2 + \sum_{k=1}^{5}\beta_k Z_k + \sum_{h=1}^{4}\delta_h E_h + \gamma F \end{aligned} \quad (6)$$

where Y, L, K, I, F are the same as in the above equations and Z_1, Z_2, Z_3, Z_4 are the variables of the gender (1 = male, 0 = female), the age (years), the number of school year (years), attending trainings (1 = Yes, 0 = No) of rice households, and E_1, E_2, E_3, E_4 are the variables of serious diseases happening during the study year (1 = Yes, 0 = No), rice monoculture (1 = yes, 0 = No), soil quality (1 = fertile soil, 0 = other soils), off-farm income ratio.

Some restrictions are used to check the constant returns to scale:

$$\begin{aligned} &\alpha_1 + \alpha_2 + \alpha_3 = 1 \\ &\alpha_{11} + \alpha_{12} + \alpha_{13} = 0 \\ &\alpha_{12} + \alpha_{22} + \alpha_{23} = 0 \\ &\alpha_{13} + \alpha_{23} + \alpha_{33} = 0 \end{aligned} \quad (7)$$

Then, the following restriction is applied to test the existence of Cobb-Douglass function:

$$\alpha_{11} = \alpha_{12} = \alpha_{13} = \alpha_{22} = \alpha_{23} = \alpha_{33} = 0 \quad (8)$$

2.2.2.Replacement Cost (RC)

Replacement cost approach is defined as payment for restoring original environment (unpolluted state) if it has already been damaged. The costs of moving away from the polluted area suffered by the victims of environmental damage or actual spending on safeguards against environmental risks are called replacement costs (Bateman *et al.* 2003; Winpenny 1991). In the study written by Reddy and Behera(2006), the replacement cost method is used to estimate the damage costs of pump sets due to water pollution. In this study, farmers in the polluted areas might spend more input costs for the compensation of rice productivity loss because they directly use the polluted water for irrigation. Thus, it is assumed that the costs of farmers in polluted areas are more than those in the non-polluted areas. In this case, the replacement cost is estimated by using the cost function approach. The basic form of cost function is given by:

$$C = C(W_s, W_h, W_f, W_p, Y, Z, E, F) \quad (9)$$

where C is the total cost of a farmer (VND/ha), W_s is the price of seed (VND/kg), W_h is the price of herbicide (VND/100ml), W_f is the price of fertilizers (VND/kg), W_p is the price of pesticides (VND/100ml), Y is the rice yield of a farmer in the studied year (tones/ha), Z is a vector of social-economic characteristics of farmers, and E is a vector of farming conditions, F is the relative location of farms (polluted site = 1, non-polluted site = 0)

Test for the existence of cost increase due to water pollution:

$$\begin{aligned} &H_0: \text{Cost increase} = 0 \text{ or Coef. of F} = 0 \\ &H_1: \text{Cost increase} > 0 \text{ or Coef. of F} > 0 \end{aligned} \quad (10)$$

The increase in input costs is defined as the difference of the average costbetween heavily polluted and less polluted areas. It is estimated by following equation:

$$\Delta C = C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E}, F = 1) - C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E}, F = 0) \quad (11)$$

whereΔC is the increase of the average cost per ha because of water pollution (VND/ha); $\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E}$ are the average price of seed, herbicide, fertilizer, pesticides, social-economic characteristics, and farming conditions, respectively.

The Cobb-Douglas formal function is applied to estimate the cost function in the study (Tim and Battese 2005):

$$\ln(C) = \varphi_0 + \varphi_1 \ln(W_s) + \varphi_2 \ln(W_h) + \varphi_3 \ln(W_f) + \varphi_4 \ln(W_p) + \varphi_5 \ln(Y) + \sum_{k=1}^{3} \beta_k Z_k + \sum_{h=1}^{3} \delta_h E_h + \gamma F \quad (12)$$

where C, W_s, W_h, W_f,W_p, F are the same as in the above equation and Z_1, Z_2, Z_3, are , the age (years), the number of school year (years), attending trainings (1 = Yes, 0 = No) of rice households, and E_1, E_2, E_3, are serious diseases happening during the year (1 = Yes, 0 = No), rice monoculture (1 = yes, 0 = No), soil quality (1 = fertile soil, 0 = other soils) respectively.

2.2.3.Profit FunctionApproach

Net economic return is defined as revenues from rice minus the cost of producing rice. It will be identified by profit function approach. The profit loss is estimated by the following basic profit function:

$$\pi^* = \pi\left(W^*, C, Z, E, F\right) \quad (13)$$

where π^* is normalized profit defined as gross revenue minus variable cost divided by farm-specific output price, W^* is a vector of variable input prices divided by output price, C is a vector of fixed factors of the farm, Z is a vector of social-economic characteristics of farmers, E is a vector of farming conditions, F is the relative location of farms (polluted site = 1, non-polluted site = 0).

Hypotheses for the existence of profit loss due to water pollution are:

$$H_0 : \pi_n = \pi_p \text{ or Profit Loss = 0 or Coef. of F = 0} \quad (14)$$
$$H_1 : \pi_n > \pi_p \text{ or Profit Loss > 0 or Coef. of F < 0}$$

The profit loss due to water pollution is defined by the difference in profit between the polluted and non-polluted areas. It is estimated by the equation:

$$\Delta\pi^* = \pi\left(\bar{W}^*, \bar{C}, \bar{Z}, \bar{E}, F = 0\right) - \pi\left(\bar{W}^*, \bar{C}, \bar{Z}, \bar{E}, F = 1\right) \quad (15)$$

where$\Delta\pi^*$is Profit loss in 1000 VND/ha. $\bar{W}^*, \bar{C}, \bar{Z}, \bar{E}$ are the average prices of inputs, the average of the fixed factors, the social-economic characteristics of farmers, the farming conditions, respectively.

We use the translog profit functional form. The formula is given as (Rahman 2002; Surjit and Carlos 1981)

$$\ln\pi^* = \alpha_0 + \sum_{j=1}^{4}\alpha_j \ln W_j^* + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4}\tau_{jk}\ln W_j^* \ln W_k^* + \sum_{j=1}^{4}\sum_{l=1}^{6}\phi_{jl}\ln W_j^* \ln C_l +$$
$$+\sum_{l=1}^{6}\beta_l \ln C_l + \frac{1}{2}\sum_{l=1}^{6}\sum_{t=1}^{6}\varphi_{lt}\ln C_l \ln C_t + \sum_{m=1}^{3}\varpi_m Z_m + \sum_{n=1}^{4}\eta_n E_n + \gamma F \quad (16)$$

where π^* is the restricted profit (total revenue minus total cost of variable inputs) normalized by price of output (P); W_j^* is the price of the jth input (W_j) normalized by the output price (P); j is the price of seed (1), the price of herbicides (2), the price of fertilizer (3), the price of pesticide (4); C_l is the quantity of fixed input, where l is total amount of seed used (1), total amount of herbicides used (2), total amount of fertilizer used (3), total amount of pesticides used (4), the number of man-days for rice production (5), the money of machines and services at all stages of rice production (6); Z_1, Z_2, Z_3 are the age (years), the number of school year (years), and attendance at training sessions (1 = Yes, 0 = No) of rice households, respectively; and E_1, E_2, E_3, E_4 are the variables of serious disease incidence happening during the study year (1 = Yes, 0 = No), rice monoculture (1 = Yes, 0 = No), soil quality (1 = fertile soil, 0 = other soils), and off-farm income ratio, respectively.

Then, the following restriction is applied to test the existence of the Cobb-Douglass function:

$$\tau_{jk} = \phi_{jl} = \varphi_{lt} = 0 \quad (17)$$

3. STUDY SITE AND DATA DESCRIPTION

3.1. Study Site

In the Mekong River Delta, there are approximately 33 industrial parks, which constitute 9.5% of the total industrial parks of the country. Almost all of these 33 parks have no wastewater treatment system. The industrial parks in Can Tho city have released the biggest pollution loads, and the province is ranked in the top 10 most polluted provinces in Vietnam (Table 1). Can Tho is also one of the biggest rice producers in the Mekong River Delta. Because of these reasons, Can Tho was selected as the study site.

Table 1. Top 10 most polluted provinces in Vietnam

Province	Air index	Land index	Water index	Overall
Ho Chi Minh city	1	1	1	1
Hanoi	5	2	2	2
Hai Phong	2	6	4	3
Binh Duong	6	3	3	4
Dong Nai	4	4	5	5
Thai Nguyen	3	5	7	6
PhuTho	7	7	6	7
Da Nang	10	9	8	8
Ba RiaVung Tau	9	8	10	9
Can Tho	8	10	9	10

Note: The pollution loads released to air, land and water were estimated for all 64 provinces in Vietnam, and then pollution indexes were calculated and rankings were made.

Source: ICEM, 2007

There are six industrial parks in Can Tho (Table 6.2), which mainly comprise agricultural and fishery processing industries, clothes and consumer goods manufacturing industries. Almost none of the industrial zones and industrial corporations located near human residences have installed wastewater treatment systems. There has been little management of toxic waste or water pollution by local authorities and business. TraNoc 1 (built in 1995) and TraNoc 2 (built in 1999) industrial zones have only recently been acknowledged by the Department of Resources and Environment while Thot Not has been considered by Can Tho authorities to evaluate the impact of environmental pollution{Resource and Environment department of Can Tho city, 2008 40 /id}. As a consequence, TraNoc 1 and 2 have released large volumes (1000s m^3) of various waste products directly into the river (Tuyen 2010).

Table 2. The industrial zones in Can Tho city

Zones	Size (ha)	Main activities	Water treatments
TraNoc 1	135	Processing, electron, clothes	No [a]
TraNoc 2	165	Machinery	No [a]
Hung Phu 1	262	Harbor, Store	No
Hung Phu 2	212	Machinery	No
Hong Bang	38.2	Consumer goods	No [a]
Thot Not	150	Processing, clothes, shoes	No [a]

a The available decision and acceptation of local authorities to evaluate the impact of environmental pollution.

Source: Resource and Environment Department of Can Tho City (2008)

3.2. Data Collection

The study region covers the area within and around TraNoc 1 and TraNoc 2 industrial zones, which were two of the most polluters in Can Tho. People living in this area have suffered various costs from the pollution: reduced crop yields, the use of cattle and agricultural equipment such as pump sets, contamination of drinking water, and increased incidence of human diseases and deaths directly and indirectly caused by water pollution.

3.2.1. Secondary Data

Secondary data related to agriculture productionand the water quality in or near the industrial zones was collected from environmental science papers, related studies and reports of Resource and Environmental department of Can Tho City, People's committee of PhuocThoi and ThoiAn district, O Mon, Can Tho, and the Can Tho Environmental Monitoring Station.

3.2.2. Primary Data

Primary data was collected through focus through focus group discussions and a household survey.

3.2.2.1. Focus Group Discussions (FGDs)

FGDs were mainly used to get the information about environmental quality, agriculture situation and ask for recommendations to select survey areas. Which rice producing areas have been much affected by water pollution? Which rice producing regions have that the same social and natural conditions with selected polluted areas are not polluted by industrial water pollution? Two FGDs, in which each group consisted of about five people (two local authorities and three local farmers), were organized.

3.2.2.2. Household Survey

Farmers were randomly selected for interview from two areas (PhuocThoi and ThoiAn) with similar social and natural conditions (e.g. the same social and farming culture, ethnicity, type of soil). The selection of the polluted and non-polluted area was based on their distance from industrial zones, and on the recommendation or suggestion of local authorities and farmers.Some of the villages in PhuocThoi are heavily polluted by wastewater from the TraNoc 1 and 2 industrial zones. The villages in ThoiAn are further away from the industrial zones than PhuocThoi and deemed to represent a non-polluted area (see Figure 1).

The group of fourteen interviewers and three local guide persons includes ten final year students, four staffs of School of Economics and Business Administration, Can ThoUniversity, one local authority from people's committee, and two local farmers.

The questionnaire composes four main parts. In the first and second parts, the personal and farming informationof householdsuch as address, age, gender, training and so on and the situation of environmental pollutionare interviewed. The inputs and output of rice production are collected in the three part and income from other activities obtained in the final section of questionnaire.*(See Appendix C)*

The time of household survey taking about 3 mouths from January to March 2010 is divided into two main periods. The first period is called as pilot-survey in January 2010. The aims of this interview are to check and then correct the questionnaire more clearly and concisely, and to help interviewers get used to and understand the content of questionnaire. After the interviewers are trained how to ask by using questionnaire, there are about 30 farmers interviewed in this period. The revised questionnaire is used in the second period from February to March 2010. In total, 364 rice farmers, consisting of 214 farmers in the polluted and 150 farmers in the non-polluted area, were interviewed in February and March 2010. Household data were collected on household level information related to production costs and income as well as the social and economic characteristics of the farmers, and their perceived damages and losses due to water pollution.

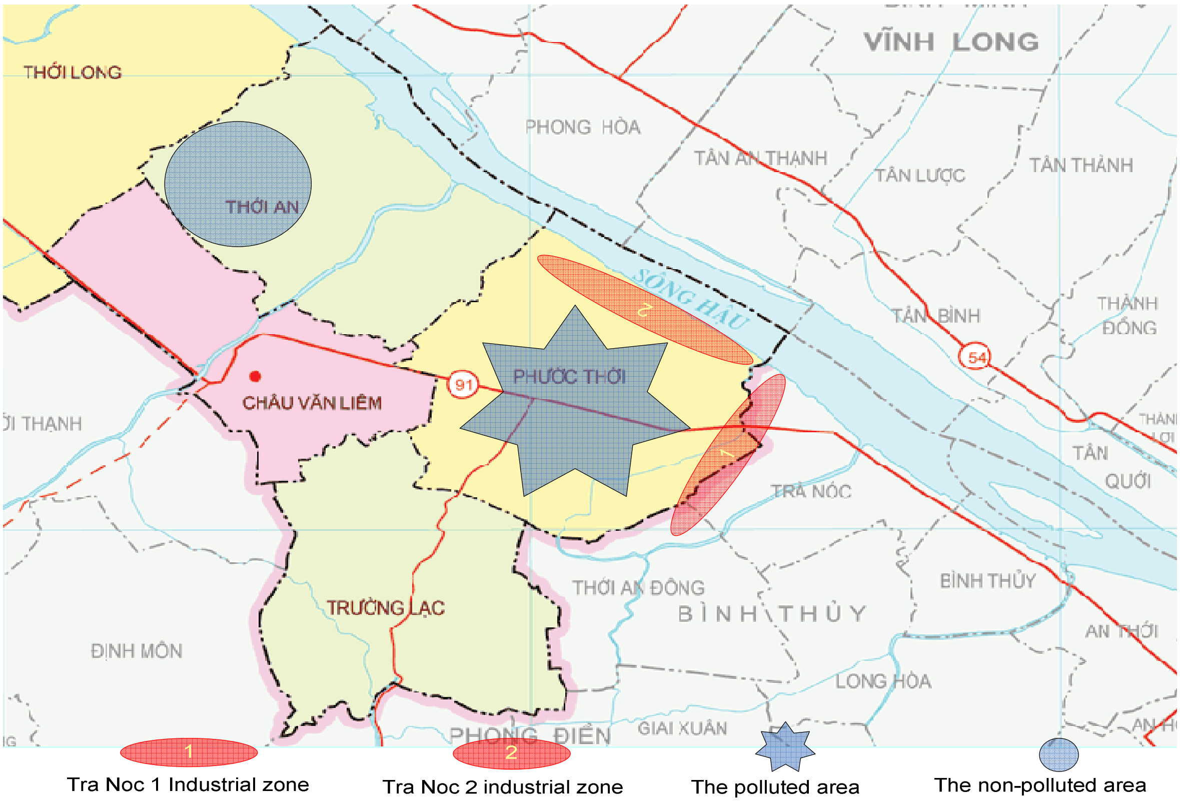

Figure 1: Map of the Study Site

Table 3 shows the water quality index of the polluted and non-polluted area. The concentrations of Total Suspended Solids (TSS) in the water refer to the concentrations of solid particles that can be trapped by a filter. This can be a problem because high concentrations of TSS can block sunlight from reaching submerged vegetation. This causes a reduction in the photosynthesis rate, and therefore less dissolved oxygen released into the water by plants. If bottom dwelling plants are not exposed to some light, the plants stop producing oxygen and die . Chemical Oxygen Demand (COD) is the amount of oxygen used during the oxidation of organic matter and inorganic chemicals such as ammonia nitrogen (NH3-N). High COD indicates a greater pollution load.

Table 3: Water quality of the polluted and non-polluted area

	TSS (mg/l)	COD (mg/l)	NH3-N (mg/l)
The polluted area (PhuocThoi) (1)			
- Sewer mouth	145	720	13.29
- Primary affected water source (2)	50	50	1.23
- Secondary affected water source (3)	60	48	0.63
The non-polluted area (Thoi An)(4)	22	5.1	0.16
Limitation value (TCVN5942,1995)			
- Class A (5)	20	10	0.05
- Class B (6)	80	35	1

Notes: (1) Measured on January 17th, 2007(Nga *et al.* 2008)

(2) The region receives wastewater directly from the industrial park.

(3) The region receives polluted water from the primary affected water source regions.

(4) Measured on January 27th, 2007(Lang *et al.* 2009)

(5) Values in Class A are from the surface water used for domestic water supply with appropriate treatments.

(6) Values in Class B are from the surface water used for purposes other than domestic water supply. Water quality criteria for aquatic life are specified in a separate index.

In the polluted area, the concentrations of TSS, COD and NH3-H in the sewer mouth, the primary affected water source and the secondary affected water source regions were mostly much higher than those of the standard water quality (see Table 3). This indicated that our selected pollution area site was heavily polluted. The concentrations of TSS, COD and NH3-N in the sewer mouth region were nearly 2-fold, over 20-fold and 13-fold higher than those of the standard water quality of class B, respectively.

Differences in the water quality index between the polluted and non-polluted area indicate that the water quality in the non-polluted area was much higher than that in the polluted area. However, the concentrations of TSS and NH3-N in the non-polluted were slightly higher than those of the Class A standard. This may be caused by non-point source pollutants, for instance, fertilizer, herbicide and pesticide released by agricultural activities in the region.

3.3. Overview of Rice Production and Social Characteristics of Rice Farmers

Table4. The characteristics of rice households in the study site

	Non-polluted area	Polluted area	Whole areas
Gender (%)	91	93	93
Age (years)	48.04	48.99	48.60
Education (years)	6.33	6.07	6.18
Number of member (person)	5.09	4.87	4.96
Training (%)	49	35	40
Experience (years)	28.27	28.87	28.63
Rice land (ha)	0.89	0.69	0.77

Source: Own estimates; data appendix available from authors.

Table 4 shows the overview of characteristics of rice farmers in the survey areas. The interviewed households are mainly male, accounted for 93 percent. They have the average age of 48 years old and 28 years in rice farming. A household with averagely 5 members in selected regions produces rice with small-scale of 0.77 ha on average. Only 40 percent of rice farmers averagely said that they have attended trainings provided by local authorities.

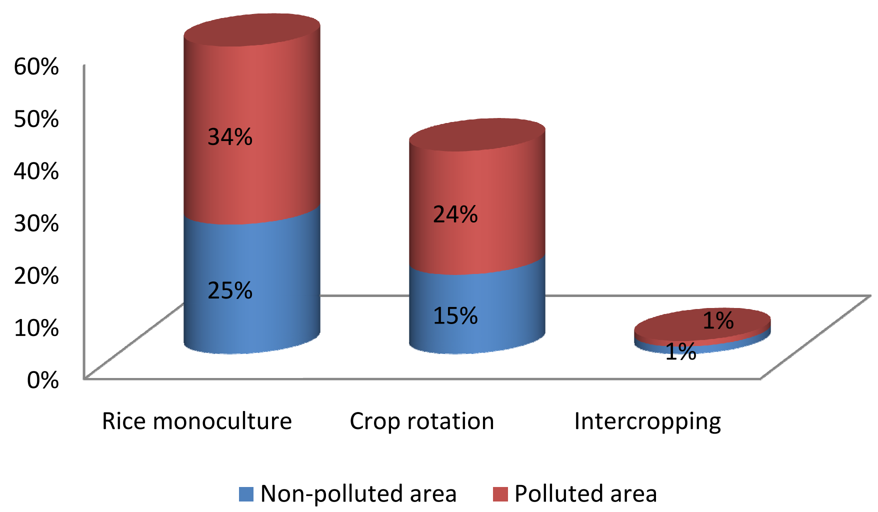

Figure 2. The models of rice production
Source: Own estimates; data appendix available from authors.

Figure 2 performs the agricultural practice of rice farmers in the study areas. Almost all farmers apply rice monoculture, accounted for 59 percent of total households (composed of 25 percent farmers in the non-polluted area and 34 percent in the polluted area). Some of them normally grow rice three crops per year (namely, Winter-Spring, Summer-Fall and Fall-Winter crop) or some only cultivates two rice crops per year (namely, Winter-Spring, Summer-Fall). Moreover, the study also reveals that there are about 39 percent of farmers in the sample who rotate rice with other crops or vegetables. They often produce two or one rice crops and one vegetable crop for rice rotation while farmers who apply intercropping model for rice cultivation are accounted for 2 percent in the sample.

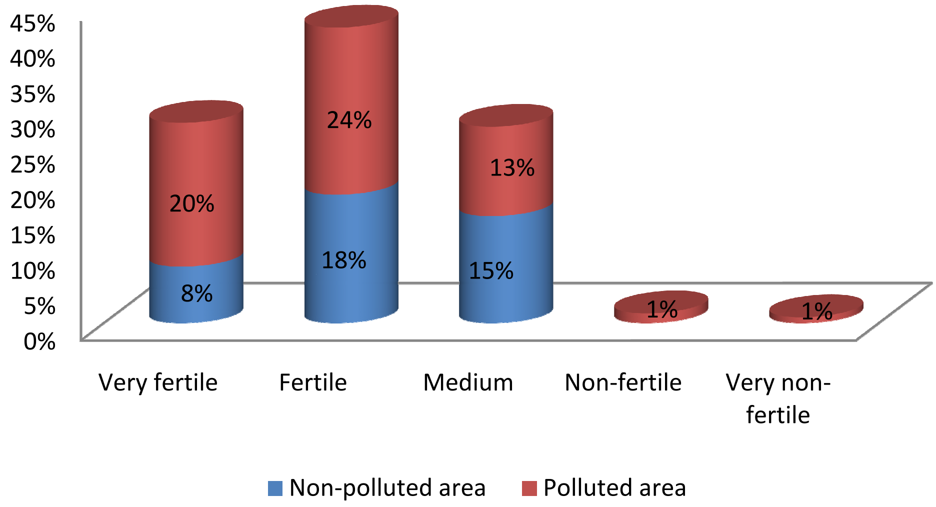

Figure 3. The soil quality of rice field in the study site

Source: Own estimates; data appendix available from authors.

Figure 3 shows that the farmers' evaluation on the quality of their rice land. The interesting results reveal that nearly 70 percent of them appraise their land fertile (composed by42 percent of fertile soil and 28 percent of very fertile soil). Possible explanation is that the study areas are located along Hau River that carries a lot of alluvial soil.

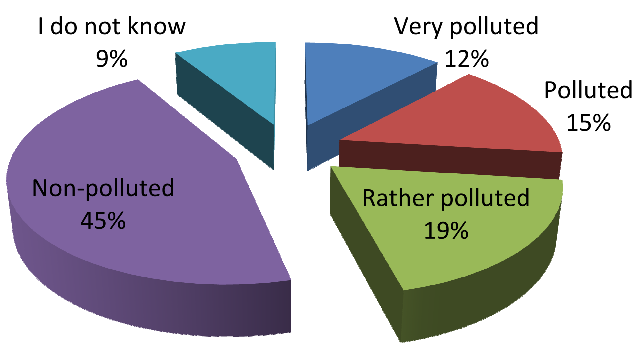

Figure 4.The perception of farmers in the polluted areas about the effect of water pollution on their land.

Source: Own estimates; data appendix available from authors.

Figure 4 shows that the recognition of farmers in the polluted area for the effect of water pollution on their rice land. Nearly 30 percent of farmers could recognize water pollution affecting their rice production, and around 19 percent of them said that water pollution has slightly impact on their rice areas while 45 percent of them could not recognize the troubles of their rice land caused by water pollution.

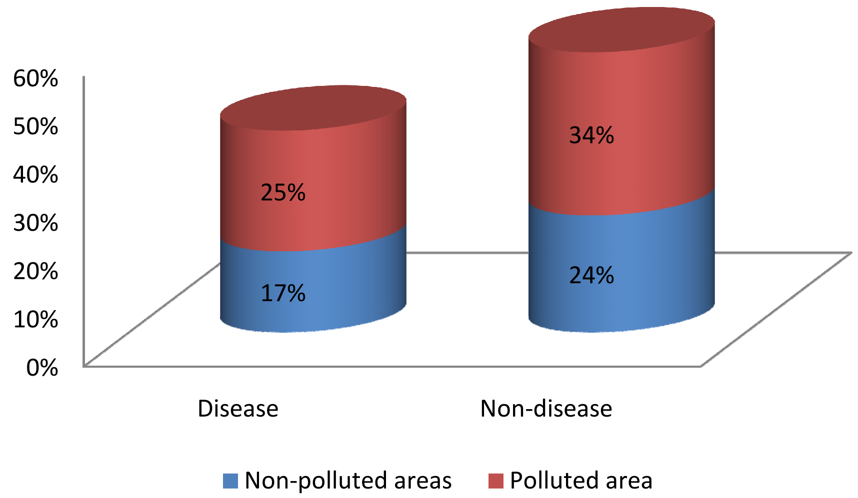

Figure 5. The situation of serious diseases happening during the study

Source: Own estimates; data appendix available from authors.

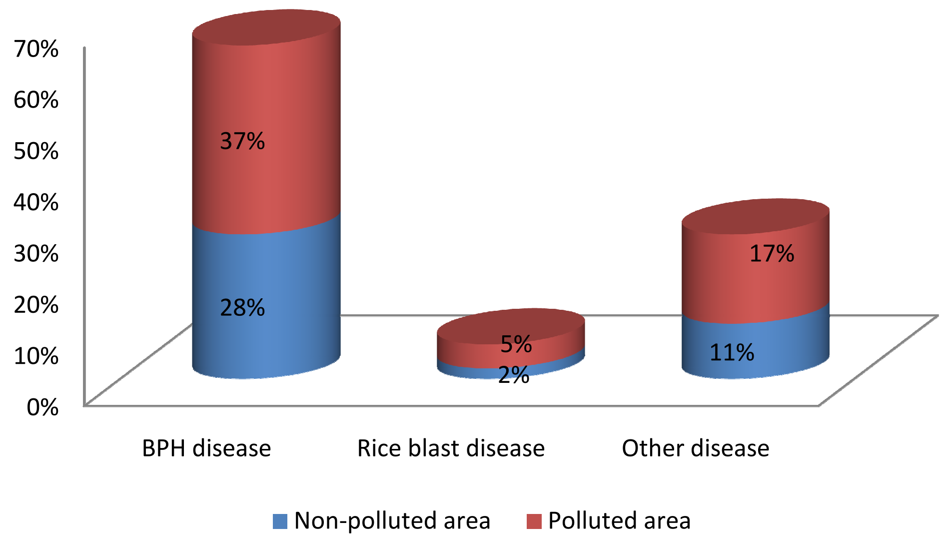

Figure 6. The kind of diseases happening in the rice production

Source: Own estimates; data appendix available from authors.

Figure 5 and 6 perform that the situation of serious diseases happening in the rice field before the study period. Farmers were interviewed that whether or not any serious disease for their rice cultivationoccur during the survey period? The results show there is over 40 percent of rice land happening diseases, of which, BPH disease is considered as one of the main problems that cause rice damage during the study period, dominated about 65 percent (Composed of 37 percent farmers in the polluted area and 28 percent in the non-polluted area).

Table 5. Description of variables used in rice production models

Variable	Description	Unit
Y	Total yield per hectare	Ton/hectare
P	Price of rice	Thousand VND/ton
C	Total cost	Thousand VND/hectare
π	Total profit	Thousand VND/hectare
C_s	Total amount of seed used	Kg/hectare
C_h	Total amount of herbicides used	Equivalent unit of 100 ml/hectare
C_f	Total amount of fertilizer used	Kg/hectare
C_p	Total amount of pesticide used	Equivalent unit of 100 ml/hectare
C_l	The number of man-days for rice production	day/hectare
C_c	The money of machines and services at all stages of rice production	Thousand VND/hectare
W_s	Price of seed	Thousand VND/kg
W_h	Price of herbicide	Thousand VND/100ml
W_f	Price of fertilizer	Thousand VND/kg
W_p	Price of pesticide	Thousand VND/100ml
Age	The age of respondents	Years
Education	The number of school year of respondents	Years
Training	Respondents attending trainings	1= Yes, 0 = No
Mono	Rice monoculture	1= Yes, 0 = No
Diseases	Diseases happening during the study year	1= Yes, 0 = No
Off-farm ratio	The ratio of off-farm income	
Soil	Soil quality	1 = fertile soil, 0 = other soils

Table 5 shows the descriptions of variables in rice production models. The volumes of herbicide and pesticide used have measurement units of equivalent units of 100 ml per hectare per crop, based on farmers' reports and experts' recommendations. This is because farmers use various types of herbicides and pesticides (mixed with water or as a powder), and sometimes mix them together, which means that it is difficult to estimate exact amounts.

Table 6. Descriptive Statistics of Rice Production per hectare per cropping

Variables	**Non-polluted area**	**Polluted area**	**t-ratio**
Y(Yield)	5.88	4.99	-7.31***
P(Price)	4,157.79	4,060.89	-3.06***
C(Total cost)	10,909.44	10,563.61	-0.84
π(Total profit)	13,623.91	9,759.35	-8.37***
C_s(Amount of seed)	224.41	206.42	-2.37**
C_h(Amount of herbicide)	10.43	11.70	1.33
C_f(Amount of fertilizer)	475.87	463.76	-0.53
C_p(Amount of pesticide)	77.26	70.23	-1.24
C_l(Number of man-days)	29.03	32.95	1.39
C_c(Money of machines and services)	3283.02	3436.20	1.06
W_s(Price of seed)	5.46	5.21	-1.34
W_h(Price of herbicide)	32.79	32.47	0.21
W_f(Price of fertilizer)	9.42	9.54	0.92
W_p(Price of pesticide)	24.86	21.70	-1.85*
Age	48.04	48.99	0.81
Education	6.33	6.07	-0.87
Training	0.49	0.35	-2.72***$^{\Psi}$
Mono	0.60	0.58	-0.39$^{\Psi}$
Diseases	0.40	0.42	-0.39$^{\Psi}$
Off-farm ratio	0.20	0.37	4.72***$^{\Psi}$
Soil	0.63	0.75	2.35**$^{\Psi}$

Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively
$^{\Psi}$ Z-ratio for two group test of proportions

Source: Own estimates; data appendix available from authors.

Table 6 shows the descriptive statistics of the main variables in the rice production model for the polluted and non-polluted areas. Although soil quality in the non-polluted area is significantly ($P < 0.05$) lower than that in the polluted area, rice productivity and profit in the non-polluted area is significantly ($P < 0.01$) higher than those in the polluted area. The price of rice in the polluted area was significantly ($P < 0.01$) lower than that in the non-polluted area. This indicates that water pollution may have reduced crop quality, and in turn its price. The difference in the off-farm income ratio between the two areas suggests that farmers are aware of the reduced profit from rice cultivation in polluted soil, and therefore have a tendency to find additional work in nearby industrial parks to supplement their income.

Other variables measured do not significantly differ between the two regions (Table 6), except the percentage of respondents attending training. The results also show that, on average, farmers were 48 years old, have had 6 years of education and 60 % of them grew rice in a monoculture.

4. ESTIMATED RESULTS

4.1. Impact of Water Pollution on Rice Productivity

Table 7. The OLS regression of rice production function

Variables	Coefficient	S.E.
ln*(Amount of seed)*	0.696	0.799
ln*(Amount of herbicide)*	-0.123	0.154
ln*(Amount of fertilizer)*	0.465	0.555
ln*(Amount of pesticide)*	-0.157	0.265
ln*(Amount of man-days)*	0.851**	0.333
ln*(Money of machines and service)*	0.572	0.439
½ ln*(Amount of seed)*^{2}	0.532***	0.196
½ ln*(Amount of herbicide)*^{2}	0.000	0.005
½ ln*(Amount of fertilizer)*^{2}	0.037	0.032
½ ln*(Amount of pesticide)*^{2}	-0.011	0.017
½ ln*(Number of man-days)*^{2}	0.059*	0.033
½ ln*(Money of machines and services)*^{2}	0.075	0.070

ln*(Amount of seed)*×ln*(Amount of herbicide)*	0.014	0.027
ln*(Amount of seed)*×ln*(Amount of fertilizer)*	-0.132	0.098
ln*(Amount of seed)*×ln*(Amount of pesticide)*	-0.057	0.052
ln*(Amount of seed)*×ln*(Number of man-days)*	-0.105*	0.058
ln*(Amount of seed)*×ln*(Money of machines and services)*	-0.216*	0.116
ln*(Amount of herbicide)*×ln*(Amount of fertilizer)*	-0.025	0.035
ln*(Amount of herbicide)*×ln*(Amount of pesticide)*	0.007	0.010
ln*(Amount of herbicide)*×ln*(Number of man-days)*	0.021	0.014
ln*(Amount of herbicide)*×ln*(Money of machines and services)*	0.008	0.023
ln*(Amount of fertilizer)*×ln*(Amount of pesticide)*	0.060	0.040
ln*(Amount of fertilizer)*×ln*(Number of man-days)*	-0.026	0.046
ln*(Amount of fertilizer)*×ln*(Money of machines and services)*	-0.022	0.084
ln*(Amount of pesticide)*×ln*(Number of man-days)*	-0.031	0.022
ln*(Amount of pesticide)*×ln*(Money of machines and services)*	0.029	0.042
ln*(Number of man-days)*×ln*(Money of machines and services)*	-0.023	0.040
Age	-0.002**	0.001
Education	0.004	0.003
Training	0.039**	0.019
Disease	-0.012	0.018
Mono	0.016	0.022
Soil	0.031	0.019
Off-farm ratio	-0.054*	0.028
Polluted (F)	-0.127***	0.019
Constant	-5.615**	2.482
R-square	0.64	
Included observation	364	

Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively

Source: Own estimates; data appendix available from authors.

Table 7 shows that the OLS result of rice production function in Translog form. The variables estimated in the model are statistically significant at 1 percent level. The estimated R-square is equal to 0.64, revealing the 64 percent change of rice yield possibly explained by independent variables in the model.

The study also examines the null hypothesis that there is a proportional output change when inputs in the model are varied or farms produce rice with constant returns to scale. The restricted least squares regression with the null hypothesis of constant returns to scale is estimated. The computed F statistic is 37.09 more than the critical value F (7, 327) of 3.58 at 0.1 percent level of significance [1)]. Thus, the null hypothesis is rejected and the study concluded that technology does not exhibit constant returns to scale.

The second test is applied to check the Cobb-Douglass formal existence of production function. With the null hypothesis of jointed parameters in (8) equal to 0, the restricted function is estimated. The computed F statistic of 1.94 is more than the critical F(21,327) of 1.91 at 1 percent level of significant[1)]. The null hypothesis is rejected and the Translog functional form is suitably applied for the data of rice production in the study.

The results show that there is no multicollinearity in the independent variables of production function because the correlations of these independent variables estimated by using the correlation matrix are less than 70 percent.The null hypothesis homoscedasticity is also acceptedby usingBreusch-Pagan test because the estimated LM of 49.72 is less than the critical $\chi^2_{36}$of 58.62 at the level of 1 percent[2)].

Table 7 shows that the coefficient of *Polluted* variable is significantly negative at 1 percent level, revealing that rice productivity in the polluted is lower than in the non-polluted area. The other variables of *Amount of man-days(C_l)*and *Training* are significantly positive. The result also indicates that more labor investments also make rice cultivation more productivity while short training courses such as 3-reduction and 3-increase, IMP program, guideline of applying new technologies and so on normally given by local extension services partly contribute an increase in rice yield.

Moreover, the negative coefficient of *Age* variable is statistically significant at 5 percent level. The older farmers the less productivity they obtain. Possible explanation is that farmers' age is averagely 48 years in the sample. At this age, decrease in health makes farmers cultivate rice less efficiently. In addition, the result shows the coefficient of off-farm income ratio variable is significantly negative at 5 percent level. Farmers who earn more off-farm income produce rice less productive. Through the farmers' survey, we finds out that recognizing rice production not profitable anymore, farmers in the polluted region have tendency to sell their rice lands for buildings or use rice lands for rent (farmers from other regions rent their lands). Local farmers try to find jobs in industrial parks that help them earn more compared to rice production. The study also discovers that water pollution makes farmers change the behavior of rice cultivation and crop intensification. Before their income mainly from rice production with three rice crops per year, now they do rice farming as part-time jobs, only grow one or two crops per year and harvest rice just enough for home consumption. These possibly are the suitable explanations for the negative impact of off-farm income on rice productivity.

The reduced productivity of rice is calculated based on findings from Table 7.After the equation (5) is used to eliminate the effects of other factors,the estimated yield in the non-polluted area is about 5.61 tons and around 4.94 tons for the polluted region. Then, the loss of rice yield due to polluted water irrigation is estimated by subtracting the yield in the polluted from yield in the non-polluted region (equation 5). Using this approach, the estimated result is about 0.67 tons per hectare per crop (5.61 tons – 4.94 tons).

4.2. Increase in Rice Production Cost Due to Water Pollution

Table 8. The OLS regression of rice cost function in the whole area

Variables	**Coefficient**	**Standard Error**
ln*(Price of seed)*	0.195***	0.049
ln*(Price of herbicide)*	0.021	0.025
ln*(Price of fertilizer)*	0.431***	0.078
ln*(Price of pesticide)*	0.007	0.024
ln*(Yield)*	0.918***	0.062
Age	0.002*	0.001
Education	-0.008	0.005
Training	-0.058**	0.029
Diseases	0.045	0.028
Rice monoculture	0.143***	0.030
Soil	-0.032	0.030
Polluted (F)	0.098***	0.030
Constant	6.140***	0.269
Statistic summary		
R-square	0.56	
Included observation	364	

Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively

Source: Own estimates; data appendix available from authors.

Table 8shows R^2 is equal to 0.56, revealing the variation of total rice costs of 56 percent is explained by independent variables in the model. The study also shows that the multicollinearity among the independent variables in cost function does not exist because the resultsestimated by correlation matrix approach show that there are no correlations in these independent variables higher than 70 percent. The result of Breusch-Pagan test performs that the estimated LM of 14.96 is less than the critical $\chi^2_{12}$of 26.22 at the level of 1 percent[2)], revealing the absence of heterscedasticity in the estimate of cost function.

The coefficient of *Polluted* variable is statistically significant positive at level of 1 percent, performing rice costs in the polluted region is higher than one in the non-polluted region. Moreover, farmers, who are older, manage their production cost more highly and less efficiently, performed by the positive effect of *Age* variable on total costs at 10 percent level. The significantly positive coefficient of *Rice monoculture* variable at 1 percent level performs that farmers with rice monoculture also spend more expenditure than other farmers with rice rotation or intercropping. Possible explanation is rice monoculture causing soil less fertile.

The same calculation with yield loss due to water pollution, cost increase affected by water pollution is estimated from Table 8 by using the statically significant variable of *Polluted* in the model.After the effect of other factors are eliminated by using the equation (11), total rice cost in the polluted area is estimated about VND 10.37 million per ha a crop while total cost in the non-polluted area is calculated around VND 9.4 per ha a crop. Cost increase because of water pollution can be estimated by subtracting total ricecost in the non-polluted area by that in the polluted area (equation 11). Applying this way, an increase in cost due to water pollution is calculated around VND 0.97 million.

4.3. Total Loss of Net Economic Return

Table 9 shows the coefficients from the ordinary least squares (OLS) regression of the rice profit model using the translog profit functional form (equation 16). The full model is statistically significant at the 1% level. The estimated R-square revealed that 50% of the variation in the rice profit can be explained by the model.

Table 9. The OLS regression of rice profit function

Variables	Coef.	S.E.
ln*(Normalized price of seed)*	-0.111	5.089
ln*(Normalized price of herbicide)*	1.211	2.260
ln*(Normalized price of fertilizer)*	-3.869	5.435
ln*(Normalized price of pesticide)*	-0.698	2.408
½ ln*(Normalized price of seed)*^{2}	0.322	0.471
½ ln*(Normalized price of herbicide)*^{2}	-0.019	0.134
½ ln*(Normalized price of fertilizer)*^{2}	-1.245**	0.625
½ ln*(Normalized price of pesticide)*^{2}	0.223	0.142
ln*(Normalized price of seed)*×ln*(Normalized price of herbicide)*	-0.017	0.180
ln*(Normalized price of seed)*×ln*(Normalized price of fertilizer)*	-0.257	0.510
ln*(Normalized price of seed)*×ln*(Normalized price of pesticide)*	-0.042	0.197
ln*(Normalized price of herbicide)*×ln*(Normalized price of fertilizer)*	0.231	0.253
ln*(Normalized price of herbicide)*×ln*(Normalized price of pesticide)*	0.030	0.105
ln*(Normalized price of fertilizer)*×ln*(Normalized price of pesticide)*	0.005	0.270
ln*(Normalized price of seed)*×ln*(Amount of seed)*	-0.648*	0.330

ln*(Normalized price of seed)*×ln*(Amount of herbicide)*	0.181	0.137
ln*(Normalized price of seed)*×ln*(Amount of fertilizer)*	0.586**	0.292
ln*(Normalized price of seed)*×ln*(Amount of pesticide)*	-0.165	0.172
ln*(Normalized price of seed)*×ln*(Amount of man-days)*	0.079	0.141
ln*(Normalized price of seed)*×ln*(Money of machines and service)*	0.029	0.364
ln*(Normalized price of herbicide)*×ln*(Amount of seed)*	-0.314	0.193
ln*(Normalized price of herbicide)*×ln*(Amount of herbicide)*	-0.064	0.081
ln*(Normalized price of herbicide)*×ln*(Amount of fertilizer)*	-0.124	0.147
ln*(Normalized price of herbicide)*×ln*(Amount of pesticide)*	0.087	0.098
ln*(Normalized price of herbicide)*×ln*(Amount of man-days)*	0.115	0.081
ln*(Normalized price of herbicide)*×ln*(Money of machines and service)*	0.244	0.150
ln*(Normalized price of herbicide)*×ln*(Amount of seed)*	0.533	0.528
ln*(Normalized price of herbicide)*×ln*(Amount of herbicide)*	-0.376*	0.205
ln*(Normalized price of fertilizer)*×ln*(Amount of fertilizer)*	-0.609	0.373
ln*(Normalized price of fertilizer)*×ln*(Amount of pesticide)*	-0.104	0.231
ln*(Normalized price of fertilizer)*×ln*(Amount of man-days)*	0.106	0.224
ln*(Normalized price of fertilizer)*×ln*(Money of machines and service)*	-0.529	0.419
ln*(Normalized price of pesticide)*×ln*(Amount of seed)*	0.025	0.205
ln*(Normalized price of pesticide)*×ln*(Amount of herbicide)*	-0.010	0.064
ln*(Normalized price of pesticide)*×ln*(Amount of fertilizer)*	-0.164	0.148
ln*(Normalized price of pesticide)*×ln*(Amount of pesticide)*	0.107	0.094
ln*(Normalized price of pesticide)*×ln*(Amount of man-days)*	-0.098	0.080
ln*(Normalized price of pesticide)*×ln*(Money of machines and service)*	0.162	0.176
ln*(Amount of seed)*	-3.393	4.697
ln*(Amount of herbicide)*	-0.540	1.584
ln*(Amount of fertilizer)*	3.341	3.373
ln*(Amount of pesticide)*	-2.241	1.936
ln*(Amount of man-days)*	2.890	1.917
ln*(Money of machines and service)*	1.432	3.872
½ ln*(Amount of seed)*^{2}	0.338	0.552
½ ln*(Amount of herbicide)*^{2}	0.012	0.065
½ ln*(Amount of fertilizer)*^{2}	-0.117	0.249
½ ln*(Amount of pesticide)*^{2}	0.013	0.074
½ ln*(Number of man-days)*^{2}	0.123	0.086
½ ln*(Money of machines and services)*^{2}	-0.107	0.207
ln*(Amount of seed)*×ln*(Amount of herbicide)*	-0.113	0.140
ln*(Amount of seed)*×ln*(Amount of fertilizer)*	0.500*	0.289

ln*(Amount of seed)*×ln*(Amount of pesticide)*	0.013	0.196
ln*(Amount of seed)*×ln*(Number of man-days)*	-0.250	0.160
ln*(Amount of seed)*×ln*(Money of machines and services)*	-0.149	0.308
ln*(Amount of herbicide)*×ln*(Amount of fertilizer)*	-0.130	0.109
ln*(Amount of herbicide)*×ln*(Amount of pesticide)*	0.054	0.058
ln*(Amount of herbicide)*×ln*(Number of man-days)*	0.148**	0.063
ln*(Amount of herbicide)*×ln*(Money of machines and services)*	0.012	0.115
ln*(Amount of fertilizer)*×ln*(Amount of pesticide)*	-0.137	0.126
ln*(Amount of fertilizer)*×ln*(Number of man-days)*	-0.055	0.134
ln*(Amount of fertilizer)*×ln*(Money of machines and services)*	-0.568**	0.231
ln*(Amount of pesticide)*×ln*(Number of man-days)*	-0.140**	0.068
ln*(Amount of pesticide)*×ln*(Money of machines and services)*	0.192	0.132
ln*(Number of man-days)*×ln*(Money of machines and services)*	-0.025	0.111
Age	-0.006***	0.002
Education	0.010	0.008
Training	0.140***	0.048
Disease	0.016	0.046
Mono	0.003	0.057
Soil	0.086*	0.049
Off-farm ratio	-0.126*	0.072
Polluted (F)	-0.300***	0.052
Constant	-20.213	33.512
R-square	0.50	
Included observation	364	

Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively

Source: Own estimates; data appendix available from authors.

Next, we can test the null hypothesis of the Cobb-Douglass functional form. The restricted function is estimated assuming the null hypothesis that the joint parameters in (17) are 0. The computed F statistic of 1.78 is more than the critical F(55,283) value of 1.57 at the 1 percent level[1)]. The null hypothesis is therefore rejected, which supports the use of the translog functional form in this study. The estimate of profit function also shows the absence of multicollinearity(the correlations of independent variables less than 70 percent) and of heterscedasticity(Breusch-Pagan testshows the critical $\chi^2_{74}$of 105.2at the level of 1 percent higher than the computed LM of 100.24[2)]).

The coefficient of *Polluted* variable representing the effect of pollution is negative and significant (P < 0.01), which confirms that water pollution reduces the profit of rice cultivation. The reduction in rice profit can be calculated using the coefficients presented in Table 9. The estimated profit is approximately VND 9.14 million for rice cultivation in the polluted area and VND 12.34 million for that in the non-polluted area after the influences of other factors are eliminated. The loss of rice profit due to wastewater irrigation can be estimated by subtracting the rice profit in the polluted region by the rice profit in the non-polluted region (equation 15). Using this approach, the loss of profit is calculated to be approximately VND 3.2 million per hectare per crop (see Table 11).

The model also shows that farmer age ($P < 0.01$) and the ratio of off-farm income ($P < 0.1$) explain variation in profit. The effect of age may be caused by declines in the health of older farmers leading to less efficient cultivation. Farmers who earn more off-farm income are associated with less profitable rice cultivation.

The percentage of respondents attending training is significantly ($P < 0.01$) different between the two areas. Training courses, such as the 3-reduction and 3-increase, IMP program, are normally offered by local authorities to provide guidance on the application of new technologies to increase rice yield. Soil quality is also an important factor affecting profit ($P<0.1$).

Table 10.Reduced profit in rice farming and key constraints

Factors	Reduced profit (Thousand VND)	Percentage of reduced profit (%)
Polluted vs. Non-polluted area	3,203	25.95
Non-fertile vs. Fertile soil	874	8.24
Non-training vs. Training	1,465	13.03
The highest off-farm vs. Zero off-farm income ratio	1,229	11.45

Source: Own estimates; data appendix available from authors.

We also use the same estimateof profit loss due to water pollution to calculatereductionsin profitcaused by other factors as presented in Table 10. Cultivation in non-fertile soil, instead of fertile soil, can reduce rice profit by 8.24%. Farmers whose main sources of income are from non-agricultural sectors obtain 11.45% less rice profit than those who only have an agricultural income. Participating in trainings is estimated to increase profit by 13.03%. Profit loss caused by water pollution is much higher than the profit loss caused by other factors, which demonstrates that environment pollution has a great significance for rice farmers near industrial parks. Because of this, we suggest that the Vietnamese authorities should place a greater importance on the development and implementation of pollution control policies.

Table 11 summarizes the total loss of rice production due to water pollution. The estimated results show there are about 26 percent of profit loss, including around 12 percentof reduced quantity (yield loss) and 9 percent of cost increase, adversely caused by industrial water pollution. In this study, we also observed that farmers in the polluted area use water irrigation from the highest water tide level to reduce the effects of wastewater on rice production. This was because the farmers thought the water at the high tide level looked less polluted than the waters at other times, despite the fact that the water was always heavily polluted near the industrial parks.

Table11. Impact of water pollution on rice production

	Amount	Percent
Quantity loss	0.67 tons/ha	12%
Cost increase	0.97 million VND/ha	9%
Total loss of net economic return	3.2 million VND/ha	26%

Source: Own estimates; data appendix available from authors.

Moreover, the use of polluted water also caused the farmers to change their cultivation management. In previous years, three rice crops were produced annually and rice cultivation was the main income source. However, because of pollution, only one or two rice crops is now cultivated in the polluted area each year, and farmers treat rice cultivation as a part-time job, producing rice sufficient only for household consumption.

During our study, we also received reports of skin diseases on the farmers working in the polluted region. For instance, a farmer in the polluted area reported that he had suffered from skin disease 5 days per year, and the treatment cost VND 500,000. The diseases also caused the loss of 2.5 workdays, equivalent to VND 250,000. Therefore, the estimate of total economic loss is underestimated if indirect costs such as the health costs suffered by farmers are not included.

5. CONCLUSIONS AND POLICY IMPLICATION

Local authorities in Vietnam have recently removed or reduced some of the environmental impact requirements to attract industrial investments to their province. Although industrial investments with low environmental standards might increase gross domestic product and create more jobs for local households, they may also bring many problems including water, air and soil pollution. This study provides an example of the negative impacts that arise from pollution by industries.

In this study, we surveyed rice farmers in two areas with the same natural environment conditions, social characteristics(e.g. the same social and farming culture, ethnicity, type of soil), and only differed with respect to pollution. One area was considered to be the polluted area, receiving wastewater from nearby industrial parks, while the other area was assumed to be the non-polluted area, being distant from sources of industrial pollutants. The productivity loss of rice production caused by water pollution was estimated by the difference in rice yield between the two regions.The similar calculation was applied for cost increase and profit loss for using wastewater irrigation. The results showed that the yield loss of rice was about 0.67 tons per hectare per crop, VND 0.97 million for cost increase and totally 26 percent of profit loss due to water pollution. Therefore, since the study includes 214 farmers in the polluted area and these 214 farmers cultivate rice in 148 hectare as a whole, theirtotal cost increase per crop because of water pollution could be estimated about VND 144 million (VND 0.97 * 148ha) and approximately VND 474 million (VND 3.2 million*148ha) for their total net economic loss.

According to The World Bank (2007), the development of rice roots and seedlings could be influenced by using wastewater for irrigation. Polluted water irrigation causes the reduction of height, leaf area and dry matter. Decrease in leaf surface area leads to the reduction of photosynthesis. These facts have directly impact on rice production. In other words, the impacts of polluted water on rice productivity mainly reduce the number of ears unit area, number of seed per ear and seed weight. The study estimated water pollution caused yield reduction about 12 percent. This result is nearly equal to the reduced yield of 10 percent in the sewage-irrigated area in comparison with clear water-irrigated areas estimated by Bai(1988), but much lower than the rice reduced productivity of 20 percent calculated by Song (2004) in the study of Lindhjem(2007) and 30 percent by Chang *et al.*(2001).

Economic developments that cause damage to natural resources and the environment are unsustainable. We suggest that the Vietnamese government needs to develop policies that ensure sustainable development. Similar to environmental policies in developed countries, the Vietnamese government could consider increasing the current environmental standards and raising environmental taxes. The increase of environmental taxes could not only encourage industries to apply new technologies that reduce environmental pollution, but also generate moneyto compensate farmers near industrial areas for the damage to their agricultural production and health and to build wastewater treatment facilities in industrial parks. Compensation could be provided directly in cash to the farmers, or indirectly by means such as funding training or activities related to new technologies and the management of agricultural inputs and expenditure. Our study showed that training helped farmers increase their profit, which may partly offset some of the losses caused by environmental pollution.

To reducepolluted water from the industrial parks, an increase in the effectiveness of implementation of Decision 64 and Circular 07 *(see Annex 1 and 2)*should be recommended. A public disclosure system for the environmental performance of polluters mentioned in Article 104 of the Law on Environmental Protection (dated 2005) and Article 23 of Degree No. 80/2006ND-CP should be considered as one of the best ways to increase the efficiency of Decision 64 and Circular 07.

Article 104 requires polluters to report and publicizethe information and data about the environment as follows:

- *Reports on the environmental impact assessment, decision on approval for reports on the environmental impact assessment and plan for the implementation of requirements stipulated in the decision on approval for reports on the environmental impact assessment;*
- *List of and information about sources of wastes, pollutants that seem potentially harmful to people's health and environment;*

- *Areas where environment is polluted and degraded seriously and extremely seriously, areas in danger of the environmental pollution.*
- *Report on the environmental situation at the provincial level, report on environmental impact assessment by industries, fields and the national report on the environment*
- *It is essential to ensure unrestricted access to publicized information*
- *Agencies publicizing information about the environment have to take responsibility on accuracy, honesty and objectivity of announced information before legal agencies.*

Article 23 provides details and instructions on how to implement Article 104 of the Law on Environmental Protection. These details and instructions include:

- *The Ministry of Natural Resources and Environment have responsibility for announcing information and data about the national environment;*
- *Ministries and ministerial-level agencies, government agencies shoulder responsibility for exposing information and data about the environment in industries and areas under their management;*
- *Agencies in charge of the environmental protection of People's Committees at all levels bear responsibility for make information and data about the environment in the area under their management publicly;*
- *Management board of economic zones, industrial parks, export processing zones, managers of manufacturing and service units accept responsibility for publicizing information and data about the environment in the area under their management;*
- *Publicity of information and data about the environment is stipulated as follows:*
    - *Information and data about the environment is publicized in form of books, news in newspapers or post on units' websites;*
    - *Information and data about the environment is publicized in form of books, news in newspapers or post on units' websites (if any), reported in people's council meetings, announced on notice boards in residential quarter meetings, or listed in headquarters of units or headquarters of commune, ward, town people's committee where units are in operation.*

The requirements of these above public disclosure system illustrate a new and significant approach for environmental authorities to force environmental laws and regulations in strong manner by increasing environmental awareness and permitting the large public to put pressure on polluters to solve current environmental problems. Such public disclosure requirements also create significant pressure on environmental authorities themselves as their own decision failures might also be widely recognized by such requirements. However, the implementation of these requirements in a clear, precise, and systematic manner is strongly needed.

Since water treatment facilities in these industrial parks must be built as soon as possible, the study on their cost effectiveness could be needed and seriously considered to decide whether we should build the water treatment facilities in every individual factory or for the whole industrial parks. Moreover, we suggest that the government should not use high-yield agricultural land for the construction of new industrial parks unless they include the latest pollution treatment technologies. The impact of environmental pollution should continue to be evaluated.

NOTES

1) Calculated by the formula $F = \frac{\left(SSE_R - SSE_U\right)/J}{SSE_U/\left(I-K\right)}$, where SSE_R and SSE_U are the restricted and unrestricted sums of squared residuals and J is the number of restrictions

2) Breusch-Pagan test for heterscedasticity:

$$LM = nR^2 \sim \chi_k^2$$

where:n is the number of observations

R^2 is the R-Square of $\left|\hat{u}_i\right| = \tilde{\delta}_0 + \tilde{\delta}_1 X_{1i} + \tilde{\delta}_2 X_{2i} + ... + \tilde{\delta}_k X_{ki} + \tilde{v}_i$

k is the number of restricted factors

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APPENDIXA – DECISION 64

Decision No 64/2003/QD-TTg of April 22, 2003 Approving the plan for thoroughly handling establishments which cause serious environmental pollution.

The Prime Minister

Pursuant to the December 25, 2001 Law on Organization of the Government;

Pursuant to the December 27, 2003 Law on Environmental Protection;

In order to enhance the environmental protection work in the period of national industrialization and modernization;

At the proposals of the Minister of natural Resources and Environment, the Minister of Science and technology as well as the concerned ministries, branches and localities.

Decides:

Article 1: To approve the plan for thoroughly handling establishments which cause serious environmental pollution (hereinafter called the plan for short with the following principal contents.

I. The plan's objectives

1. Immediate objectives till 2007:

To concentrate efforts on thoroughly handling 439 establishments causing serious environmental pollution out of a total of 4,295 polluting establishments, which had been scrutinized and listed by 2002, including 284 production and business establishments, 52 rubbish dumps, 84 hospitals, 15 plan protection drug warehouses, 3 toxic chemical storage zones and 1 wartime bomb warehouse, in order to settle immediately the hottest and most burning environmental pollution sports in urban centers, densely populated areas and severely polluted areas, thus contributing to protecting the environment and community's health, to step up the word of pollution prevention and preclusion, step by step control and limit the rate of increase in the number of establishments causing serious environmental pollution throughout the country.

2. Long-term objectives till 2012:

To continue thoroughly handling the remaining 3,856 establishments which cause serious environmental pollution and newly arising establishments. To further step up the work of pollution prevention and preclusion proceeding to control and limit the rate of increase in the number of establishments causing serious environmental pollution throughout the country, ensuring the sustainable developments in the period of national industrialization and modernization.

II. Handling principles

1. The thorough handling of environmental pollution causing establishments shall be conducted on the principle of ensuring the sustainable development.

2. The thorough handling of establishments causing serious environmental pollution must be conducted in a resolute manner and suitable to the reality of each locality each branch and each establishments; to review and select the most typical and burning polluting establishments for handling first in order to draw experiences for widespread application.
3. Those subjects that cause environmental pollution must take the responsibility to thorough treat and overcome the pollution. The State shall have to treat overcome environmental pollution in particular cases.

4. In the course of thoroughly handling establishments which cause serious environmental pollution, the laborers legitimate interests must be ensured according to the current legislation.

III. The Plan's contents

1. Stage 1 (2003-2007):

To concentrate efforts on thoroughly handling 439 establishments which cause serious environmental pollution mentioned in Appendices No 1 and 2 to this Decision (not printed herein) of which.

a. From 2003 to 2005, to concentrate efforts on immediately handling 51 establishments which cause particularly serious environmental pollution, including 29 production and business establishments, 3 toxic chemical storage zones, 1 warehouses and 3 rubbish dumps (Appendix No 1, not printed herein).

b. At the same time, to expeditiously elaborate plans, handle and complete the handling of the remaining 388 establishments which cause serious environmental pollution of stage 1 (Appendix No 2, not printed herein), including:

- To renovate and upgrade technologies at 55 production and business establishments.
- To build waste treatment works at 200 production and business establishments.
- To control pollution, upgrade, renovate and build the pollution treatment system at 49 former and existing rubbish dumps.
- To treat environmental pollution at 84 hospitals.

2. Stage 2: (2008-2012):

On the basis of making final review on, and draw experiences from, the handling in the 2003-2007 period, to take synchronous measures, continue thoroughly handling the remaining 3,856 establishments which cause serious environmental pollution and newly arising establishments.

IV. Basic solutions:

In order to efficiently implement the plan throughout the country, the concerned ministries, branches, localities and establishments should apply the following synchronous solutions.

1. To study, elaborate, promulgate or supplement and perfect the system of relevant legal documents as well as mechanisms and policies with a view to ensuring the high efficiency of the plan implementation.

2. To diversity investment capital sources for the plan implementation (own capital, State budget capital, loan capital from different funds and other sources)

The establishments' owners shall take the prime responsibility for capital investment in the treatment of serious environmental pollution they have caused; be entitled to use financial-assistance sources and voluntary contributions of domestic and foreign organizations and individuals for the implementation thereof, be considered for borrowing preferential capital from Vietnam Environmental Pollution Fund according to the provisions in the Prime Minister's Decision No 82/2002/QD-TTg of June 26, 2002 on the establishment, organization and operation of Vietnam Environmental Pollution Fund.

The ministries, branches and localities, which manage establishments causing serious environmental pollution, shall draw up plan on partial capital support from the State budget for the plan implementation (for part under the responsibilities of their respective ministries, branches and localities).

3. The owners of the establishments causing serious environmental pollution, who implement the plan, shall be entitles to enjoy tax exemption and/or reduction policies or preferences on tax rates, enterprise income tax, tax on the import of advanced machinery and equipment as well as clean production and environment-friendly technologies; enjoy policies, land use levy, land rental and land use tax preferences or exemption according to the provisions of the Government's Decree No 51/1999/ND-CP of July 8, 1999 detailing the implementation of the Domestic Investment Promotion Law (amended).

4. To encourage the renovation and upgrading of technologies; to step up the application of clean and environment-friendly technologies to enterprises' production.

5. To enhance the work of State management over environment from the central to local level, especially in examining, inspecting, monitoring and urging the plan implementation as well as the work of State inspection and specialized inspection of environmental pollution. To encourage and support enterprises to apply the environmental management system according to the Vietnamese Environmental Standards. To study and apply the fixture of environmental labels on enterprises products, first of all experimentally apply it in Hanoi and Ho Chi Minh cities.

6. To step up the word of education and communication on the mass media for the plan implementation. To mobilize and encourage all people and each population community to actively participate in preventing and treating pollution as well as overcoming environmental decline.

7. To enhance international cooperation with a view to exploiting resources of foreign organizations and individuals for the plan implementation.

8. To take administratively coercive measures as prescribed by law for those establishments causing serious environmental pollution, which commit acts of dragging on, delaying the implementation of, or involuntarily implementing, the plan already approved by the Prime Minister.

V. Organization of implementation.

1. To set up an inter-branch Steering Committee to direct the plan implementation, which is composes of the Minister of Natural Resources and Environment as its head, a vice-minister of Natural Resources and Environment as its standing deputy-head, and vice minister of Planning and Investment, Finance, Science and Technology, Industry, Construction, Communications and Transport, Agriculture and Rural Development, Health, Aquatic Resources, and Defense, as its members. The inter-branch Steering Committee has its standing section based at the Ministry of Natural Resources and Environment. The Steering Committee operates under the Regulation issued by its head in accordance with the current law provisions.

2. The Minister of Natural Resources and Environment shall have the tasks:

   a. To act as a standing body of the Steering Committee, which is tasked to assist the Government in assuming the prime responsibility and coordinating with the concerned minister, branches and localities in organizing the plan implementation.

   b. To organize the through study of the plan contents for the subjects participating in thoroughly handling establishments which cause serious environmental pollution.

   c. To elaborate and promulgate according to its competence or submit to the Prime Minister for promulgation legal documents as well as mechanisms and policies on environmental protection, preferences in investment capital, credit, taxed, land, and techniques, and ensure the legitimate interests of laborers of the environmental pollution establishments which implement the plan.

   d. To take responsibility for urging, examining, inspecting, monitoring and organizing the coercion for plan implementation. To synthesize, review and evaluate the plan implementation, make annual reports and submit them to the Prime Minister.

3. The Minister of Planning and Investment shall assume the prime responsibility and coordinate with the Minister of Finance in properly balancing and apportioning capital for the concerned ministries, branches and localities in order to support them and ensure that the plan is implemented strictly according to the schedule already approved by the Prime Minister.

4.The minister, branches and local administrations mentioned in Appendices 1 and 2 (not printed herein), which manage establishments causing serious environmental pollution, shall have to coordinate with the Minister of natural Resources and Environment; Planning and investment; and Finance in evaluating and approving the establishments’ handling schemes; mobilize capital sources and direct the plan implementation strictly according to the time and tempo prescribed in Appendices No 1 and 2.

5.The establishments causing serious environmental pollution mentioned in Appendices No 1 and 2 shall have to elaborate schemes, invest capital and organize the treatment of environmental pollution they have caused.

6.Communication agencies should intensity the propagation and education contents on environmental protection, pollution prevention and through handling of establishments causing serious environmental pollution and bad impacts on ecological environment and health.

Article 2: This Decision takes implementation effect 15 days after its publication in the Official Gazette.

Article 3: The ministers, the heads of the ministerial-level agencies, the heads of the agencies attached to the Government, the presidents of the People's Committees of the provinces and centrally-run cities as well as the concerned organizations and individuals mentioned in Appendices No 1 and 2 shall have to implement this Decision.

APPENDIX B – CIRCULAR 07

CIRCULAR OF THE MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT NO. 07/2007/TT-BTNMT DATED 03RD JULY 2007 PROVIDING GUIDELINES ON THE CLASSIFICATION AND DECISION OF SERIOUS POLLUTERS NEEDED TO BE HANDLED THOROUGHLY

Pursuant to the Law on Environmental Protection dated November 29th 2005

Pursuant to Decree No. 80/2006/ND-CP dated August 9th 2006 of the Government stipulating detailed regulations and guidelines on the implementation of some articles of the Law on Environmental Protection;

Pursuant to Decree No. 91/2002/ND-CP dated November 11th 2002 of the Government stipulating functions, tasks, powers and organizational structure of the Ministry of Natural Resources and Environment;

Decision No 64/2003/QD-TTg of April 22, 2003 Approving the plan for thoroughly handling establishments which cause serious environmental pollution.

The Ministry of Natural Resources and Environment provides guidelines on classification and decision of serious polluters needed to be handled thoroughly as follow:

I. Foundation for the classification of establishments which cause environmental pollution

1. The classification of establishments that cause environmental pollution bases on the level of breach of Vietnam environmental standards (in this Circular, the phase “environmental standard” is used in accordance with the regulation of the Law on Environment and understood as phase “technical standard” regulated in the Law on Standards and Technical Standards) of primary polluted parameters of wastewater, exhausted air, noise and vibration.

2. The primary polluted parameters of wastewater, exhausted air, noise and vibration include:

2.1. pH, temperature of wastewater;

2.2. Radioactive substances in wastewater, exhausted air;

2.3. Parameters regulated in the Vietnam Standard on Environment are identified by governmental Authorities based on environmental assessment reports; or certificates of meeting environmental standards (established prior to 01st July 2006); or engagement document on environmental protection (established prior to 01st July 2006); or project on environmental protection (established prior to 01st July 2006) approved or confirmed by governmental Authorities or according to the Annex enclosed to this Circular.

3. In case establishments breach regulation of solid waste management and cause environmental pollution, governmental Authorities take further step to identify primary polluted parameters of wastewater, exhausted air caused by the solid wastes according to the guidelines at Article 2 of this Circular for classifying those establishments.

II. Criteria for the classification of establishments which cause environmental pollution

1. Establishment which causes serious environmental pollution belongs to one of following cases:

1.1. Having 02 (two) and more than 02 (two) common polluted parameters which exceed Vietnam environmental standard 05 (five) times or above

1.2. Having 02 (two) or more than 02 (two) hazardous polluted parameters which exceed Vietnam environmental standard 03 (three) times or above

1.3. Having 01 (one) common polluted parameter which exceeds Vietnam environmental Standard more than 05 (five) times or above; and 01 (one) hazardous polluted parameter which exceeds Vietnam environmental standard 03 (three) times or above.

1.4. Having the average value of 02 (two) polluted parameters, which exceed Vietnam environmental standard 06 (six) times or above.

1.5. Having 02 (two) or more than 02 (two) polluted parameters, which exceed Vietnam environmental standard; and having at least 01 (one) common polluted parameter, which exceeds Vietnam environmental standard 10 (ten) times or above.

1.6. Having 02 (two) or more than 02 (two) polluted parameters, which exceed Vietnam environmental standard; and having at least 01 (one) hazardous polluted parameter, which exceeds Vietnam environmental standard 5 (five) times or above.

1.7. Having radioactive substances causing environmental pollution exceeding permitted level.

1.8. Having pH of waste water, value of which is 2 (two) or below; or value of which is 12.5 (twelve point five) or above.

1.9. Having the temperature of wastewater, which is more than $45^{0}C$ (forty five)

2. Establishment causing environmental pollution refers to the one that does not belong to one of above cases at Article 1 but has 1 (one) or more than 1 (one) environmental parameter regarding wastewater, exhausted air, noise and vibration that exceeds Vietnam environmental standard.

III. Procedures for classification and decision of establishments causing serious environmental pollution that needed to be handled thoroughly

1. Prior to the date 31st March annually, based on the latest inspection, investigation regarding environmental protection and foundation, criteria for classification of polluters regulated at Article II of this Circular, Departments of Natural Resources and Environment (DoNREs) update the list and propose solutions to handle thoroughly establishments that cause environmental pollution, serious environmental pollution in local territory (excluding establishments belonging to National Defense and Security) according to the Template 1 and Template 2 enclosed to this Circular, report to provincial People’s Committee and the Ministry of Natural Resources and Environment; send the list of establishments that cause

environmental pollution, serious environmental pollution to ministries, agencies that are same level as ministry, governmental agencies, economic Corporation, Corporation 91 (hereinafter refer to the ministries, agencies) that are involved.

2. Prior to the date 30th April annually, based on reports of Departments of Natural Resources and Environment, provincial People's Committees, People's Committees of cities under the central Government conduct following activities:

2.1. Decide the list and solutions to handle thoroughly establishments, which cause environmental pollution and serious environmental pollution in local territory (excluding establishments belonging to National Defense and Security) in accordance with regulation at Point b, Clause 3, Article 49 of the Law on Environmental Protection; in case establishments are under the administration of Ministries, Agencies, the handling of those enterprises must have prior consultation process before making decision.

2.2 Report the list of establishments that cause serious environmental pollution in local territory (excluding establishments belonging to National Defense and Security), in which those establishments that are beyond the scope of administration of People's Committees, Ministries, will then be reported according to the Template 3 enclosed to this Circular, the Ministry of Natural Resources and Environment then submitted to the Prime Minister for decision in accordance with regulation at Point d, Clause 3, Article 49 of the Law on Environmental Pollution.

3. Prior to the date 31st March annually, environmental agencies under the Ministry of Defense, the Ministry of Public Security review the results of environmental inspection and investigation and based on criteria for the classification of establishments causing environmental pollution in accordance with section II of this Circular to take lead, coordinate with Departments of Natural Resources and Environment (DoNREs) updating the list of those establishments belonging to National Defense and Security according to the Template 4 and Template 5 enclosed to this Circular and submit to the Ministers of two above Ministries and send to the Ministry of Natural Resources and Environment.

4. Prior to the date 30th April annually, based on reports of environmental agencies, Ministers of the Ministry of Defense and the Ministry of Public Security conduct following activities:

4.1. Decide the list of establishments causing environmental pollution, serious environmental pollution under the ministry's administration

4.2. Report the list of establishments causing serious environmental pollution that are beyond the scope of the ministry's administration according to the Template 6 enclosed to this Circular; the Ministry of Natural Resources and Environment process and submit to the Prime Minister in accordance with the regulation at Point d, Clause 3, Article 49 of the Law on Environmental Protection.

5. Prior to the date 30th May annually, based on reports and solutions for thorough handling of establishments causing serious environmental pollution proposed by provincial and central-governmental-city's People's Committees, the Ministry of Defense, the Ministry of Public Security, the Ministry of Natural Resources and Environment submit the list and solut

6. The supervision of the implementation of handling thoroughly establishment causing environmental pollution and serious environmental pollution is regulated at Clause 4 Article 49 of the Law on Environmental Protection.

IV. Implementation

1. Environmental protection agencies of ministries, governmental agencies and Departments of Natural Resources and Environment (DoNREs) closely coordinate with each other in the process of classifying, updating the list of establishment causing environmental pollution, serious environmental pollution.

2. Departments of Natural Resources and Environment (DoNREs) inform the district and commune People's Committee regarding the list and decision of handling and disclose publicly this information.

3. Vietnam Environment Protection Agency (VEPA) supervises and monitors the classification of establishments in accordance with this Circular; publicize on mass media the information of establishment causing serious environmental pollution in accordance with regulation at Point d, Clause 1, Article 04 of the Law on Environmental Protection.

4. Any problems and difficulties arising from the implementation process, Ministries, Agencies, People's Committees of province and central-governmental city, Departments of Natural Resources and Environment, involved organizations and individuals report timely to the Ministry of Natural Resources and Environment for consideration and adjustment.

APPENDIXC - QUESTIONNAIRE

The date of interview: ______________________________

Interviewer: ________________________________

Code: ____

I. PERSONAL INFORMATION OF HOUSEHOLDER

1. The name of householder:_______________________________

2. Address:____

3. The gender of interviewee: 1. Male 2. Female

4. The education of interviewee:

1. None 2. Primary 3.Elementary 3.Hight school 4. University

5. The date of birth:____________year.

6. Number of members in the family: ______persons.

Including: Male: ______The number of males who are more 16 years old: ______

Female: _____The number of females who are more 16 years old :__

7. Do you take part in any rice trainings? 1. Yes 2. No

The number of trainings:_____What is the period of two trainings? _____ month(s).

II. INFORMATION ABOUT FARMER

1. Total area: ______ (ha);

2. Including, rice area: _____ (ha).

3. When did you begin to grow rice? Year _____

4. Why did you choose to grow rice?

€ More profit than other crops	€ Available experience
€ Easy to sell	€ Following Governmental policies
€ Suitable lands	€ Supported technologies and finances
€ To improve lands	€The high productivity
€ Using rotational cultivation	€ Other:______
€ Supported by limited companies	

5. The number of crops per year: ____ crop(s)

6. Rice area is located in irrigation area? 1. Yes 2. No

7. According to you, whether your land is fertile or not?

1. Vey fertile 2. Fertile 3.Medium 4.No-fertile 5. Very no-fertile

8. How far is rice land located from industrial zones?__________km

9. According to you, whether your rice land is polluted by industrial zones?

1. Vey polluted 2. Polluted 3.Rather polluted 4. Non-polluted 5. I don't know

10. In 2008-2009, are there any diseases influencing on rice production?

1. Yes 2. No

10.1. If yes, please give the name of diseases:________

11. In 2008-2009, are there any disasters influencing on rice production?

1. Yes 2. No

11.1. If yes, please give the name of disasters:___________________

12. Compared to 3 years ago (2006), whether does your rice land decrease or not?

1. Decrease 2. The same 3. Increase

12.1. If Decrease, How many hectares:_____________________ha.

12.2. The reason why decrease in rice land?

1. Polluted 2. Building house 3. Sell 4. Giving the children 5. Other______

13. Compared to 3 years ago (2006), do you have the improvement of your living?

1. Improvement 2. The same 3.Decrease

The reason why decrease in your standard living?

	Main reason	Extra-reason
- Decrease in yield:	(1)	(1)
- Ill people:	(2)	(2)
- Borrowing with high interest:	(3)	(3)
- Selling products with low price:	(4)	(4)
- Buying inputs with high price:	(5)	(5)

14. The variety of rice: ________________________________

15. Do you borrow money from the financial organizations?

1. Yes 2. No

III. RICE PRODUCTION

1. Summer-Autumn season

1.1.Cultivation land:…………..ha

1.2.The period :…………….months

1.3.Total cost:…………………….1000 VND

Item	Amount	Unit	Total
1.Land preparation			
Hired labor (days)			
Family labor (days)			
2. Seeding			
Seed amount (kg)			
Seeding cost			
Family labor (days)			
3. Weeding			
Hired labor (days)			
Herbicide amount			
- Name 1:...................................			
- Name 2:...................................			
Family labor (days)			
4.Fertilizer			
Fertilizer amount (kg)			
- NPK			
- URE			
- Phosphate			
- Kali			
- DAP			
Hired labor (days)			
Family labor (days)			
5.Pesticidde			
Hired labor (days)			

- Insecticide 1:			
- Insecticide 2:			
- Fungicide 1:			
- Fungicide 2:			
- Other pesticide 1:			
- Other pesticide 2:			
Family labor (days)			
6.Irrigation			
Service cost			
Fuel (doing by self)			
Family labor (days)			
7.Harvest			
Service cost			
Hired labor (days)			
Family labor (days)			
8.Processing and Selling			
Milled cost			
Drying cost			
Family labor (days)			
Transportation cost			
Family labor (days)			
9.Other costs			

1.4. Total family labors:......................................days.

1.5.Income:…………………….1000 VND per total area..

Yield (tons/ha)	Amount (tons)	Sale amount (tons)	Min price (1000VND/ton)	Max price (1000VND/ton)	Current price (1000 VND/ton)

2. Autumn-Spring season

2.1.Cultivation land:…………..ha

2.2.The period :…………….months

2.3.Total cost:…………………….1000 VND

Unit: 1000VND

Item	**Amount**	**Unit**	**Total**
1.Land preparation			
Hired labor (days)			
Family labor (days)			
2. Seeding			
Seed amount (kg)			
Seeding cost			
Family labor (days)			
3. Weeding			
Hired labor (days)			
Herbicide amount			
- Name 1:....................................			
- Name 2:....................................			
Family labor (days)			
4.Fertilizer			
Fertilizer amount (kg)			
- NPK			
- URE			
- Phosphate			
- Kali			
- DAP			
Hired labor (days)			
Family labor (days)			

5.Pesticidde			
Hired labor (days)			
- Insecticide 1:			
- Insecticide 2:			
- Fungicide 1:			
- Fungicide 2:			
- Other pesticide 1:			
- Other pesticide 2:			
Family labor (days)			
6.Irrigation			
Service cost			
Fuel (doing by self)			
Family labor (days)			
7.Harvest			
Service cost			
Hired labor (days)			
Family labor (days)			
8.Processing and Selling			
Milled cost			
Drying cost			
Family labor (days)			
Transportation cost			
Family labor (days)			
9.Other costs			

2.4. Total family labors:......................................days.

2.5.Income:…………………….1000 VND per total area..

Yield (tons/ha)	Amount (tons)	Sale amount (tons)	Min price (1000VND/ton)	Max price (1000VND/ton)	Current price (1000 VND/ton)

3. Spring-Winter season

3.1.Cultivation land:…………..ha

3.2.The period :…………….months

3.3.Total cost:…………………….1000 VND

Unit: 1000VND

Item	**Amount**	**Unit**	**Total**
1.Land preparation			
Hired labor (days)			
Family labor (days)			
2. Seeding			
Seed amount (kg)			
Seeding cost			
Family labor (days)			
3. Weeding			
Hired labor (days)			
Herbicide amount			
- Name 1:...................................			
- Name 2:...................................			
Family labor (days)			
4.Fertilizer			
Fertilizer amount (kg)			
- NPK			

- URE			
- Phosphate			
- Kali			
- DAP			
Hired labor (days)			
Family labor (days)			
5.Pesticidde			
Hired labor (days)			
- Insecticide 1:			
- Insecticide 2:			
- Fungicide 1:			
- Fungicide 2:			
- Other pesticide 1:			
- Other pesticide 2:			
Family labor (days)			
6.Irrigation			
Service cost			
Fuel (doing by self)			
Family labor (days)			
7.Harvest			
Service cost			
Hired labor (days)			
Family labor (days)			
8.Processing and Selling			
Milled cost			
Drying cost			
Family labor (days)			

Transportation cost			
Family labor (days)			
9.Other costs			

3.4. Total family labors:......................................days.

3.5.Income:…………………….1000 VND per total area..

Yield (tons/ha)	Amount (tons)	Sale amount (tons)	Min price (1000VND/ton)	Max price (1000VND/ton)	Current price (1000 VND/ton)

4. Do you have any disadvantages and advantages in rice cultivation?

Disadvantages:

- Lack of good varieties
- Input prices increase
- Lack of market information
- Water more pollution
- Lack of capital
- low technology
- Decrease in yield
- Other

Advantages:

- Fertility soil
- Seed support from local authorities
- Irrigation management
- Often trained new technologies
- Borrowing with Low interest
- Other

5. What do you think the yield of rice when compared to 10 years ago (1999)?

1. Increase   2. Same   3.Decrease   4. I don't know

5.1. If decrease, Do you think how many percent of decrease of rice yield?..........................%

Please give reasons why is the decrease of rice yield?

1. Water pollution   2. Less fertility soil   3. More disaster   4. Other

IV. INCOME FROM OTHER PRODUCTS AND JOBS:

Jobs	**Amount (1.000 VND/year)**	**Note**
1. Jobs:		
1.1. Cost/year		
1.2. Income/Year		
2. Jobs:		
2.1. Cost/year		
2.2. Income/Year		
3. Jobs:		
3.1. Cost/year		
3.2. Income/Year		
4. Jobs:		
4.1. Cost/year		
4.2. Income/Year		