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Conference Paper

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Measurement of Value of Statistical Life by Evaluating Diarrhea Mortality Risk due to Water Pollution in Laos and Vietnam

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Abstract: Diarrhea mortality risk due to water pollution is one of serious problems that threaten human life in Asian developing countries. This study aims to provide basic information for cost-benefit analysis of countermeasures against such a problem in Laos and Vietnam, with a measure of VSL (value of statistical life) concerning diarrhea mortality risk by using CVM (contingent valuation method). With a dataset of questionnaire, the damage cost function explained by the change of diarrhea mortality risk has been derived. VSL has been also calculated as 15,853-47,898 US$ for Laos and 65,726-209,660 US$ for Vietnam.

JEL classification: I18, J17, Q53

Keywords: *diarrhea mortality risk, water pollution, Laos, Vietnam, CVM, VSL*

1. Introduction

Recently, it has been reported sensationally that the water level of Mekong River is lowering. Such a situation is said for the first time in these 5 decades in Thailand, Laos and Vietnam, and will have a devastating consequence to ensure a water supply for agricultural, fishery and domestic purposes. Causality is rather controversial. One possible explanation is current rapid economic growth of countries belong the basin, and the other one is construction of several huge dams in Yunnan province (though the upstream-downstream effect is denied by China and in MRC Technical paper (2008)). Also worldwide extreme weather or climate change may concern the situation disaster of water shortage (in year of 2010, south areas of China have suffered damages from a severe drought).

For any reason, such water shortage also induces another type of environmental problem, water contamination. The US Centers for Disease Control and Prevention (2006) estimated that waterborne diseases caused 1.8 million deaths each year while about 1.1 billion people lacked proper drinking water. It is clear that people in the developing countries need accessibility to good quality water in sufficient quantity, water purification technology and availability and distribution systems. However, in many parts of the world the only sources of water are from small streams often directly contaminated by sewage.

Nevertheless, there is also a strong and opposite way of thinking that the economic growth is good for the environment. It has been justified by an empirical relation as "inverted-U shape” between income per capita and some measures of environmental quality, so-called “Environmental Kuznets-Curve (EKC)” hypothesis. This hypothesis involves optimistic nuance to some extent because there is nothing to be concerned about environmental worsen due to economic development in the long term when the empirical rule is established. 'Whether this empirical law is robust or not' has been argumentative for these years; see Naito (2006). As a whole, the rule seems to be established for the air pollutant matter which may affect human’s health directly (ex. CO, NOx, SOx, SPM). In addition to that, only a limited water pollution matters seems to obey to the rule, and several recent empirical findings are mostly consistent with negative remarks about the law; see Arrow et.al. (1995). On these view points, especially for the developing countries, spontaneous effort to improve water environment may not be so fast and sensitive, and it may be prone to delay implementation of countermeasure.

Generally speaking, implementation of sewage and water-supply system is the most effective policy against such health problems related with the water worsening. Regarding Mekong Delta and Ho-Chi-Minh City in Vietnam which is the subject area in this study, the maintenance level of these water systems are heard to be insufficient in contrast to their recent notable economic development. In fact, Vietnam has enjoyed much high economic growth in these years, where average of real growth rate is 7.6% from year of 2000 to 2008. On the other hand, the World Health Organization (WHO, 2010) reported that the rate of population using improved drinking-water sources was 94% (92% in 2009), and that the rate of population using improved sanitation was 75% (65% in 2009). These numbers seems extreme high when one overlooks real nature of the other developing countries.

There is still technical difficulty to obtain a certain index and the values of several statistics are different each other (see Asian Development Bank 2007). However, it is an indisputable fact that someone should propose some evidence derived with obviously objective criteria when he tries to appeal water crisis and emergency in the subject area. And also only with the published macro data mentioned above, we have less persuasiveness to refer the value of water environment improving policies.

In this study, we have conducted interview survey in Laos and Vietnam in 2011 and 2010. The content of questionnaire sheet is to ask the willingness to pay (WTP) of residents to have a right to obtain improved water resources in their daily usages and avoid diarrhea mortality risk due to water pollution. By using the data set, we can know how much the residents want to pay for risk reduction, and also how much they evaluate their own life in monetary term, which is the value of statistical life (VSL). Also, by summing up the WTP and comparing with the implementation cost, we can see whether or not they will agree to implement some policies or infrastructures. This kind of methodology, the contingent valuation method (CVM), is directly linked to context of cost-benefit analysis under uncertainty.

2. Review of precedent studies

Environmental Protection Agency (EPA, 1999) in USA surveyed 26 precedent studies on cost-benefit analysis of risk reduction, and derive the mean as 4.8 million US$ in 1990 from each optimum values of VSL. Furthermore, the value has been altered to be 6.3 million US$ in 2000 with the effect of inflation rate. Just for reference, GDP (PPP) per capita of USA was 46,859 US$ in 2008.

Until just recently in Japan, by summing up health expenditure, lost earnings and payment for pain and suffering, only about 0.3 or 0.4 million US$ had been used as a representative value of individual life. But lately, some study has conducted with estimation of VSL based on CVM mentioned above. Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2007) in Japan suggested the standard value of VSL as about 2.7 million US$ when one evaluate implementation effect of a public project, especially for death risk of traffic accident related with road construction. And there are some other VSL estimates in precedent studies on VSL in Japan (see Table 1). Just for reference, GDP (PPP) per capita of Japan was 34,115 US$ in 2008.

Table 1: List of precedent studies on VSL in Japan

Researchers (year)	Subject (method)	VSL estimates
Yamamoto et.al. (1994)	Water pollution (CVM)	21.69-34.38 mil. US$
Takeuchi et.al. (2001)	Traffic accident (CVM)	1.63 mil. US$
Imanaga (2001)	Traffic accident (CVM)	3.75 mil. US$
Matsuoka et.al. (2002)	Air pollution (CVM)	24.85-34.19 mil. US$
Matsuoka et.al. (2003)	Air pollution (CVM)	4.59 mil. US$
Imanaga (2003)	Air pollution (CVM)	1.20 mil. US$
Kabutoyama et.al. (2003)	Traffic accident (Standard Gamble)	1.28 mil. US$
Kei et.al. (2004)	Traffic accident (CVM)	2.44 mil. US$
Furukawa et.al. (2004)	Traffic accident (Wage Risk)	7.23-9.06 mil. US$
Koshi (2004)	Traffic accident (CVM)	12.82 mil. US$
MLIT of Japan (2005)	Traffic accident (CVM)	1.44 mil. US$
Itaoka et.al. (2005)	Traffic accident (CVM)	0.93-3.15 mil. US$
Tsuge et.al. (2005)	Traffic accident (CVM)	3.15 mil. US$
Kashima (2006)	Traffic accident (CVM)	8.18 mil. US$
Cabinet office of Japan (2007)	Traffic accident (CVM)	1.90 mil. US$
Okuyama (2009）	Marine accident (CVM)	0.57-1.03 mil. US$
Ohno et.al. (2009)	Heat stroke (CVM)	0.95-1.12 mil. US$
Miyasato (2010）	Industrial accident (Wage Risk)	9.23-24.10 mil. US$
Maeno (2010）	Industrial accident (Wage Risk)	45.71-91.43 mil. US$

3. Overview of subject region

As mentioned at exordium of this paper, lowering water level and quality worsen off of Mekong River has been extreme recently. It is reported in WHO Report (2004) and Watanabe et al. (2007) that in developing countries 180 million people die of diarrhea and about 90% of which is caused by contaminated water. And also that in Southeast Asia, the death due to diarrheal disease occupied 8.5% of all causes of one's death, that 90% of the death due to diarrheal disease is taking place to infants and children under 5 years old. Moreover that one out of 8 children loses his/her life before he/she become 5 years old in Laos and Cambodia, and that 65-70 newborn babies die every day in Vietnam.

Needless to say, a representative countermeasure against such water quality problem is implementation of water supply and sewage systems. The current situation of 6 countries on the basin of Mekong River is not what it's cracked up to be (see Table 2), and also it is not sufficient level compared with it of Japan. In addition, readers should exercise of caution that the values are not so statistically confidential ones when one imagines about the subject area.

Our main concerns in this study are summarized as follows;

1. Can the sufficient benefits be obtained to cover the full implementation cost?
2. Can residents pay themselves for the full cost without ODA?
3. On what kind of development stage can they clear these problems above?

Table 3 shows so-called "Ruler of Risk" that is the number of people who has been died by each specific cause per every 100,000 population annually. This shows just current annual probability to die due to the cause for each region, and one can see that average death risk in 6 countries is much larger than one of Japan. Especially for diarrheal disease, death risk of Japan is nearby 0. Except for contribution of medical technology development, such a countermeasure, implementation of water supply and sewage systems, seems to be so strong and effective.

Table 2: Some fundamental statistics of 6 countries (2008)

Member state	Population	Gross national income per capita (PPP $)	Access to improved drinking-water sources (%)	Access to improved sanitation (%)
Japan	127,293,000	34,115	100	100
China	1,345,751,000	5,962	89	55
Cambodia	14,805,000	2,066	61	29
Laos	6,320,000	2,204	57	53
Myanmar	50,020,000	1,159	71	81
Thailand	66,405,000	8,100	98	96
Vietnam	87,375,000	2,783	94	75

Source: WHO (2010).

Table 3: Mortality risk by each specific cause (* / 100,000)

Cause-specific mortality	Average of 6 countries on the basin of Mekong River	Japan
Cardiovascular diseases	330	12
Cancer	127	250
Digestive diseases	41	15
Diarrheal diseases	36	0.51
HIV / AIDS	38	0.04
Road traffic accidents	21	9
Self-inflicted injuries	13	24
Violence and war	13	0.52

Sources: WHO (2004) and Ohno et.al. (2009).

4. Implementation of interview survey

Interview survey has been implemented around Vientiane City in Laos in 2011 and around Ho-Chi-Minh City in Vietnam in 2010. We have got 2,825 samples in Laos and 1,000 samples in Vietnam, where 2,807 and 889 samples are valid respectively. Basic statistics of respondents are shown in Tables 4 and 5.

Table 4: Basic statistics of respondents in Laos

Sex	Proportion(%)
Male	60.0
Female	40.0
Total	100.0

Age	Proportion(%)
under 19	1.7
20-29	33.7
30-39	29.5
40-49	22.0
50-59	10.3
over 60	2.8
total	100.0

Annual income	Proportion(%)
under 99$	5.1
100-299$	8.4
300-499$	9.2
500-999$	18.3
1,000-1,499$	22.2
1,500-1,999$	13.5
2,000-2,999$	11.0
over 3,000$	12.3
Total	100.0

Table 5: Basic statistics of respondents in Vietnam

Sex	Proportion(%)
Male	53.3
Female	46.7
Total	100.0

Age	Proportion(%)
under 19	0.3
20-29	15.2
30-39	28.5
40-49	30.8
50-59	19.4
over 60	5.8
total	100.0

Annual income	Proportion(%)
under 99$	1.5
100-299$	0.9
300-499$	3.2
500-999$	13.5
1,000-1,499$	27.5
1,500-1,999$	23.7
2,000-2,999$	22.9
over 3,000$	6.8
Total	100.0

Questionnaire sheets which have been used in the interview survey consist of 5 parts as follows;

1. Recognition of general mortality risk,
2. Consciousness for water quality,
3. First time to ask WTP for implementation of countermeasure,
4. Second time to ask WTP for implementation of countermeasure, and
5. Personal information.

The countermeasure mentioned above is set as a service that supplies safer water and decreases death risk due to diarrhea and diseases of the various digestive organs. Table 6 shows a sample of questionnaire sheet about part 3.

Table 6: Sample of questionnaire sheet about part 3

From here, we ask hypothetical questions. Please answer the following questions by assuming, "If you can obtain such a service that supplies safer water and decreases death risk due to diarrhea and diseases of the various digestive organs". For examples of such a service are as, implementation of water supply and sewerage systems, or, distribution of drinking water in PET bottles. However, it is charged (not free). You have to pay a certain amount to get the service. In addition, please imagine, -Your death risk from diarrhea or diseases of the various digestive organs will be 100/100,000 a year without the service described above. -Your death risk from diarrhea or diseases of the various digestive organs will be X/100,000 a year with the service described above. Next items (1)-(10) each has shown the annual fee level to be paid for receiving the service described above. In each condition, will you receive these services or not? Please choose the one that applies. Please sure that you have to own the following amount of money as an annual subscription to get the contract that you can get such a water service as much as you want. And, the amount of money that you paid for the service is subtracted from your annual free disposal income. (1) When the annual fee of the service is 1 dollar, 1. You will receive the services. 2. You will not receive the services. (2) When the annual fee of the service is 3 dollars, 1. You will receive the services. 2. You will not receive the services. : (10) When the annual fee of the service is 300 dollars, 1. You will receive the services. 2. You will not receive the services. To the person who chose "2. You will not receive the services." for the item (1) above, we will ask the reason why you chose it. Please choose the one that applies. In the case of choosing "6.others", please write the reason concretely into ( ). 1. Though it is preferable to reduce my death risk from diarrhea or diseases of the various digestive organs, it seems that there is no worthy of $1 in a year to receive the safe water supply service. 2. Because it is not preferable to reduce my death risk from diarrhea or diseases of the various digestive organs. 3. Because it is not reliable whether the safe water supply service is really effective to reduce my death risk. 4. Because I think that I will never suffers from diarrhea or the disease of the various digestive organs. 5. Because I cannot judge it from information only on this. 6. Others( )

In Table 6, the diarrhea mortality risk without implementation of countermeasure is assumed to be fixed as 100/100,000 per year. And we set several patters of diarrhea mortality risk with implementation of countermeasure, which is indicated as ‘X/100,000’ in Table 6, as follows;

Table7: diarrheal mortality risk (* / 100,000)

Case	1st time risk (Net risk reduction level)	2nd time risk (Net risk reduction level)
Case 1	80 (20)	60 (40)
Case 2	80 (20)	40 (60)
Case3	60 (40)	20 (80)
Case4	40 (60)	20 (80)
Case5	60 (40)	80 (20)
Case6	40 (60)	80 (20)
Case7	20 (80)	60 (40)
Case8	20 (80)	40 (60)

And we set 10 patterns of annual fee of the service, which supplies safer water and decreases diarrhea mortality risk, at each time question in each questionnaire sheet; 1, 3, 5, 7, 10, 30, 50, 70, 100 and 300 US$.

5. Measurement of WTP and VSL

In order to estimate WTP for reducing diarrhea mortality risk due to water pollution, we specify the following individual utility function;

$$\Delta V = V_{yes} - V_{no} = a + b \cdot \ln[t], \tag{1}$$

where ΔV : utility difference between two levels,

V_{yes}, V_{no} : utility levels when one answers 'yes' or 'no' for buying the water service,

t : suggested annual fee to buy the water service, and

a, b : unknown parameters.

Equation (1) means that one's utility difference is expressed by the function of two variables, the dummy and the fee, for buying the water service. Based on the random utility theory, we can express one's choice behavior as the following logit model;

$$P_{yes} = \frac{\exp[w \cdot V_{yes}]}{\exp[w \cdot V_{yes}] + \exp[w \cdot V_{no}]} = \frac{1}{1 + \exp[-w \cdot \Delta V]}, \tag{2}$$

$$P_{no} = 1 - P_{yes}, \tag{3}$$

where P_{yes}, P_{no} : theoretical probability of one's decision to answer 'yes' or 'no', and

w : parameter of variance (generally set to be 1 for convenience).

The simultaneous probability density function, that is likelihood function, is constructed by using Equations (2) and (3). And unknown parameters of Equation (1) are estimated by the maximum likelihood procedure, by applying peoples' choice behavior for buying the water service (see Table 6).

Now, we measure the median value as the typical value of WTP for reducing diarrhea mortality risk due to water pollution in each country. The median value of WTP is defined as the fee level where 50% of people will agree to pay for the water service, and it is derived as follows;

$$WTP_{median} = \exp\left[-\frac{a}{b}\right]. \tag{4}$$

And VSL, which is defined as the value of willingness to pay for saving one life statistically, is derived as follows;

$$VSL = \frac{WTP[\Delta r]}{\Delta r}, \tag{5}$$

where $WTP[\Delta r]$: willingness to pay for Δr, and
Δr: reduction level of mortality risk.

The results of estimation are indicated in Tables 7, 8, 9 and 10, where C1-2nd means the 2nd time question in case 1 for example. Tables 7 and 9 show the estimated parameters of individual utility function in Laos and Vietnam, respectively. It is found that all estimated parameters have enough statistical significance level because all t-values of estimated parameters exceed 3.291 at the significance level 0.05%. Tables 8 and 10 show the measured values of WTP and VSL in Laos and Vietnam, respectively. The values of WTP and VSL are derived by Equations (4) and (5), respectively. The values of WTP for reducing diarrhea mortality risk are measured as 5.720-17.601 US$ per year in Laos and 38.729-59.458 US$ per year in Vietnam, and the values of VSL are measured as 13,838-44,723 US$ per person in Laos and 57,610-229,484 US$ per person in Vietnam.

Now, we have got 16 measured values of WTP in each country, so that it is able to estimate the WTP-function as a function of mortality risk reduction level and to derive the VSL-function by Equation (5). Then we specify the log-linear function, and have estimated the following WTP-function by regression analysis (see Figures 1 and 2);

$$WTP_{Laos} = 2.875 + 2.238 \cdot \ln[\Delta r \times 100{,}000], \tag{6}$$

$$WTP_{Vietnam} = 18.92 + 7.682 \cdot \ln[\Delta r \times 100{,}000], \tag{7}$$

and have derived the following VSL-function;

$$VSL_{Laos} = \frac{2.875 + 2.238 \cdot \ln[\Delta r \times 100{,}000]}{\Delta r}, \tag{8}$$

$$VSL_{Vietnam} = \frac{18.92 + 7.682 \cdot \ln[\Delta r \times 100{,}000]}{\Delta r}. \tag{9}$$

By using the WTP-function and the VSL-function, the values of WTP for reducing diarrhea mortality risk are measured as 9.580-12.682 US$ per year in Laos and 41.932-52.581 US$ per year in Vietnam, and the values of VSL are measured as 15,853-47,898 US$ per person in Laos and 65,726-209,660 US$ per person in Vietnam (see Tables 11 and 12).

Table 8: Estimated parameters of individual utility function in Laos

Case	*a* *constant	*b* *ln[suggested fee]	Likelihood ratio	Hit ratio	Number of samples
C1-1st	2.954 (25.055)	-1.348 (-28.954)	0.422	0.819	3,120
C2-1st	2.612 (23.949)	-1.313 (-28.971)	0.404	0.816	3,340
C3-1st	3.663 (27.601)	-1.640 (-29.983)	0.502	0.854	3,450
C4-1st	3.089 (26.106)	-1.345 (-29.735)	0.425	0.825	3,180
C5-1st	2.806 (24.673)	-1.174 (-28.646)	0.371	0.796	2,940
C6-1st	3.424 (27.450)	-1.389 (-30.459)	0.444	0.828	3,180
C7-1st	3.487 (27.780)	-1.260 (-30.467)	0.407	0.820	3,080
C8-1st	3.212 (32.983)	-1.206 (-36.749)	0.387	0.809	4,590
C1-2nd	3.466 (27.606)	-1.208 (-30.515)	0.432	0.825	3,120
C2-2nd	3.088 (27.631)	-1.200 (-31.139)	0.384	0.808	3,340
C3-2nd	4.118 (30.435)	-1.474 (-32.794)	0.477	0.852	3,450
C4-2nd	3.504 (28.299)	-1.250 (-30.956)	0.403	0.823	3,180
C5-2nd	2.060 (19.490)	-1.181 (-26.160)	0.356	0.812	2,940
C6-2nd	2.656 (22.135)	-1.472 (-26.854)	0.438	0.839	3,180
C7-2nd	2.677 (23.180)	-1.343 (-27.800)	0.413	0.819	3,080
C8-2nd	2.701 (29.189)	-1.276 (-34.731)	0.398	0.813	4,590

Note: t-values are in brackets ( ).

Table 9: Measured values of WTP and VSL in Laos

Case	Δ r [* / 100,000 / year]	WTP [US$ / year]	VSL [US$]
C1-1st	20	8.945	44,723
C2-1st	20	7.310	36,550
C3-1st	40	9.329	23,323
C4-1st	60	9.948	16,580
C5-1st	40	10.908	27,270
C6-1st	60	11.756	19,593
C7-1st	80	15.911	19,888
C8-1st	80	14.349	17,937
C1-2nd	40	17.601	44,004
C2-2nd	60	13.114	21,857
C3-2nd	80	16.330	20,413
C4-2nd	80	16.503	20,629
C5-2nd	20	5.720	28,602
C6-2nd	20	6.073	30,367
C7-2nd	40	7.345	18,363
C8-2nd	60	8.303	13,838

Table 10: Estimated parameters of individual utility function in Vietnam

Case	*a* *constant	*b* *ln[suggested fee]	Likelihood Ratio	Hit ratio	Number of samples
C1-1st	4.169 (16.247)	-1.108 (-16.124)	0.338	0.787	1,030
C2-1st	2.898 (15.999)	-0.786 (-15.568)	0.219	0.749	1,150
C3-1st	5.029 (16.606)	-1.283 (-16.426)	0.388	0.822	1,110
C4-1st	5.860 (16.506)	-1.533 (-16.715)	0.460	0.843	1,150
C5-1st	5.022 (16.410)	-1.291 (-16.291)	0.391	0.807	1,080
C6-1st	5.883 (16.094)	-1.526 (-16.244)	0.456	0.830	1,100
C7-1st	7.738 (14.799)	-1.894 (-14.767)	0.512	0.868	1,160
C8-1st	6.269 (15.900)	-1.637 (-16.159)	0.483	0.843	1,110
C1-2nd	5.127 (15.897)	-1.288 (-15.629)	0.386	0.820	1,030
C2-2nd	3.599 (16.837)	-0.933 (-16.257)	0.273	0.782	1,150
C3-2nd	5.535 (16.259)	-1.384 (-16.057)	0.412	0.833	1,110
C4-2nd	6.948 (15.592)	-1.804 (-15.901)	0.516	0.862	1,150
C5-2nd	3.758 (16.440)	-0.982 (-16.013)	0.292	0.772	1,080
C6-2nd	3.220 (16.173)	-0.881 (-15.946)	0.256	0.758	1,100
C7-2nd	4.844 (16.983)	-1.214 (-16.591)	0.364	0.811	1,160
C8-2nd	5.706 (16.268)	-1.472 (-16.343)	0.441	0.832	1,110

Note: t-values are in brackets ( ).

Table 11: Measured values of WTP and VSL in Vietnam

Case	Δ r [* / 100,000 / year]	WTP [US$ / year]	VSL [US$]
C1-1st	20	43.021	215,103
C2-1st	20	39.885	199,424
C3-1st	40	50.326	125,816
C4-1st	60	45.730	76,217
C5-1st	40	48.848	122,120
C6-1st	60	47.184	78,640
C7-1st	80	59.458	74,323
C8-1st	80	46.088	57,610
C1-2nd	40	53.566	133,916
C2-2nd	60	47.283	78,805
C3-2nd	80	54.533	68,166
C4-2nd	80	47.043	58,803
C5-2nd	20	45.897	229,484
C6-2nd	20	38.729	193,646
C7-2nd	40	53.991	134,977
C8-2nd	60	48.215	80,359

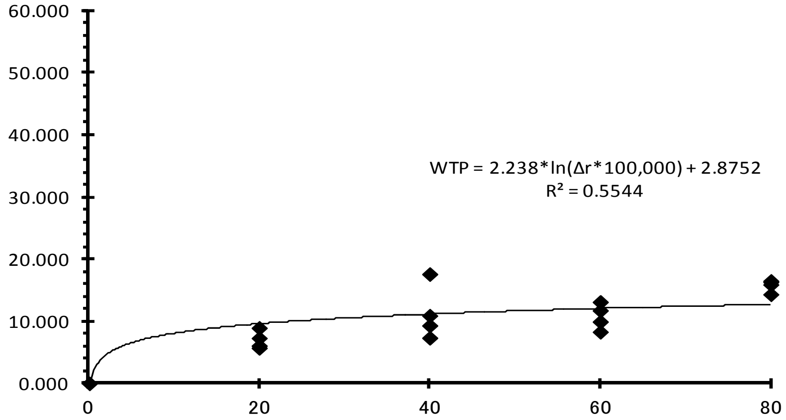

Figure 1: Estimated WTP-function in Laos

Table 12: Measured values of WTP and VSL by WTP-function in Laos

Δ r [* / 100,000 / year]	WTP [US$ / year]	VSL [US$]
20	9.580	47,898
40	11.131	27,827
60	12.038	20,064
80	12.682	15,853

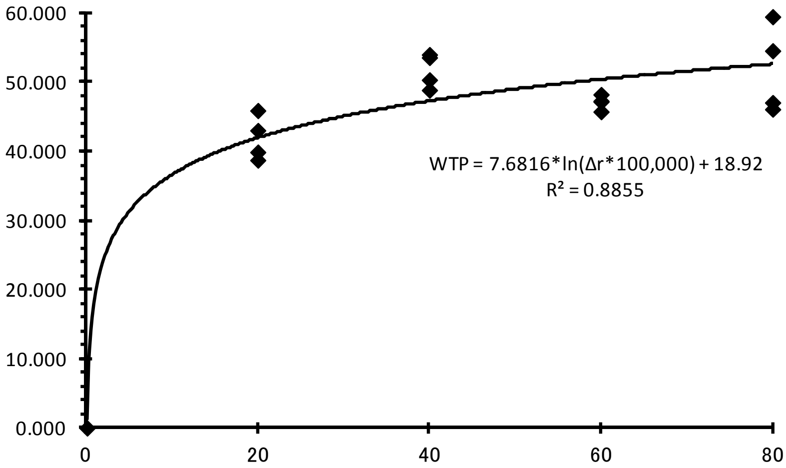

Figure 2: Estimated WTP-function in Vietnam

Table 13: Measured values of WTP and VSL by WTP-function in Vietnam

Δ r [* / 100,000 / year]	WTP [US$ / year]	VSL [US$]
20	41.932	209,660
40	47.256	118,141
60	50.371	83,952
80	52.581	65,726

6. Concluding remarks

The main purpose of this study is to provide basic information for cost benefit analysis of countermeasures against water pollution problem in Laos and Vietnam. Up to here, we have derived the resident's WTP function for each mortality risk reduction level. That is just the damage cost function of death risk due to diarrhea and diseases of the various digestive organs. WTP has been measured 9.580-12.682 US$ per year in Laos and 41.932-52.581 US$ in Vietnam. As we have seen in Table 3, the average mortality risk for 6 countries on the basin of Mekong River in 2004 is around 80/100,000 and for Japan is 16/100,000 (especially almost 0 about diarrhea). Actually, all of the difference between them couldn't be reduced to implementation level of those water-related facilities, but considerable degree of effect is expected for it, so to speak, around 40-60/100,000 of mortality risk reduction. Our estimates of WTP for the range seem to be comparably stable. Therefore it may be suitable to employ these values to calculate WTP and VSL in correspondence (see Equation (5)).

It may be worthwhile to compare WTP with actual water charge in urban zone. Water supply is charged in either of Ho-Chi-Minh City and Hanoi City as 0.17-0.47 US$/m^3 for domestic sector; see JICA (2008). In fact, the fee is not so much smaller than the one of Japan, 0.24-1.19 US$/m^3. Because of lack of data about the amount of annual water usage per capita or household in Vietnam, direct comparison is unenforceability. However, with the fact that the average annual expenditure for water supply per household in Japan is around 300 US$, then it may be said that the derived WTP is short yet to implement water-related infrastructures fully in Vietnam without any international aids. The same logic may be applicable to the case of Laos.

On the other hand, VSL has been measured as 83,952-118,141 US$ in Vietnam and 20,064-27,827 US$ in Laos (at 40-60/100,000 of mortality risk reduction). In contrast with these values, GDP (PPP) per capita of Vietnam was 2,783 US$ in 2008 while the average annual income of these respondents is 1,689 US$., also 2,204 US$ in 2008 while the one of these respondents is 1,474 US$ for Laos. The value of VSL measured here is counted about 30-40 times of GDP (PPP) per capita for Vietnam and 9-12 times of it for Laos. Looking back to the argument in Chapter 2, representative value of VSL (though the subject risk is traffic accident) was come near 70 times of the GDP per capita in Japan. These results show consistency with the EKC hypothesis, that is, the ratio of people's lifeguard expenditure to their income will be larger as they become richer.

Acknowledgment:

These outputs of this study are our first attempt to approach the water resource conflict problem of Mekong River. For those regions, sustaining effort to find out certificate values of water resource is quite necessary, and exactly as extension of it, we can collect the guideline to avoid such the worst catastrophic situation.

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References

1) Asian Development Bank (2007): Access to Drinking Water and Sanitation in Asia: Indicators and Implications, Asian Water Development Outlook 2007 Discussion Paper.
2) Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. S. Holling, B. Jansson, S. Levin, K. Maler, C. Perrings, D. Pimentel (1995): Economic gowth, carrying capacity, and the environment Science, Vol.268(5210), pp.520-521.
3) C. D. Kolstad: Environmental Economics, Oxford University Press, 1999.
4) Mekong River Commission (2008): An assessment of water quality in the Lower Mekong Basin, MRC Technical Paper, No. 19.
5) Naito (2008): Survey Research of Environmental Kuznets Curve Hypothesis, Journal of Faculty of Economics, KGU, Vol. 15, pp.117-131, in Japanese.
6) U.S. Centers for Disease Control and Prevention (2006): Safe Water System: A Low-Cost Technology for Safe Drinking Water, Fact Sheet, World Water Forum 4 Update, Atlanta GA.
7) U.S.EPA: The Benefits and Costs of the Clean Air Act, 1990 to 2010, EPA Report to Congress, EPA-410-R-99-001, November 1999.
8) World Health Organization (2010): World Health Statistics 2010.