Analysis of Citizens' Qualitative Risk Assessment for the Development of Environmental Risk Communication in Contaminated Sites

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Abstract: - Investigations on stakeholders' risk judgments potentially provide basic understanding on how to develop integrated risk management and risk communication strategies. This study investigates factors affecting laypeople's risk perception. The model for investigations was created in order to examine relationship between laypeople's risk perception and its determinants. In this model, the relationship between lay peoples' risk perception and potential predictive factors, including socio-demographic characteristics of laypeople and factors related to the nature of risks (perceived probability of environmental contaminations, probability of receiving impacts, and severity of catastrophic consequences), were examined by means of multiple regression analysis. Psychological and cognitive factors, such as the ability to control the risk, concern, experiences, perceived benefits of industrial development, and social trust were also included in the analysis. The observations have been carried out in the Maptaphut municipality in Rayong Province, Thailand. 181 questionnaire sheets were distributed to residents who live in industrial communities. The results showed that the laypeople' risk perception was constructed based on their perceived severity of catastrophic consequences, and perceived probability of receiving impacts; however, people in low-risk communities perceived risks based on their experimental processing system which is influenced by their collective experiences and social trust.

Key-Words: - *Qualitative Risk Assessment, Integrated Risk Management, Collaborative Environmental Risk Communication, Risk Perception*

1 Introduction

Most of industrial activities developed all around the world have given rise to catastrophic consequences to environments and human health [1–4]. The Maptaphut industrial development area, a chemical industry hub of Thailand, is one of various cases representing a failure in environmental and health risk management. Since its establishment, various types of environments in the area, including soil, water resources, and air, have been contaminated with hazardous gas and compounds [5–6, 22–23]. The most serious problem concerning the public is air pollutants, which has been assumed as a cause of respiratory disease among patients in the area [7, 8]. The result of air monitoring during 2007–2013 reported by Pollution Control Department revealed that various types of volatile organic compounds (VOCs) in ambient air were above the annual standard [9], including Benzene, 1,3 Butadiene, Chloroform, and 1,2 Dichloromethane. In 2003, the National Cancer Institute in Thailand reported that the number of cancer patients in the area was higher than the national average and the number of patients in Bangkok City [10]. It was also found that the rate of patients with disease caused by pollution in the environment has also increased rapidly in the area since 2003 [11].

The environmental situation in area became crisis and critical to the public. Though, the environmental problems in the area have been enthusiastically solved by national, provincial, local governments as well as the industrial sector, many stakeholders still believe that the risks associated with industrial activities still exist. One of the critical issues is a failure in risk communication among lay people, governments, and the industrial sector. This failure has impacted a decision-making process which, until now, cannot be carried out based on all parties' agreement. Public participation in environmental risk management often came out fail. Governments mostly make a decision regarding the development of industrial activities based upon scientifically estimated risks provided by experts from consultant companies; however, local residents' risk judgments are not well comprehended and taken into account. As a result, industries have been growing despite lay people's protests. Thus, the differences in risk judgments among lay people, governments, and industrial sectors are a major cause of the problems in risk communication [11–13].

It is essential to investigate factors determining lay people's risk judgments and perceptions. Understanding laypeople' risk perceptions can help developing integrated risk management and effective risk communication between stakeholders and lay people [12, 14, 16–17]. It also help improving risk communication in several aspects; for instance, effectively establish communication efforts, properly select pieces of information and the format for such information [23], and foster information sharing between relevant parties. Risk perception is viewed differently by people due to their attitudes and moral values [14]. In addition to social and cultural factors, such as gender, value systems, and social norms, people's conscious, analytical way of thinking may cause significant differences in risk perception [14]. Crawford-Brown [18] noted that residents' perceived risk might depend on the evidence they possess regarding the frequency, severity, and variability of effects. Lay people's risk judgment involves judgments of probability [13, 15], severity of catastrophic consequences [15], and perceived control [15]. However, currently, the contribution of perceived probability, severity of catastrophic consequences, and ability to control the risk to people's risk judgment is still unclear. Furthermore, how the relationships between these factors differ among people experiencing a different level of threat is not well understood. This study therefore emphasizes these particular issues so that risk communication can be properly designed.

This study aims to examine relationship between laypeople's risk perception and influential factors, including, (1) socio-demographic characteristics of residents (gender, age, income, education) (2) lay understanding of the nature of risks (perceived probability of environmental contamination, perceived probability of receiving impacts, and perceived severity of catastrophic consequences) and (3) psychological and cognitive factors (perceived ability to control the risk, concerns about family, previous experiences in facing polluted air, perceived benefits from industrial development, and social trust. The Maptaphut industrial estate development area in Rayong Province, Thailand was selected as a case study. The study consists of three parts. First, the study analyses the degree of risks perceived by laypeople. Second, the relationship between risk perception and selected potential predictive factors is analysed by conducting a multiple regression analysis. The study also identifies how the relationship between these factors differs among people facing a different level of hazardous gas contamination. Finally, the discussion on the development of risk communication based on the findings is conducted and risk communication strategies are proposed.

2 Maptaphut Industrial Development Area, Thailand

The Maptaphut Industrial Estate (MIE), located in the Rayong Province in Thailand, is one of the 29 industrial estates in Thailand. It is located at around 12.5 N (lat.), 101.5 E (long.), nearby the Gulf of Thailand. The project was first established in 1989 by the state enterprise, the Industrial Estate Authority of Thailand (IEAT), and the Ministry of Industry [19]. MIE initially had a total area of 6.72 Km^2 that used to consist of agricultural farms, waste land, and small rural farming and fishing communities. In 2002, the area increased to 11.2 Km^2, and it was later found that many factories are situated in nearby residential areas [20]. Currently, there are five industrial estates in Maptaphut area: Maptaphut, East Hemaraj, Asia, Padaeng, and RIL. About 1,800 factories and a seaport are situated in the area [19]. Most of the industrial plants are petrochemical factories, coal-fired power plants, chemical fertilizer factories, and oil refineries. Since its first operation in 1990, many pollution problems have been reported by the public media. In 1997, it was reported that 1,000 students and teachers from Maptaphut Panphittayakarn School suffered from illnesses after inhaling the toxic emissions from factories situated nearby and were hospitalized for breathing difficulties, nasal irritation, headaches, and nausea. The Ministry of Education finally approved the relocation of the school in 2005. The industrial development in the area has been critiqued by the public due to health impacts suffered by local people as well as other social impacts, including drug abuse, crime, and pregnancy among young people [21].

Environmental problems in Maptaphut have concerned the public, industrial investors, governments, and NGOs. Among those problems, air contamination is perceived as the most serious problem [22]. According to the result of air quality monitoring conducted by the department of pollution control during 2007–2013, several types of Volatile Organic Compounds (VOCs) were found to be above the national standard. There are also other air pollutants distributed throughout the area, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM10) [22, 23].

3 Concepts and Theories

3.1 Risk-related concepts

Currently, risk-related concepts are various. According to Lash and Wynne [17], risks can be conceptualized as the probabilities of catastrophic harm caused by technological or other modernization processes. According to Otway and Thomas [24], there are at least two major risk concepts. The first is the realist approach which views risk as a physical reality that is estimated based on our scientific knowledge. The second is risk as a social construct which emphasizes the contrasting definitions of the risks in social reality. In other words, risk can be conceptualized into the following three approaches: objective, subjective, and perception approaches [18]. The objective approach refers to risk as a product of scientific research conducted based on experiments and scientific methods. In contrast, the subjective approach claims that risk is not solely objective. Risk varies depending on our state of mind influenced by collective experiences, social norms, and uncertainties. The last approach is the perception approach. Risk is defined as the set of all destructive consequences which a person believes to be possible when he/she has evidence about the frequency, severity, and variability of effects [18]. However, Fischoff [25] stated that no definitions of risk are ultimately correct as there is no one suitable definition which applies to all problems. Recently, traditional risk assessment based on science alone has increasingly come into question [16]. This is because the risks to society are exhibiting far more diverse aspects beyond the scope of scientific estimated risk. Ropeik [16] stated that although scientific risk assessment is thoroughly conducted by using reliable methods, results will conflict with the inherent way human beings perceive risk because the way normal people live is not well understood by experts and policy makers. Many scholars are becoming increasingly interested in risk perception. Understanding how it is perceived can potentially contribute to the improvement of risk communication [12, 13, 30]. Furthermore, such understanding can also help mitigate underlying impacts [26, 27] and support the long-term engagement of related parties in risk management [28].

3.2 Risk perception

Risk perception is a judgment of adverse consequences of a particular hazard and can be made by an individual, a group of people, or public society [29]. The term "risk perception" is generally used in referring to natural hazards and threats to the environment or health [14]. Risk perception can be formed based on both belief and self-appraisal [29, 14, 36]. Up until now, four approaches have been used to study how risks are perceived. The first approach is the socio-cultural paradigm, including the cultural theory of risk, often referred to as cultural theory. Based on the cultural theory, risk perception is constructed from beliefs influenced by social forces in our society [39, 40]. Although it is constructed from beliefs, this sort of risk perception reflects the interest and value of each group, the diverse meaning of the term "risk," and natural phenomena within each group [29, 43]. The second approach is the psychometric paradigm, which includes the psychometric model and the basic risk perception model (BRPM). The psychometric model proposed by Fischhoff in 1978 addressed how human risk perception is significantly influenced by the physical properties of risks as well as emotional factors, such as dread, control, and knowledge [13, 25]. Some scholars working with this approach have critiqued the cultural theory. For instance, the study conducted by Sjoberg [35] revealed that the relationship between culture adherence and risk perceptions were low. His explanation is that risk perception is related to real risks rather than cultural aspects. In 1993, Sjoberg developed his own model, i.e., the basic risk perception model, which explains more diverse dimensions of risk perception. The psychometric dimension is adapted [41], and four factors, i.e., attitude, risk sensitivity, specific fear, and trust, are included. The third approach is the interdisciplinary paradigm which applies several concepts to explain risk perception. In this paradigm, the most distinct concept is Kasperson's social amplification of risk framework (SARF) [33]. It is a systematic way to conceptualize how the scientific risk is influenced by psychological, social, institutional, and cultural processes [34]. Regarding this framework, risk is viewed as both a social construct and the physical nature of risk [31]. The last approach is the axiomatic measurement paradigm which focuses on the way normal people subjectively transform objective risk information [32]. Perceived probability and perceived severity are related to the degree of risks perceived by people.

To summarize, risk perception is a dynamic process that takes place in a society. The factors determining risk perception can be related to all approaches, and may differ in each specific threat. In the case of environmental health risk associated with industrial development, risk perception may not be determined only by social adherence and/or emotional factors. It is also important to understand the nature of risks, including probability and consequence. People need information related to the physical nature of the risk presented to them in a way they can understand. That is why studies on risk perception are essential.

3.3 Study framework

To develop risk communication model and strategies, the study conducts investigation on laypeople' risk perception. It was believed that laypeople performed risk assessment based on their analytical ways of thinking [14, 15], and their risk assessment could reflect actual risks [35]. According to the literature review, the factors potentially affecting risk perception could be divided into three main groups. The first group comprises factors related to the nature of risks, such as perceived probability of environmental contamination, probability of receiving impacts, and perceived severity of catastrophic consequences. The second group consists of psychological and cognitive factors, including perceived ability to control risks, concerns about family members, previous experiences with air pollution, perceived benefits from industrial development, and social trust. The third group is factors related to socio-demographic characteristics of residents such as gender, age, income, and education. This study investigated the relationships between these selected factors and risk perception held by laypeople in contaminated sites.

The study defined lay people's risk perception as expected losses or potential adverse consequences caused by environmental contamination [29]. To measure risk perception held by lay people, the study explores lay perceptions of potential impacts of industrial activities on human health and well-being which were classified into the following five aspects: 1) psychological effects, i.e., the negative impacts of air pollutants on the human psychological system, such as anxiety or mental disorder; 2) physical health effects, i.e., the impact of air pollutants on the human immunity system; 3) respiratory effects, i.e., any respiratory diseases caused by inhalation of air pollutants; 4) lifestyle disruption, i.e., a negative change in local people's daily life, local customs, or tradition; and 5) nuisance, i.e., annoying conditions caused by the change of living environments, including, for example, noise pollution. The conceptual framework shown in figure 1, and the hypotheses are derived and inspected in this study.

(1) *Lay people's perceived risks are determined by factors related to the physical nature of risk rather than socio-demographic characters and psychological/cognitive factors.*

(2) *Determinants of risk perception constructed by laypeople living in a different community experiencing a different level of risks might be different because of using a different risk processing system*

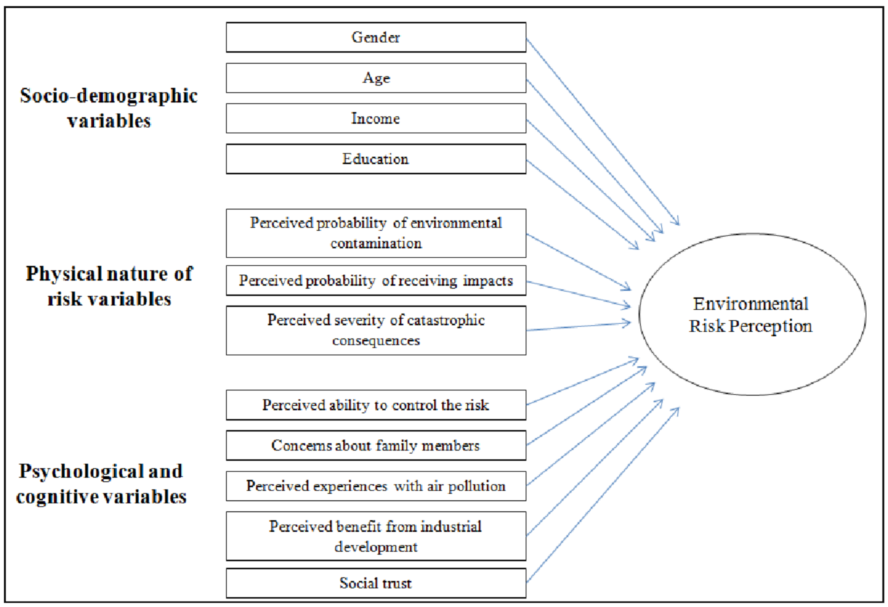

Figure 1- Study framework

4 Methodology

4.1 Case study

The Maptaphut municipality and related areas, located in Rayong Province, Thailand, was selected as a case study because of the seriousness of environmental contamination and the need for risk mitigation and communication strategies in this area. Up until 2013, there were 38 communities in the Maptaphut area. The population is 56,591 people (28,504 male and 28,087 female), and the number of households is 42,295 [42]. The area contains five industrial estates which are surrounded by residential and commercial areas.

4.2 The sampling group

Residents living in industrial communities in Maptaphut area were defined as the sampling group of this study. In addition, a sampling group was divided into three groups based on the degree of hazardous gas contamination throughout the Maptaphut area. To classify a level of potential threat faced by communities, the study employed the result of a study on VOCs (Benzene and 1,3 Butadiene) contamination conducted by Thepanondh et al. [22] as well as the results of a study on SO_2, and NO_2 concentrations conducted by Chusai et al. [23]. The hazardous gas and compounds investigated in those two studies have been assumed to be a cause of respiratory disease and cancer in the area [8].

Regarding the study conducted by Thepanondh and his colleagues, measurements of VOCs concentration across the Maptaphut area were carried out by means of gas chromatography mass/spectrophotometer (GC/MS) and conducted based on the US.EPA TO 15 procedure. The result showed that concentration of VOCs in the area varied according to the proximity to emission sources and types of compounds. Although this investigation was conducted during 2007–2008, the result is still consistent with the result of air monitoring conducted on a monthly and annual basis by the department of pollution control [46]. More specifically, benzene and 1,3 butadiene have, thus far, been found to be higher than the annual national standard. In the case of SO_2, and NO_2 concentrations, the study carried out by Chusai and colleagues included observations of the dispersion of NO_2 and SO_2 throughout the Maptaphut area by using a spatial model called the American Meteorological Society-Environmental Protection Agency Regulatory Model (AERMOD). The result showed varying degrees of NO_2 and SO_2 concentrations caused by both stack and non-stack sources; the result also varied depending on geographical and atmospheric conditions in each particular area.

Ten local communities, all of which were relatively old and established before the industrial projects, were selected for this study. These selected communities were categorized into three types in accordance with the level of hazardous gas contamination experienced by each community. Communities located in areas with high concentrations of Benzene, 1,3 Butadiene, SO_2, and NO_2 will be given a score of 3. Communities located in areas with moderate concentrations of those hazardous gases and compounds will be given a score of 2 and 1, respectively, and communities located in an area associated with a degree of pollutant concentration lower than the national standard will be given a score of 0. The result is shown in table 2.

Table 2 - Degree of potential risk faced by Maptaphut communities [N=181]

Community	Degree of Concentration* (μg/m3)			Average**	Potential Risk	N.
	1,3 Butadiene	*Benzene*	*NO_2/ SO_2*			
Banprayoon and Namrin	1	1	1	1.00	Low	19
Nuangfab	1	1	1	1.00	Low	11
Bantrakual	3	2	2	2.33	High	20
Nuenpra	2	2	3	2.33	High	31
Maptaphut	2	1	3	2.00	Moderate	40
Banbonnuen	0	1	2	1.00	Low	14
Banpandintai	0	1	1	0.67	Low	8
Nuenkrapork	0	1	3	1.33	Low	8
Mapkha	0	2	3	1.67	Moderate	18
Nuenpayom	0	3	3	2.00	Moderate	12

*(0 = No concentration; 1 = low concentration; 2 = moderate concentration; 3 = high concentration)
**(0-1.50 = low risk; 1.51–2.25 = moderate risk; 2.26–3 high risk)

4.3 Data collection and analysis

In-depth interviews with local people were conducted in February-March 2013. Then, the questionnaire sheet was created and distributed to 200 people living in the selected communities during October and November 2013. In total, 181 questionnaire sheets (about 90%) were completed. Factors, variables, and types of questions used to collect the data are shown in table 3. A Likert scale, a single-select rating scale question [38], was used to collect the data related to respondents' attitudes about industrial risks. The provided answer choices range from one (no impact) to four (high impact). For other questions, answer choices were also provided which were similar to a Likert-scale question, albeit slightly different in some questions.

All collected data are statistically analyzed by using a multiple regression analysis. To identify the factors determining the risk perception, a multiple regression analysis was performed in order to evaluate the relationship between risk perception (dependent variable) and selected potential predictive factors (independent variables), such as socio-demographic characteristics of laypeople, factors related to the physical nature of risks, and psychological factors. The results are presented as a set of regression equations describing the statistical relationship between the dependent and independent variables. A multiple regression was performed again in order see the determinants of risk perception held by lay people living in each type of community. All results are discussed in terms of their implications for the development of risk communication strategies which potentially bridge the risk perception gap.

Table 3 - Factors, variables, and development of questionnaire [N=181]

Factors	Variables	Questions
Risk perception	Lifestyle disruption	-Have industrial activities in the area impacted your original career? -As a result of industrial development, how much can you use local resources for your leisure activities?
	Respiratory effect	-Has air quality in the area caused respiratory disease among residents?
	Physical heath effect	-Has air quality in the area caused several kinds of cancer among residents? -Has air quality in the area caused disease related to self-immunity systems such as immunity disorder, fever, etc.?
	Psychological effect	-As a result of industrial development, do you feel worried about your health? -As a result of industrial development, do you feel worried about your future life?
	Nuisance effect	-Have industrial activities caused nuisances such as noise or smells? -Has the current condition of the community caused nuisances such as traffic jam, congestion, noise, smells, etc.?
Socio-demographic factors	Gender	-Please identify your gender
	Age	-Please identify your age
	Income	-How much is your average income per month?
	Educational level	-What is your highest educational level?
The nature of environmental risks	Probability of contamination	-What is the possibility that industries have still generated pullulated air in the area?
	Probability of receiving impacts	-What is the possibility that you will be impacted by air pollution in the area?
	Severity of consequences	-How severely can contaminated air in the area affect humans?
Psychological factors	Ability to control the risk	-Do you know how to protect yourselves from contaminated air?
	Concern (number of family members)	-How many family members do you have?
	Previous experiences in facing polluted air	-Have you ever felt irritated in your eyes or nose when staying near the vicinity of factories?
	Perceived benefit from industrial development	-Has industrial development in the area generated more income for your family?
	Social trust	-Do you think that public authorities have the capability to prevent an occurrence of air pollutants in the area? -Do you think that industrial agencies have the capability to prevent an occurrence of air pollutants in the area?

5 Results and Discussion

5.1 General characteristics of respondents

The number of male respondents is slightly higher than one of female respondents, 51.4 and 48.6 percent respectively (see table 4). Most of respondents are in working age; namely, respondents in the age of 30-39 and 20-29 years old occupied a major proportion, 30.4 and 28.7 percent. Most of them have only high school's degree which is considered sufficiently eligible for several kinds of low-skilled jobs such as labor force in service sectors and industrial manufacturing sectors, construction worker as well as labor in agricultural sector. The survey showed that people working in agricultural sector as well as working as a labor are a majority career of respondents occupying 31.5 percent; whereas, the number of people working as an industrial staff was counted as 17.1 percent. Considering the type of communities in relation to a degree of hazardous gas concentrations, the result of the survey showed that 70 people, almost 39 percent, live in moderate-risk communities, and 60 people, 33 percent, live in low-risk communities. Respondents living in high-risk communities are counted as 28.2 percent.

Table 4 - General characteristics of respondents [N=181]

General Characteristics of Respondents [N=181]		N	%
Gender	Male	88	48.6
	Female	93	51
Age	Less than 20 years old	18	4
	20-29 years old	52	9.9
	30-39 years old	55	28.7
	40-54 years old	45	24.9
	55 and more than 55 years old	11	6.1
Education	Primary school	21	11.6
	High school	100	55.2
	Vocational degree and associate degree	11	6.1
	Undergraduate degree	44	24.3
	Higher than undergraduate degree	5	2.8
Career	Public servant	18	9.9
	Laborer in agriculture and service sectors	57	31.5
	Industries' staff	31	17.1
	Private company	21	11.6
	Self-employment, including self-business, services, and merchants	34	18.8
	Student	15	8.3
	Housewife	5	2.8
Types of community	Low-risk community	60	33.1
	Moderate-risk community	70	38.7
	High-risk community	51	28.2

5.2 Lay people's risk perception

A degree of risk perception is presented in a form of mean scores calculated by adding the values of all variables related to risk perception (see table 5), and then dividing that sum by the number of total variables. The value of the calculated mean was regrouped and divided into 5 categories, ranging from 0 (no risk perception) to 4 (extremely high risk perception). The higher score represents higher perceived risks. The result demonstrated that people living nearby factories were highly concerned with the impacts of pullulated air on physical health, respiratory health, and nuisance respectively; furthermore, lay people were moderately concerned with the impacts on local lifestyle and psychological health.

Table 5 - Risk perception [N=181]

Perception on environmental and health risks		Mean*	SD.
Respiratory health impacts	Has air quality in the area caused respiratory disease among residents?	2.71	.868
Physical health impacts	Has air quality in the area caused several kinds of cancer among residents?	2.77	.920
	Has air quality in the area caused disease related to self-immunity systems such as immunity disorder, fever, etc.?	2.82	.885
Psychological health impacts	As a result of industrial development, do you feel worried about your health?	2.57	.924
	As a result of industrial development, do you feel worried about your future life in Maptaphut?	2.40	.993
Lifestyle disruption	Have industrial activities in the area impacted your original career?	2.24	1.152
	As a result of industrial development, how much can you use local resources for your leisure activities?	2.36	1.059
Nuisance	Have industrial activities caused nuisances such as noise or smells?	2.85	.853
	Has the current condition of the community caused nuisances such as traffic jams, congestion, noise, smells, etc.?	2.61	.934

* level of risk perception: 0–0.80 = No perception: 0.81–1.6 = Low perception: 1.61–2.40 = Moderate perception: 2.41–3.20 = High perception: 3.21–4 = Extremely high perception

5.3 Factors determining risk perception

Multiple regression analysis was performed to test if the factors related to social-demographic characteristics of residents, the nature of environmental risks, and psychological factors significantly predicted respondents' risk perceptions. The predictors were the eleven indices, while the criterion variable was the degree of risk perception. The results indicated that the linear combination of the three types of predictors could predict the degree of risk perception exhibited by respondents. Three regression models are shown in table 6.

In model 1, only variables related to socio-demographic characteristics of respondents were included in the analysis, and the result showed that the linear combination of those four variables, including gender, age, income, and education, was significantly related to the degree of risk perception, $F(4,176) = 5.735$, $p = .000$. The multiple correlation coefficient was .340, indicating that only 11.5% of the variance in risk perception can be accounted for by the linear combination of those selected predictors. In model 2, factors related to socio-demographic characteristics of respondents and factors related to the nature of risks, including lay people's perceived probability of environmental contamination, perceived probability of receiving impacts, and perceived severity of catastrophic consequences, were included in the analysis, the results showed that the linear combination of those variables was also significantly related to the degree of risk perception, $F(7,173) = 10.742$, $p = .000$. The multiple correlation coefficient was .550, indicating that approximately 30.3% of the variance in risk perception can be accounted for by the linear combination of selected predictors. In model 3, all types of factors were analyzed, and the result shown that the linear combination of those variables was significantly related to the degree of risk perception, $F(13,165) = 11.028$, $p = .000$. The multiple correlation coefficient was .682, indicating that approximately 46.5% of the variance in risk perception can be accounted for by the linear combination of selected predictors. However, only seven variables showed significant relationship with the degree of risk perception. Those variables were gender, income, lay people's perceived probability of environmental contamination, perceived probability of receiving impacts, perceived severity of catastrophic consequences, perceived benefit from industrial development, and trust in public authorizes.

Table 6 - Summary of regression analysis for variables predicting environmental risk perception

Variable		Model 1				Model 2				Model 3			
		B	SE B	β	VIF	B	SE B	β	VIF	B	SE B	β	VIF
Socio-demographic Variables	Gender	-0.281	0.095	-0.211***	1.013	-.184	.087	-.139**	1.060	-.179	.079	-.134**	1.082
	Age	0	0.004	0.007	1.075	.001	.004	.023	1.088	.000	.004	.007	1.149
	Income	3.09E-05	0	0.297***	1.478	2.253 E-05	.000	.216***	1.522	1.736 E-05	.000	.167**	1.563
	Education	-0.051	0.037	-0.114	1.407	-.023	.034	-.052	1.491	.006	.032	.014	1.619
Physical nature of risk variables	Perceived probability of environmental contamination					.254	.078	.253***	1.472	.143	.075	.143*	1.694
	Perceived probability of receiving impacts					.176	.075	.186**	1.569	.203	.071	.213***	1.721
	Perceived severity of catastrophic consequences					.108	.067	.116	1.274	.169	.062	.177***	1.290
Psychological and cognitive variables	Perceived ability to control the risk									.076	.070	.064	1.074
	Concerns about family members									-.055	.021	-.157	1.087
	Perceived experiences with air pollution									.085	.065	.080	1.164
	Perceived benefit from industrial development									.118	.033	.217***	1.135
	Trust in public authorities									-.119	.054	-.169**	1.810
	Trust in industrial agencies									-.046	.050	-.068	1.691
R square		0.115				0.303				0.465			
F for change in R square		5.735				10.742				11.028			

Note: ***p < .01. **p < .05.*p < .10

5.4 Factors determining risk perception constructed by laypeople in different communities

In this section, the study aims to examine determinants risk perception held by lay people living in a community experiencing the different levels of hazardous gas contaminations. Respondents were classified into three groups according to the level of pollutant concentrations experienced by their communities; high-risk community, moderate-risk community, and low-risk community (details regarding classification methods are shown section 4.2; Sampling group).

The results indicated that the linear combination of the twelve predictors could predict the degree of risk perception exhibited by respondents, but its power to explain the degrees of risk perception held by the respondents in the three types of communities was different (see Table 7). In high-risk communities, the linear combination of the selected predictors was significantly related to the degree of risk perception, $F(13,36) = 7.467, p = .000$. The multiple correlation coefficient was .854, indicating that approximately 72.9% of the variance in risk perception can be accounted for by the linear combination of selected predictors. The linear combination of these predictors could also explain a significant proportion of the variance in the risk perception score given by respondents in moderate-risk communities ($R^2 = .559$, $F(13,56) = 5.460$, $p = .000$) and low-risk communities ($R^2 = .520$, $F(13,46) = 3.829$, $p = .000$).

The significance of individual variables in predicting risk perception scores is presented in Table 4.9. It was found that the variables significantly predicting risk perceptions held by the respondents in the three types of communities were different. For respondents in high-risk communities, two of the twelve predictors were statistically significant: perceived probability of environmental contamination and perceived benefits from industrial development. In contrast, the perception score given by respondents in moderate-risk communities was significantly predicted by the variables of perceived probability of receiving impacts and perceived severity of catastrophic consequences. The perception score given by respondents in low-risk communities was significantly predicted by two predictors: perceived experiences with air pollution in the area and trust in public authorities. A regression model with significant predictors of risk perception held by respondents in each type of community could be presented as follows.

Table 7 - Variables predicting risk perception constructed by respondents in three types of communities

Variable		High-risk Community [N=50] missing 1				Moderate-risk Community [N=70]				Low-risk Community [N=60]			
		B	SE B	β	VIF	B	SE B	β	VIF	B	SE B	β	VIF
Socio-demographic Variables	Gender	-.230	.170	-.149	1.627	-.119	.121	-.098	1.245	-.184	.118	-.184	1.328
	Age	.003	.008	.037	1.538	.001	.007	.025	2.009	-.004	.004	-.104	1.110
	Income	-1.181E-05	.000	-.105	3.007	2.641E-05	.000	.197	1.923	9.560 E-06	.000	.144	1.699
	Education	.080	.073	.162	2.922	.045	.046	.104	1.434	-.016	.048	-.051	2.084
Physical nature of risk variables	Perceived probability of environmental contamination	.581	.215	.433***	3.400	.069	.096	.075	1.359	.050	.098	.069	1.737
	Perceived probability of receiving impacts	.157	.219	.132	4.506	.329	.081	.413***	1.325	.068	.102	.098	2.049
	Perceived severity of catastrophic consequences	.001	.162	.001	1.937	.199	.080	.242**	1.201	-.016	.090	-.022	1.534
Psychological and cognitive variables	Perceived ability to control the risk	-.105	.157	-.075	1.679	.000	.094	.000	1.066	-.034	.103	-.039	1.294
	Concerns about family members	-.040	.035	-.120	1.421	-.055	.038	-.143	1.272	-.041	.027	-.162	1.106
	Perceived experiences with air pollution	.011	.138	.009	1.629	-.084	.103	-.075	1.089	.334	.095	.428***	1.405
	Perceived benefit from industrial development	.232	.059	.446***	1.715	.063	.052	.122	1.278	.093	.057	.180	1.165
	Trust in public authorities	-.207	.165	-.266	5.953	-.061	.077	-.090	1.606	-.135	.073	-.260*	1.860
	Trust in industrial agencies	-.019	.150	-.025	5.389	-.060	.071	-.091	1.467	.025	.071	.050	1.899
R square		0.729				0.559				0.5200			
F for change in R square		7.467				5.460				3.829			

Note: ***p < .01. **p < .05.*p < .10

5.4.1 High-risk Communities

The result showed that the potential predictor variables are perceived probability of environmental contamination and perceived benefit from industrial development. People who have high scores of these variables tend to have a higher risk perception score. The regression model with two predictors produced R = 0.773, $R^2 = 0.598$, $F(2,48) = 35.728$, $p = 0.000$. Perceived probability of environmental contamination had a significant positive regression weight (β = .624, $p = .000$), as did perceived benefit from industrial development (β = .413, $p = .000$). This indicates that respondents with high perceived probability of environmental contamination and high perceived benefit from industrial development gave relatively high scores of environmental risk perception. The equation for predicting risk perception held by respondents in high-risk communities is as follows:

$$Y = -0.535 + 0.829X_1 + 0.215X_2 \quad (1)$$

Note: where Y is a degree of risk perception. X_1 is a degree of perceived probability of environmental contamination, and X_2 is a degree of perceived benefit from industrial development.

5.4.2 Moderate-risk Communities

It was found that two variables related to the nature of environmental risks could predict risk perception held by respondents in moderate-risk communities. Those two variables are perceived probability of receiving impacts and severity of catastrophic consequence. Respondents who gave high scores for those variables tend to exhibit higher risk perception. The regression model with two predictors produced R = 0.643, $R^2 = 0.414$, $F(2,67) = 23.675$, $p = .000$. Perceived probability of receiving impacts had a significant positive regression weight (β = .496, $p = .000$), as did perceived severity of catastrophic consequences (β = .280, $p = .006$). When considering standardized coefficients (Beta) of each variable, it was found that the variable of perceived probability of receiving impacts was more influential than the variable of perceived severity of catastrophic consequence. The equation for predicting risk perception is as follows:

$$Y = 0.649 + 0.23X_1 + 0.395X_2 \quad (2)$$

Note: where Y is a degree of risk perception. X_1 is a degree of perceived severity of catastrophic consequences, and X_2 is a degree of perceived probability of receiving impacts.

5.4.3 Low-risk Communities

Surprisingly, no factors related to lay understanding of the nature of risks could predict risk perception held by people in low-risk communities. Two variables showed a significant influence on the risk perception score, i.e., previous experiences in facing polluted air (β = .554, $p = .000$) and a level of trust in public authorities (β = -.232, $p = .030$). Respondents who gave high scores for this variable tend to exhibit higher risk perception. The regression model with one predictor produced R = 0.621, $R^2 = 0.385$, $F(2,57) = 17.852$, $p = .000$. The result can be interpreted that people in low-risk communities might not judge risk based on self-appraisal. Instead, they might possibly judge risk based on their belief, which could be influenced by their previous experiences.

$$Y= 1.694 + 0.433X_1-0.121X_2 \quad (3)$$

Note: where Y is a degree of risk perception, and X_1 is a number of previous experiences in facing polluted air, and X_2 is a level of trust in public authorities.

Based on the findings, environmental risks were determined differently by respondents who live in the three different types of communities. Similar to what Aven [29] addressed, this study found that respondents may either use beliefs or self-appraisal to judge and perceive risk. Risk perception held by respondents from high-risk and moderate-risk communities have been proven to be significantly related to how they think about the nature of risks. This finding is partly related to the work of Slovic [15], which suggested the influence of the nature of risk on environmental risk perception held by the public. People in high-risk communities judged risk based on their perceived probability of environmental contamination; however, people in moderate-risk communities judged risks by considering the probability that they might be impacted by the contamination as well as the potential adverse impacts they might face. Different from the perception held by respondents in those two types of communities, the perception exhibited by respondents from low-risk communities was not significantly determined by factors related to the nature of risks, but was instead significantly influenced by two of the psychological variables, i.e., previous experiences in facing polluted air and trust in public authorities. It is possible that perceptions held by those in low-risk communities might not be formed based on the result of self-appraisal, but was instead formed based on their belief.

In addition, besides being determined by perceived probability of contamination, risk perceptions held by respondents in high-risk communities were also significantly influenced by their perceived benefit generated from industrial development in the area. This finding is related to the studies conducted by Slovic [47] and Gregory and Mendelsohn [49], which also stated the influence of perceived benefit on perceived risk; however, the positive relation between perceived benefit and perceived risk found in this study was unexpected and different from some of the previous studies [48–49]. For instance, the study carried out by Gregory and Mendelsohn [49] concluded that individual risk assessment is included with individual's perceived benefits. Alhakami and Slovic [48] stated that when technologies are perceived as being of high benefit, risks are relatively devalued. In this study, respondents in high-risk communities seem to understand the fact that the more benefit they had gained, the more risk they faced; whereas respondents in other types of communities did not include benefits in their risk assessment and perception at all.

Overall, the results indicated that lay people have different viewpoint in judging risks, and factors related to the physical nature of environmental risks play more important roles in shaping risk perception held by lay people in high-risk and moderate-risk communities than selected psychological factors. It is possible that people became more knowledgeable. This finding could provide an important implication for the development of risk management and risk communication which aims to involve lay people in decision-making processes for the sustainable development of an industrial complex.

6 Implications for Development of Risk Communication and Management

Risk communication can play an important role in bridging the gap of risk perception and supporting decision making process among related parties [44, 45]. The study provided basic understanding of how lay people determined environmental risks. This gives a constructive direction to create risk communication in three aspects such as determining the goals of communication efforts, selecting relevant information, and formatting information in the way lay people can understand. According to the findings, it is not a simple job to communicate risk with people having diverse cognitive model of risk judgment and perception. Communication efforts should be taken into account of these two pillars. First, it doesn't matter how much risk people are taking. People who are facing a certain level of risk should be equally receiving information that potentially contributes to laypeople's capability to assess and manage risks. Judging risk based on only belief can provide some values for risk mitigation, but is hardly accepted when a decision on environmental action or policy is made. To be capable to participate in decision making process, people in low-risk communities should be able to explain risk in the way other parties can understand and are convinced as well. Second, the concept of two-ways communication should be applied. People are not only a receiver but also a message sender as well. The results show that people judged risk based on their perceived probability of receiving impacts. This means people's susceptibility or community sensitiveness, an important element of scientific risk assessment, was taken into account. No other parties have known about those issues better than people who live in contaminated sites; therefore, other parties may need to be communicated with information occupied by people as well.

Additionally, understanding people' risk judgment and perception is useful to information selection process and information design. This study revealed diverse viewpoints in risk judgments. Therefore, a comprehensive structure of the process creating an environmental risk should be included in risk communication, and those relevant information need to be communicated in the way that each particular group of people can comprehend. People in high-risk and moderate-risk communities are more interested in information related to the nature of environmental risks such as probability that industries can cause contamination, susceptibility to polluted air, and potential catastrophic consequences. Scientific data presenting about the nature of risks can be more accepted by people in high-risk and moderate-risk communities but might be completely rejected by people in low-risk community. However, it doesn't mean that people in low-risk communities do not need information related to the nature of risks. To be included in decision making process, those people still need to understand the nature of risks and explain how it relates to their life. Therefore, a specific information format should be designed for people who judged risk based on a belief.

7 Conclusion

The study presents how environmental risks are determined by laypeople living in contaminated sites, and how risk communication can be created based on lay cognitive models. The study found that factors related to the physical nature of risks play important role in shaping risk perception of people living in areas with high and moderate concentrations of hazardous gas; whereas, people living in an area with low concentration have perceived risk based on their experiences and their risk perception was also influenced by trust in public authorities. To effectively communicate risks with lay people and to increase capability of lay people in decision making process, a comprehensive structure of the process creating an environmental risk should be included in risk communication. In addition, people with different risk perspectives need to be communicated with different information formats. People who judge risks based on belief may completely deny scientific information related to the nature of risk, but it might be accepted by people who perceive risks based on their self-appraisal.

Acknowledgements

The study was funded by Kochi University of Technology, Kochi, Japan. The authors would like to acknowledge all local residents in Maptaohut communities, NGOs, Maptaphut municiparity for the support and participation in the study.

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