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Perceived environmental and health risks of nuclear energy in Taiwan after Fukushima nuclear disaster

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ABSTRACT

After the nuclear disaster in Fukushima in Japan in 2011, a nation-wide survey using a standardized self-administered questionnaire was conducted in Taiwan, with a sample size of 2,742 individuals including the residents who live within and beyond 30 km from a nuclear power plant (NPP), to evaluate the participants' perceived nuclear risk in comparison with their perceived risks from selected environmental hazards and human behaviors. The three leading concerns of nuclear energy were "nuclear accidents (82.2%)," "radioactive nuclear waste disposal (76.9%)" and "potential health effects (73.3%)." Respondents (77.6%) perceived a higher relative risk of cancer incidence for those who live within 30 km from an NPP than those who live outside 30 km from an NPP. All the participants had a higher risk perception of death related to "nuclear power operation and nuclear waste" than cigarette smoking, motorcycling, food poisoning, plasticizer poisoning and traveling by air. Moreover, the residents in Gongliao where the planned fourth NPP is located had a significantly higher perceived risk ratio (PRR) of cancer incidence (adjusted odd ratio (aOR) = 1.84, p value = 0.017) and perceived risk of death (aOR = 4.03, p value < 0.001) related to nuclear energy. The other factors such as female gender (aOR/p value, 1.25/0.026 and 1.34/0.001 respectively), lower education levels (aOR/p value: 1.31/0.032; 2.03/<0.001) and the participants' concerns about nuclear accidents (aOR/p value: 1.33/0.022; 1.51/<0.001) and potential health effects (aOR/ p value: 2.95/ <0.001; 2.56/<0.001) were found to be commonly associated with the PRRs of "cancer incidence" and "perceived risk of death" related to nuclear energy, respectively. In addition, the respondents' concerns about nuclear waste disposal and possible eco-environmental damage made significant contributions (aOR/ p value: 1.39/ 0.001; 1.40/<0.001) to predict their perceived risk of death related to nuclear power. These factors are considered as important indicators and they can be used for suggesting future policy amendments and public referendum on the decision of the operation of the planned NPP.

1. Introduction

1.1. Existing studies on nuclear-related risk perception

With the increasing threats of energy shortage and the impact of global climate change, many countries are facing more challenges of identifying alternative sources of energy to ensure a more sustainable environment. The arguments about using nuclear power as a green and clean solution to global climate change were ardently disputed, accompanied with the issues of radioactive wastes management (Barke and Jenkins-Smith, 1993; Slovic et al., 1991).

Before the Fukushima accident, an opinion poll conducted by the International Atomic Energy Agency indicated that public acceptance of building a new NPP had an increasing trend in the United States and Europe in recent 10 years(OECD, 2010). The report indicated that many Europeans agreed that nuclear energy increased their energy supply, ensured lower and more stable energy prices and helped to limit global warming. They suggested that one of the greatest risks associated with nuclear energy was the safety of disposal of radioactive waste. The risks of nuclear energy were considered to outweigh its advantages by 53% of the European respondents overall, whilst only 33% thought that the advantages outweigh the risks that it posed.

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After the Fukushima accident, an international comparative study involving a sample of nearly 19,000 people in 24 countries in June in 2011 indicated that the support for nuclear power had dropped significantly, with 62% worldwide opposed to further development of nuclear power (Carrington, 2011). Also, increasing concerns about potential nuclear accidents has reduced the support for nuclear energy in many other countries including America, Japan, Switzerland, UK and Taiwan since the Fukushima nuclear accident occurred in 2011 (Hixson, 2012; Ho et al., 2013; Ieong et al., 2014; Keller et al., 2012; World Nuclear News, 2012).

A risk rating measurement developed by Slovic et al. (Slovic, 1987) had been widely used in risk perception analysis to identify different characteristics of risk perception among 30 items related to various types of technologies and human activities, based on the research participants' judgments on their perceived magnitude of risks. The difference between the risks perceived by the public and the scientifically estimated risk is regarded as the biggest problem in public acceptance of nuclear energy. The risk assessment of everyday activities involved subjective judgment that depends on the perception of risk by individuals. Recently, a study based on the risk rating scales indicated that nuclear power was regarded as a high-risk item by the Japanese respondents in the past 25 years, whereas the perception by the public fluctuated with events such as the Chernobyl and Fukushima accidents (Kanda et al., 2012).

Public responses to environmental risks such as nuclear-related risks can be explained by a complex cognitive process. It is now widely recognized that effective communication is a crucial element during and after a nuclear accident (Covello, 2011; Robertson and Pengilley, 2012). Risk perceptions of nuclear power are mainly influenced by trust on the authorities and the operators, as well as demographic characteristics such as age, gender, ethnicity, race, attitude and knowledge of nuclear power and perceived effects on the quality of everyday life of residents near an NPP (Greenberg, 2009; Hung and Wang, 2011). Several studies revealed that people who were opposed to nuclear power plants (or had high-risk perception toward nuclear power) often associated nuclear power plants (NPPs) with potential nuclear accidents, waste disposal, excess radioactivity and nuclear safety, negative health consequences, negative environmental effects and socioeconomic impacts (Aldrich, 2012; Jenkins-Smith et al., 2011; Keller et al., 2012; Parkhill et al., 2010). However, the information about how the above-mentioned concerns influenced lay people's risk perception toward nuclear power has not been well addressed. The interaction of the local setting exposed to the nuclear power plants with existing personal knowledge and experience of nuclear energy had a significant impact on risk perceptions of local residents towards nuclear power (Hung, 2009). Studies have shown that public perception and acceptance of nuclear power play very important roles in determining the promotion and development of nuclear technology (Greenberg, 2009; Jenkins-Smith et al., 2011).

1.2. Potential high risk of nuclear safety in Taiwan

Taiwan established its first nuclear power plant in the 1970s. There are 3 NPPs involving six reactors currently operating, while the fourth NPP is being planned and under construction. The nuclear energy currently contributes slightly less than 20% of the overall power supply in Taiwan. Geographically, the first and the second nuclear power plants are located in 22 km and 28 km, respectively, from the capital Taipei City where there is a population of more than six million. The journal *Nature* highlighted the above-mentioned two nuclear plants in Taiwan as the world's second and third most dangerous power plants (Butler, 2011). The nuclear safety issues were raised quickly in Taiwan after Fukushima nuclear accident in 2011, as both NPP 1 and NPP 2 are located in its northeast coastal line where is prone to the effects of tsunamis and earthquakes, and which may affect more than 6 millions of population within a radius of 30–40 km (Chao, 2011).

Public opposition to the new 4th NPP increased from around 58% in March 2011 to 74% in March 2013, reported by the public polls (Wang, 2013; Jou, 2011). It indicated that the public poses concerns about nuclear power in Taiwan 2 years after Fukushima nuclear disaster. With an increasing anti-nuclear movement in progress, an expectance on the termination of operation of the planned 4th NPP has been ongoing to be discussed after Fukushima nuclear accident (Ho et al., 2013). It showed that trust was the key determinant of the acceptance of a new nuclear power plant and a very small proportion (17%) of respondents in Taiwan trusted the Government's nuclear safety management after Fukushima accident.

1.3. Hypothesis and purpose of the study

Drawing on the basis of international studies on nuclear risk perception and growing concerns of nuclear safety in Taiwan, the study hypothesizes that the Fukushima nuclear disaster might have trigger public concern about potential environmental and health effects associated with nuclear energy so as to increase their risk perception toward nuclear power plants in Taiwan (Fig. 1).

A series of nuclear risk perception research has been conducted in several developed countries since 1990s, but population-based risk perception studies are limited in the Asia-Pacific region. Therefore, the purpose of the study is to provide population-based evidence to further investigate the main public concerned items associated with nuclear energy and to evaluate the perceived risks of cancer and death potentially related to nuclear energy in comparison with those of other technologies or human activities, and understanding the effect of the public's concerned nuclear safety, geographic linkage with nuclear power plants and demographic characteristics, which might be underlying public perception of nuclear-related health risks. The results obtained from this study are expected to illustrate useful information for decision making on the planned new NPP and nuclear safety management.

2. Methods

2.1. Study areas and participants

A cross-sectional study of the risk perception on nuclear power in Taiwan was conducted from August of 2011 to February of 2012 after the Fukushima nuclear accident in Japan. Surveys were conducted in three townships within 5 km of the 1st Nuclear Power Plant (NPP1) and the 2nd Nuclear Power Plant (NPP2) in the northern Taiwan, the Shimen (SM), Wanli (WL) and Jinshan (Brandejsky et al.) townships, as well as three townships within 15 km of the Third Nuclear Power Plant (NPP3) in southern Taiwan, the Hengchun (HC), Manzhou (MZ) and Checheng (Pugh-Clarke et al.), and the township of Gongliao (GL) within 2 km of the planned 4th NPP on the northeastern coast of Taiwan. Residents and students in "other areas" of more than 30 km away from the NPPs were also included in the survey conducted in the communities and schools distributed around Taiwan (Fig. 2).

In order to compare the responses of different communities, we decided to study all the townships hosting the three existing NPPs and the GL township, which hosts the planned fourth NPP. Out of 346 communities that were beyond 30 km away from the above area in Taiwan, 17 communities and townships were randomly sampled for the study as "other regions." With the townships decided, the questionnaires were administered and collected according to the proportion of the total populations of specific townships. To make collection of effective samples from these townships feasible, interviewers conducted the surveys during regular daytime hours and mostly on weekdays in each community simultaneously. Interviewers' workstations were set up in several public business locations such as convenience stores, bus stations, main business streets, shopping centers, local administration centers, schools, hospitals and health service centers when local residents who walked into these stations were invited to respond to the