# The Change in Residents' Participative Behavior in Polluted Areas: A System Dynamics Perspective

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## SUMMARY

This article explores the reasons for the declining public participation of residents in a severely polluted community from a system dynamics perspective by examining a set of communities polluted with dioxin in southern Taiwan. The study examines three aspects affecting participative behavior intention: residents' perception of the pollution, peer impact, and how residents perceive the impact of participation on government response. A face-to-face interview conducted from August to September 2008 revealed that the unintended side effect of the government's indemnity policy has created a balancing feedback loop that offsets the reinforcing feedback system suggested by the normative theory of participation. In addition, the unique nature of pollution victims mitigates the influence of an existing reinforcing feedback system. This article concludes with policy suggestions to increase public participation in a highly polluted community.

Key Words
dioxin pollution; system dynamics; public participation; environmental governance; An-shun Plant; Taiwan

## INTRODUCTION

Although environmental pollution and protection have been key issues in environmental governance and sustainable development for decades, only recently has public participation started to attract the attention of governments who try to make the sustainability of polluted communities possible. Public participation has been a key issue in the field of governance, which emphasizes the importance of involving

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citizens in policy-making processes. It is believed that a higher level of public participation during the stage of policy formulation can make things easier when the policy comes down to the stage of implementation (Pierre & Peters, 2000: 1). Recently, public participation started to attract global attention in the field of environmental governance. For example, one of the vital statements of Agenda 21 emphasizes the importance of public decision making in the process of social and economic change. It encourages public participation and involvement in environmental decision-making processes, including policy formulation, legalization, and implementation, so that sustainable development can be possible (United Nations Department of Economic and Social Affairs Web site). Accordingly, to formulate and implement sustainable community programs in the polluted areas, residents' participation is vital in the entire process.

However, how does the government motivate residents in polluted areas to participate in local public affairs such as environmental and sustainable policy making? In a sizable dioxin pollution case in southern Taiwan, the incentive for residents' participation in a related policy process rose at the beginning and then declined even before the real problem was solved. Why did resident's participative incentives change? This study seeks to answer these questions by examining the case of the dioxin-polluted communities surrounding the An-shun PCP manufacturing plant (An-shun plant) in southern Taiwan. The An-shun plant dioxin pollution is quite typical of severe, sizable environmental pollution, and the communities that have been polluted have been deteriorating socially and economically. For the past four decades, residents who consumed products grown in nearby water ponds have been suffering from high blood dioxin levels and poor health. It was only four years ago, after a long delay, that central and local governments started to respond positively to the pollution victims' requests by providing health care and indemnity. The government and the pollution enterprise are now working on a clean-up project, but the residents' incentive to participate in these issues has declined over time. Local government bureaucrats complained about this declining level of public participation in the community at a meeting held on October 31, 2008. Frontline civil servants did not understand the reason why residents' participation declined after the government started to respond positively (An-shun Plant Dioxin Research Project Community Meeting Report, 2008). According to the theory of public participation, a positive policy response from the government can drive up the level of public participation because the public will start to believe in the government's willingness to solve the problem. However, the participative behavior in the dioxin-polluted community of southern Taiwan did not correspond to this theory. Therefore, this study intends to explore the major reasons for the change in residents' participative behavior from a

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systemic perspective.

## BACKGROUND ON THE DIOXIN POLLUTION OF AN-SHUN PLANT

The now-defunct An-shun plant, located northwest of Tainan City in southern Taiwan, was identified as a pollution remediation site by the Environmental Protection Administration (EPA) of Taiwan in May 2004. The plant had been established by the Japanese company Kanegafuchi Soda in 1942 to produce a variety of chemical products, including hydrochloric acid, caustic soda, and liquid chlorine, as well as poison gas for the Japanese navy. When Taiwan's government took over the plant at the end of World War II in 1945, it turned the plant over to a state-owned company named Taiwan Alkali Industrial Corp (TAIC). Placed under the supervision of the Ministry of Economic Affairs in the 1960s, the An-shun plant started to produce pentachlorophenol (PCP)-related products—pesticides, herbicides, antifungal agents, bactericides, and wood preservatives. These products were exported mainly to Japan. By the early 1970s the plant had become Asia's biggest producer of the pesticide dichlorodiphenyltrichloroethane (DDT). In 1982, the government shut An-shun down because of economic and environmental reasons, but these reasons were kept confidential at the time. The government also stockpiled 5,000 kilograms of PCP at the plant site (Huang, 2002). Declassified government documents show that one of the main reasons the government shut down An-shun was that some officials were aware of mercury pollution around the plant site. However, despite this knowledge, the government took no action to either prevent the further spread of pollution or forbid the consumption of water products grown in these contaminated areas (Wang, 2005).

The Chinese Petroleum Corporation (CPC Corp.), another state-owned enterprise, bought out TAIC in 1967. In 1983, right after the An-shun plant ceased to operate, the government ordered the plant property be made part of a CPC Corp. subsidiary, the China Petrochemical Development Corp. (CPDC). CPDC was privatized in 1994 (China Petrochemical Development Corp., 2007: 107–108). Although the An-shun plant did not generate any environmental pollution after the merger with CPDC, it was still surrounded by a very serious case of environmental pollution generated during its four decades of operation. The major pollutants are pentachlorophenol, dioxin, and mercury (Huang, 2002; Research, Development, and Evaluation Commission, 2006). The mud at the bottom of the nearby Luermen River has the highest dioxin level of all rivers in Taiwan. In January 2006, the dioxin concentration in one ditch on the site was found to be 64 million toxic equivalents, or TEQ ng/m3, which is 64,000 times the accepted standard (MacFarquhar, 2006). The dioxin level in fish caught from the reservoir (which was used by TAIC as a toxic waste dump) was

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28.3 pg-TEQ/g, significantly higher than the 4pg WHO-TEQ/g the World Health Organization (WHO) has set as a safe level for human consumption. A record-high dioxin level—247pg-TEQ/g, more than 60 times the WHO standard—was found in fish from the reservoir in 1995 (Huang, 2005). For decades, residents have been economically and nutritionally dependent on catching and selling fish, oysters, shellfish, and crabs grown in nearby reservoirs, fish farms, and ponds. They were never informed of the danger of eating these water products.

Looking into the demographic statistics of An-nan district, where the An-shun plant is located, we find that the residents' average educational attainment is lower than that of other districts in Tainan City. In addition, the district's poverty rate is the highest in the entire city (Tainan City Government, 2005). Although the existence of dioxin pollution in nearby areas seems to have been widely accepted, and although warning signs have been placed in the critically polluted areas, some residents refuse to take this warning seriously. This is understandable, as these people, who have depended upon the nearby waters for their food all their lives, find it difficult to believe that the fish in the water are poisoned; it is therefore not surprising that even recently people have still been catching and selling water products from the polluted areas (Tsai, 2005; Liu, 2005).

A study conducted by National Cheng Kung University at the request of the Tainan City government tested blood samples from 570 residents in Hsien-gong, Lu-er, and Si-tsao townships, which surround the An-shun plant. The results show that 72 percent have higher levels of dioxin in their blood than the tolerance limit set by the United Nations, with the average level being 71.1pg compared with the accepted level of 32.0pg. One local resident has a blood dioxin level of 951.0pg, the highest recorded in Taiwan. The average dioxin level of blood samples from Hsien-gong township, located right next to the An-shun plant, is the highest of the three townships (Chang and Chen, 2007). Dioxins are carcinogens that can cause birth defects, diabetes, immune system abnormalities, and many other health problems when exposure is excessive. The cancer rate in polluted areas is higher than it is at clean sites. For example, the death rate from cancer between 1999 and 2003 in Hsien-gong township is 39.3 percent, while the national average is 25.5 percent (Wang, 2005)

In July 2005, the Ministry of Economic Affairs agreed to set aside NT$ 1.3 billion (US$ 40 million) for a period of five years to compensate victims of dioxin pollution from the An-shun plant. However, the government stated that the compensation would be distributed only out of humane consideration. It held that the government should not bear responsibility on behalf of CPDC, a privatized company. Those registered as residents in Hsien-gong, Lu-er, and Si-tsao townships before June 30, 2005 are entitled to receive a monthly cash payment of NT$ 1,814 (US$ 55) per

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person. People whose blood dioxin level is higher than 64pg-TEQ/g lipid will receive NT$ 3,000 (US$ 91) a month, and those who have become physically or mentally handicapped or seriously ill because of the pollution will receive NT$ 15,840 (US$ 480) a month. The relatives of people who died as a result of the pollution will be entitled to a one-time payment of as much as NT$ 200,000 (US$ 6,061) in compensation. These monthly payments are intended to pay for the continuing medical treatment of various illnesses, including cancer, as well as for social welfare and living expenses (Tainan City Government, Bureau of Social Affair Web site). However, residents have complained that the monthly payment of NT$ 1,814 per person is insufficient to cover their medical bills and other expenses. Many seriously ill residents are seeking state compensation on grounds that the plant was owned by the government at the time it produced the dioxin pollution. The change in ownership of An-shun plant, however, has made the issue a lot more complicated. Although the pollution occurred when the plant belonged to the state-owned TAIC, in November 2007 the Highest Administrative Court held that CPDC was solely responsible and ordered the company to pay the compensation and clean-up costs (Tainan City Government, 2007). Since it was held responsible for cleaning up the dioxin pollution, CPDC started to propose a clean-up plan to the government in 2008 (Cheng, 2008).

## THE REINFORCING FEEDBACK LOOPS BASED ON THEORY

Public participation means that the public participates in policy formulation, planning, and implementation processes (Arnstein, 1969: 216; Kweit & Kweit, 1987: 29; Chandler and Plano, 1988: 175). It is believed that the level of public participation is related to the government's policy responses. A positive interaction between citizens and the government can help both sides develop trust toward each other. Consequently, a policy can be implemented smoothly based on a cooperative relationship between the two (Arnstein, 1969; Desario & Langton, 1978). In the literature regarding environmental issues, it is generally believed that the participation of stakeholders is a must-do in environmental policy processes. Especially for people who are pollution victims or potential victims, their opinion inputs in related policy processes can help the government develop programs that are customized to local characteristics and meet local needs. When better customized programs are formulated to meet local needs, citizens' participative behaviors can be encouraged; therefore, both the government and the citizens will cooperate closely to deal with the unsolved problems together (Rydin & Pennington, 2000; Konisky & Beierle, 2001; Daley, 2008).

Figure 1 shows the conceptual positive feedback loops drawn from the above theory. Loop 1 shows an information feedback loop. The residents' higher level of

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participation requires clear and responsive information released from the government. In other words, clear and easily understandable information from the government can help the public realize in depth the on-going problems; hence, residents' participative incentive can be raised. A higher level of public participation can pressure the government to expedite the problem-solving process and release more information. Loop 2 is also a positive feedback loop showing that the government's positive policy response makes participants feel fulfilled and positive about their participation and therefore raises their participative incentive. Loops 3 and 4 are about policy implementation. It is believed that public participation can make the policy implementation process run smoothly. Consequently, the government is willing to encourage a higher level of participation by releasing related information and positive policy responses to the public. In summary, loops 1, 2, 3, and 4 demonstrate an increasingly closer relationship between the government and the citizens. The government's positive responses, including information release and customized policy, can be a trigger for developing a good relationship with the public; hence, a higher level of public participation can be reached.

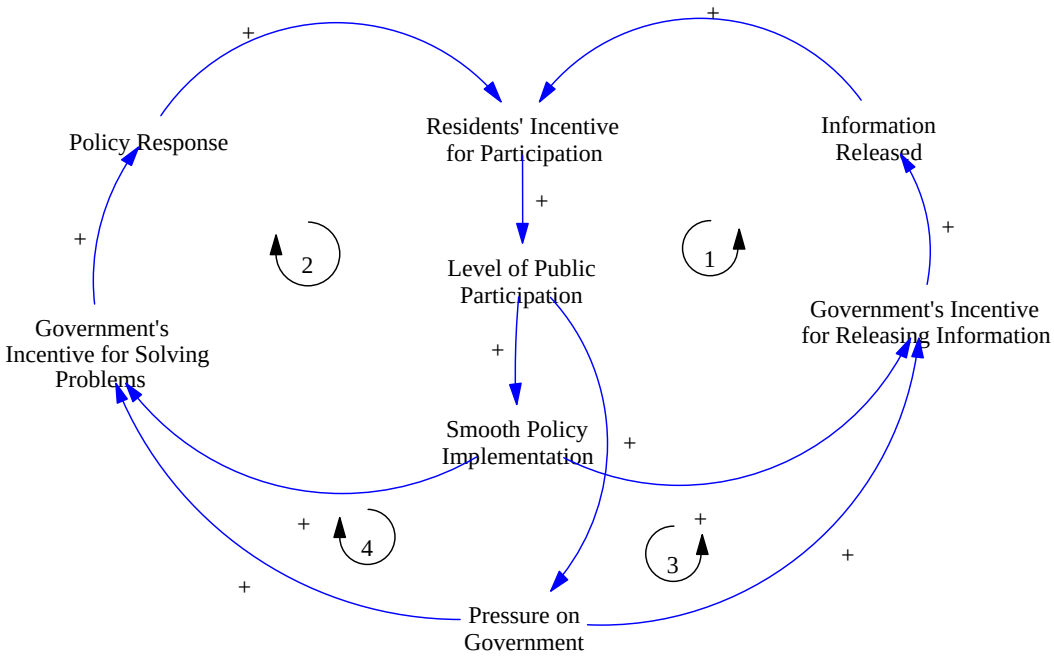


Figure 1. Loops drawn from theory

Based on conceptual model drawn from the theory shown in figure 1, figure 2 shows the system dynamics model. In figure 2, loop R1 and R2 sketch how the government was motivated by public participation to release information and

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formulate policies, respectively. The level of public participation is defined by the stock variable named *people participating related activities*. If people are willing to participate in activities such as public hearings or discussion forums, they can learn more about the related professional knowledge and government's future policies. According to the theory stated previously, more communication and mutual understandings between the government and the public can help the government implement policy smoothly. This concept is represented by a higher number of *compliant people*. Smooth policy implementation encourages the government to take policy actions. Government's incentive for taking actions is defined by *government's incentive multiplier*. In this model, *government's incentive multiplier* is formulated differently from what the theory addresses. Although a smooth policy implementation motivates the government to respond positively, government's policy responses can not be unlimited. In reality, the government's response may slow down because of various reasons such as limited budget, bureaucratic inertia, or perceiving policy goals having been reached. Accordingly, *government's incentive multiplier*, formulated as table function, rises at the beginning and then goes down along with the increase in the number of compliant people. This specific formula makes both loop R1 and R2 switching from a positive to negative loop along with the increasing level of public participation.

Loop R3 and R4 show that a higher level of public participation can actually pressure the government to take positive actions including releasing more information and formulating more policies for the pollution victims residing in the community. Both loops are positive.

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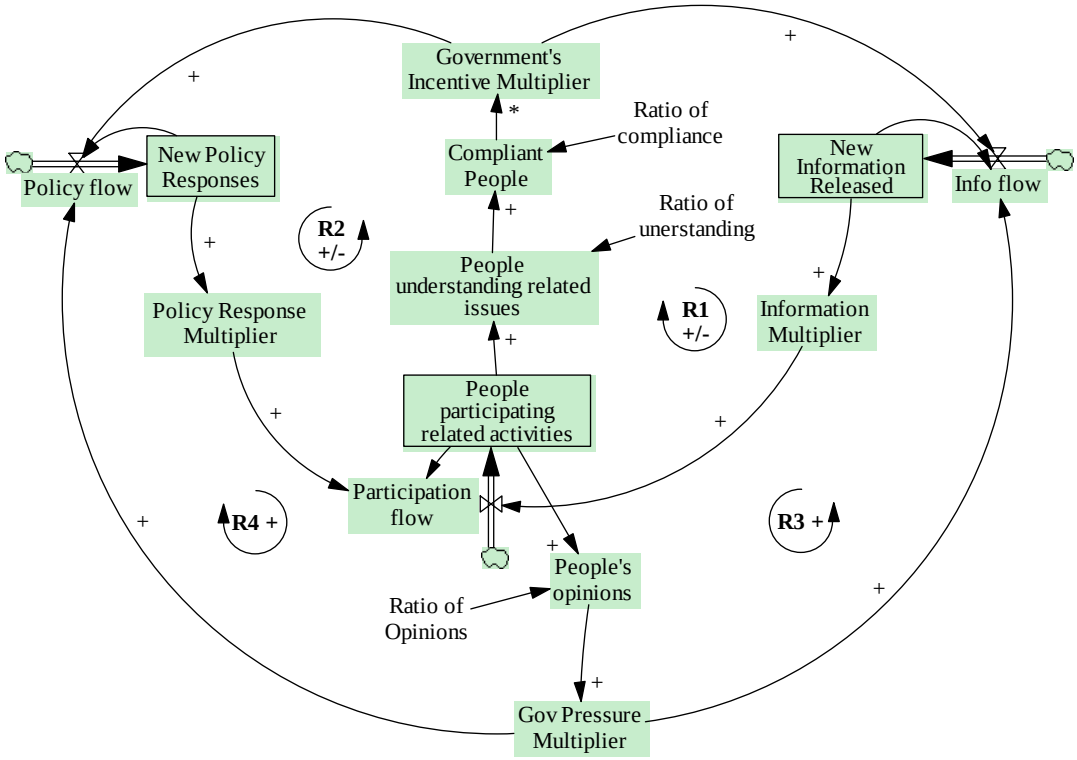


Figure 2 System Dynamics Model Based on Theory

The simulation result of the theory model is shown in figure 3. The number of *people participating related activities* goes up dramatically and then keep equilibrium due to the formulation of *government's incentive multiplier*. The system behavior does correspond to the theory that public participation can be encouraged by the improved interactions between the government and the public.

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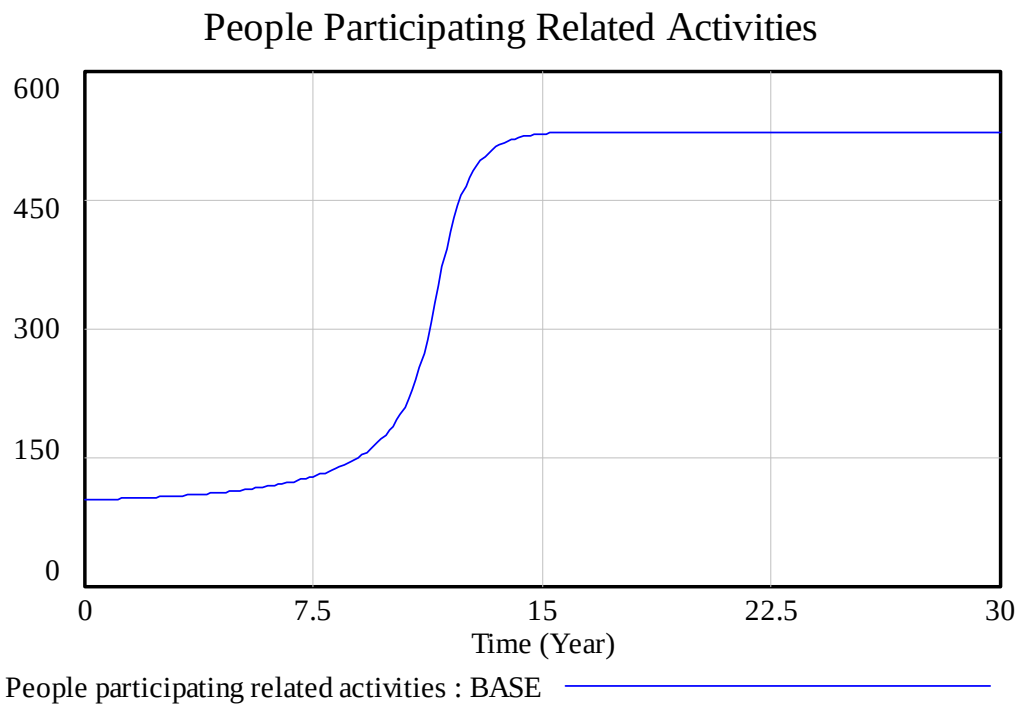


Figure 3 Simulation Result of Theory Model

However, the reality presented at the dioxin pollution site in southern Taiwan does not fully correspond to the above theory. As stated previously, frontline civil servants complained that residents' participation declined after the government started to respond positively (An-shun Plant Dioxin Research Project Community Meeting Report, 2008). Why do the residents of polluted community behave differently before and after the government took positive policy actions? From a system dynamics perspective, this situation may happen when balancing feedback loops start to function and offset the impact of the reinforcing feedback loops. What are the balancing feedback loops? How are they constructed? This study will try to find the answer through the following research design.

## RESEARCH METHOD AND ANALYTICAL FRAMEWORK

To identify the change in public participative behavior and the reasons for this change, a face-to-face interview was employed. The interview questions were developed from the conceptual framework that included residents' perception of the pollution, peer impact, and how residents perceive the impact of participation on government response. These three aspects can be used to predict the change in behavior intention (Ajzen, 1991: 181-185; 2005: 132-136).

Ten residents from the polluted communities were selected for a personal

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interview. Five of them are opinion leaders of the community and the other five were randomly selected from the communities that have resided in the polluted communities for at least 10 years. Interviews were conducted from August to September 2008 using open-ended questions.

## RESULTS AND DISCUSSIONS

The analysis of the qualitative interview data shows that the characteristics of the polluted areas have formed a very strong negative loop in the system and, in the meanwhile, made the power of the existing positive loop much less than expected by the theory.

Figure 4 revises Figure 1 by adding two feedback loops to substitute for loop 2 of Figure 1. These two loops were developed after the government set aside NT$ 1.5 billion for compensation. The compensation policy divided residents of the polluted areas into two groups. One group was qualified to receive more cash benefits (NT$ 3,000 per month) because of a higher blood dioxin level compared to the 64pg-TEQ/g lipid benchmark. The other group of residents can only get a maximum compensation of NT$ 1,814 per month because their blood dioxin levels are lower than 64pg-TEQ/g lipid. The first balancing loop (loop 5) shows that for the people who qualified for higher compensation, their ongoing fight with the government appeared toward the end and that the problems appeared to be solved temporarily for them. Consequently, their intention to participate in continuing affairs (e.g., health care, clean-up project, etc.), which may even be more important than cash benefits, declined. This situation is caused by the poverty of the polluted areas. For low-income residents in the polluted areas, getting cash benefits for short-term survival is more important than developing a clean-up project for long-term community sustainability. According to the interview data, this study finds that the residents do not believe in the possibility of pollution cleaning up in the near future. They just do not trust the government and the company that generated the pollution, especially because this company was once run by the government before it was privatized. It is difficult for the residents to believe that the government and the company will invest a huge amount of money to clean up a socially and economically inferior community. Therefore, getting cash benefits is much more practical for them than fighting for an uncertain future. These thoughts make the balancing loop even more powerful.

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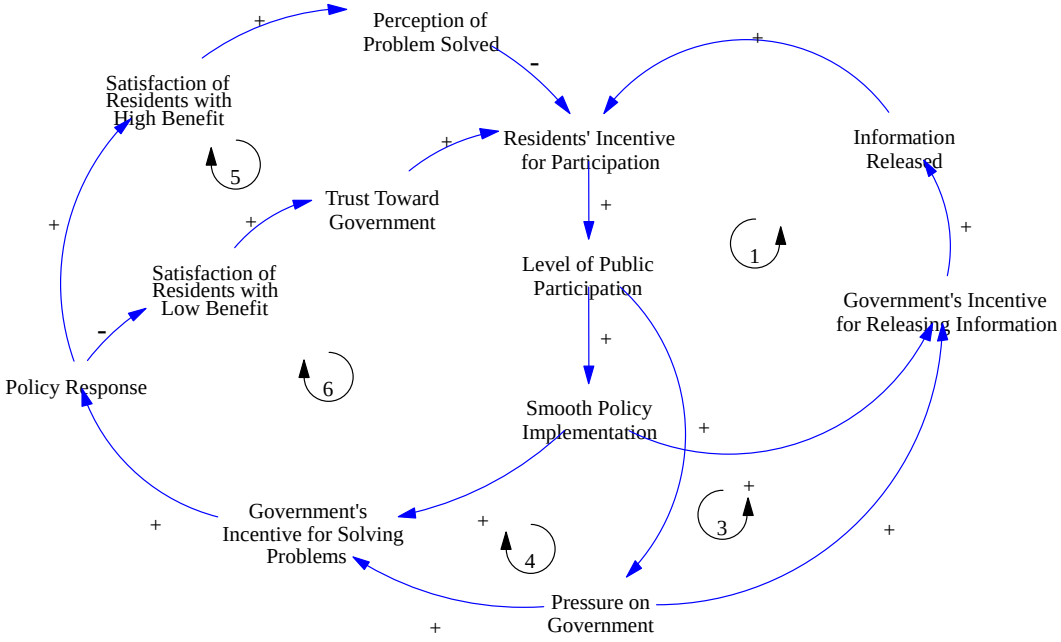


Figure 4. Loops from Interview Data

The second balancing loop (loop 6) illustrates how the residents who did not qualify for higher cash benefits responded to the government's policy response. Although these people obtained some compensation, they were not satisfied with the policy results because they felt unfairly treated. They complained that the decision-making process of setting the 64pg-TEQ/g lipid compensation benchmark was not transparent. Their trust toward the government declined accordingly and so did their participative incentive.

In addition, the low education level of the residents can make loop 1 less powerful. The demographic data of the polluted communities show that the residents' education level is much lower than the city average. Although the government has released some information to the public, this professional knowledge cannot be easily understood by the public. For the people whose education level is low, it is time-consuming for them to comprehend the professional and technical information. The incomprehensible information is definitely a high barrier for residents to raise their participative incentive. In fact, a sizable questionnaire survey conducted by the author in February and March 2008 has shown that one-fourth of the questionnaire respondents are illiterate. Therefore, the loop 1 in Figure 1 cannot be as strong as what the theory expected.

In the interview data, this study also finds that one of the three aspects predicting people's behavior intention—peer pressure—is not significant in this case. Although they know that participation is good for community development, there are always

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reasons to pull themselves back from participating, for example, work, poor health, old age, and so forth. People living in the same community share the same characteristics, thus they will not blame their neighbors for non-participatory behavior.

A revised system dynamics model based on interview data analysis is shown in figure 5, a revision of figure 2. We used loop R5 and R6 in substitution for loop R2 and R4 of figure 2. In both loop R5 and R6, the partial government's policy responses are transformed to be *accumulated services for high dioxin level*. For people who are not qualified for these services, an increase in such services for residents with high blood dioxin level can drive down trust toward the government and therefore, decreases their incentive for further participation. This feedback loop is shown as R5. For people who are qualified for *accumulated services for high dioxin level*, they may consider problem temporarily solved and therefore withdrew from further participation. Participating public events held by the government is not a usual hobby for the residents residing remote and socially inferior areas. Beyond everything, there are various reasons (ex. Poor health, working etc.) that could excuse residents from participating public events. This feedback system is shown as R6.

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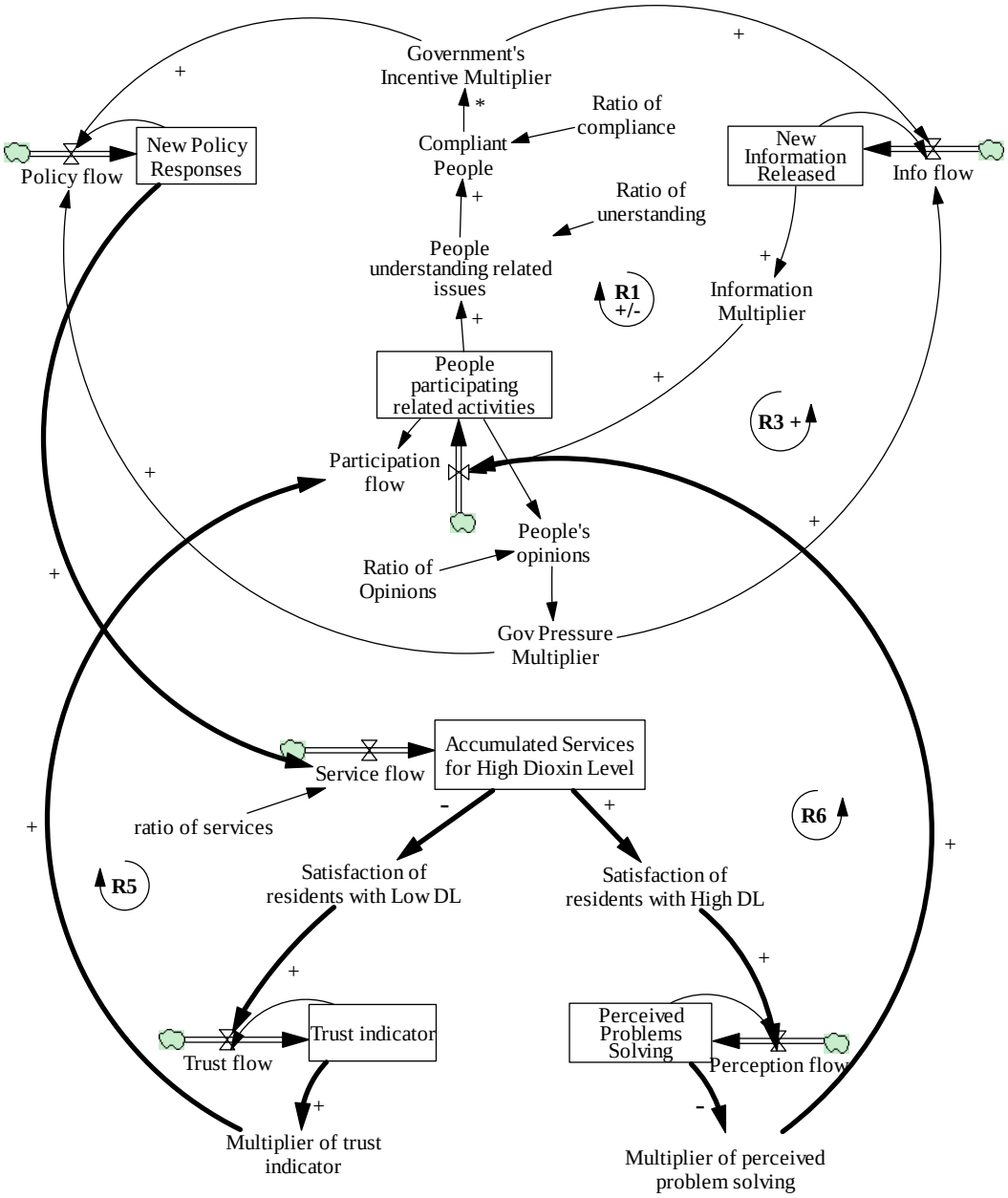


Figure 5 System Dynamics Model Based on Interview Data

Figure 6 shows the different system behavior between the theory model and the revised model. The revised model does show a small overshoot behavior which correspondent to the reality. Participative behavior of residents was discouraged along with an increase in government's policy responses.

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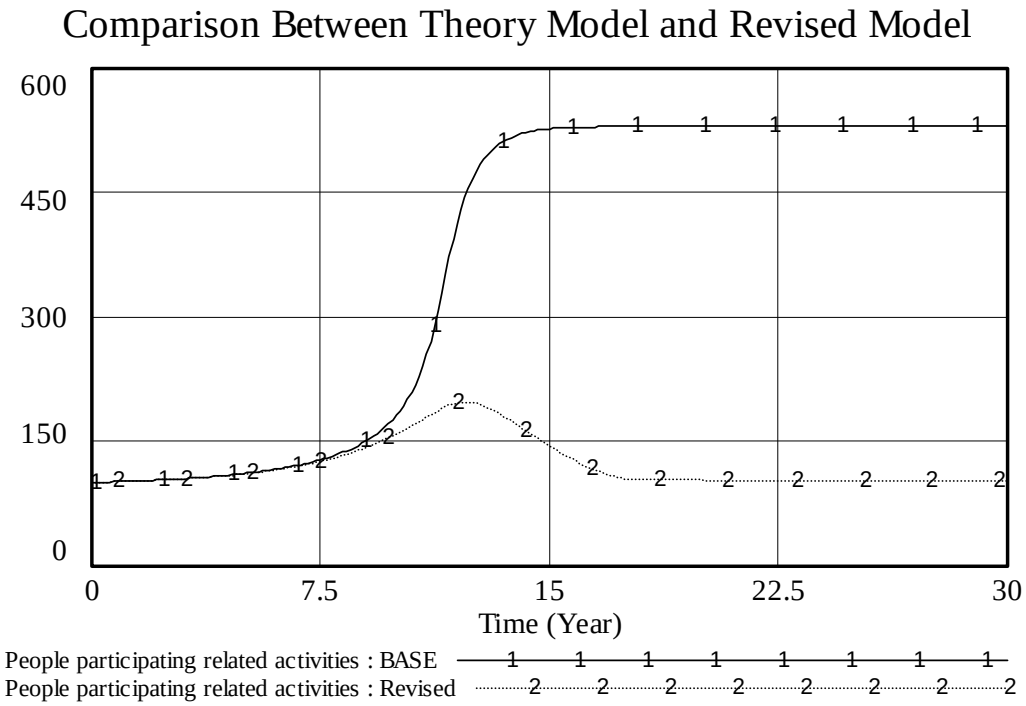


Figure 6 System Behavior Comparisons

## CONCLUSIONS

This study has found two interesting points that the theory failed to notice through a system dynamics perspective. First, for each stakeholder, a policy response from the government is not necessarily positive. When there is a benefit gap among stakeholders, people who obtain comparatively low benefits will not be satisfied with the policy. In this case, their participatory intention can decline. Second, the characteristics of policy stakeholders have a significant impact on their participatory intention. For residents who can barely meet the subsistence level, their attention will focus more on cash benefits rather than long-term pollution clean-up. Short-term cash benefits can easily satisfy them and therefore mute their complaints. For the government who does not want to pay too much attention to hard work such as pollution clean-up, indemnity is an easy strategy for suppressing the noise from polluted communities. However, for a government who wants to cooperate with the polluted communities for future sustainable development, indemnity should be carefully delivered. In addition, a lower education level makes it difficult for residents to participate in a policy process that is filled with professional and inexplicable knowledge. Therefore, in order to raise the participatory incentive of polluted victims, the government should learn how to translate the scientific phrase of environmental

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pollution issues into an easily understandable language for people to understand.

Although this qualitative study does not employ modeling to examine the problem, the system dynamics perspective is employed here for three reasons. Believing in the existence of a balancing feedback loop in the system helps the author focus on searching for the balancing power in the system. In addition, the system dynamic perspective helps us understand that the power of the dynamic loop can be changed over time. It can become less powerful when some triggers reach their limits. The system dynamics perspective also reminds policy makers to look into the dynamic system constructed by the interactions between the government and the pollution victims and understand that the system is changing over time. The government's response can generate unexpected side effects and therefore offset the positive impact expected by the normative theory.

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Appendix 1 Model Formula

(01) Accumulated Services for High Dioxin Level= INTEG (Service flow,0)

(02) Compliant People=People understanding related issues*Ratio of compliance

(03) FINAL TIME = 30

(04) Gov Pressure Multiplier = WITH LOOKUP (People's opinions, ([(0,1)-(300,2)],(0,1),(30,1.15),(60,1.29),(90,1.41),(120,1.54),(150,1.63),(180,1.65),(210,1.67018),(240,1.68),(270,1.69),(300,1.69) ))

(05) Government's Incentive Multiplier = WITH LOOKUP (Compliant People, ([(0,-1)-(100,1)],(0,0),(10,0.08),(20,0.16),(30,0.25),(40,0.35),(50,0.42),(60,0.32),(70,0.06),(80,-0.19),(89.5928,-0.43),(100,-0.7) ))

(06) Info flow=New Information Released*Government's Incentive Multiplier*Gov Pressure Multiplier

(07) Information Multiplier = WITH LOOKUP (New Information Released, ([(0,0)-(100,0.8)],(0,0),(10,0.1),(20,0.2),(30,0.3),(40,0.4),(50,0.5),(60,0.56),(70,0.58),(80,0.6),(90,0.6),(100,0.6) ))

(08) INITIAL TIME = 0

(09) Multiplier of perceived problem solving = WITH LOOKUP (Perceived Problems Solving, ([(0,0)-(300,1)],(0,1),(300,0.01) ))

(10) Multiplier of trust indicator = WITH LOOKUP (Trust indicator, ([(0,-0.3)-(1,1)],(0,-0.3),(0.13,0.27),(0.28,0.59),(0.53,0.84),(0.73,0.94),(1,1) ))

(11) New Information Released= INTEG (Info flow, 1)

(12) New Policy Responses= INTEG (Policy flow, 1)

(13) Participation flow=People participating related activities*Information Multiplier*Multiplier of trust indicator*Multiplier of perceived problem solving

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(14) People participating related activities= INTEG (Participation flow, 100)

(15) People understanding related issues=People participating related activities*Ratio of understanding

(16) People's opinions=People participating related activities*Ratio of Opinions

(17) Perceived Problems Solving= INTEG (Perception flow, 1)

(18) Perception flow=Perceived Problems Solving*Satisfaction of residents with High DL

(19) Policy flow=Government's Incentive Multiplier*New Policy Responses*Gov Pressure Multiplier

(20) Ratio of compliance=0.5

(21) Ratio of Opinions=0.5

(22) ratio of services=0.3

(23) Ratio of understanding=0.5

(24) Satisfaction of residents with High DL = WITH LOOKUP (Accumulated Services for High Dioxin Level,
([(0,0)-(100,1)],(0,0),(10,0.1),(20,0.2),(30,0.3),(40,0.4),(50,0.5),(60,0.6),(70,0.7),(80,0.8),(90,0.9),(100,1) ))

(25) Satisfaction of residents with Low DL = WITH LOOKUP (Accumulated Services for High Dioxin Level,
([(0,-1)-(100,0)],(0,0),(10,-0.28),(20,-0.52),(30,-0.73),(40,-0.82),(50,-0.88),(60,-0.91),(70,-0.94),(80,-0.97),(90,-0.99),(100,-1) ))

(26) SAVEPER = TIME STEP

(27) Service flow=New Policy Responses*ratio of services

(28) TIME STEP = 0.125

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(29) Trust flow=Trust indicator*Satisfaction of residents with Low DL

(30) Trust indicator= INTEG (Trust flow, 1)

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