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A Study on the Improvement of Safety Awareness through Process Safety Management of Biogas Plant

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Abstract

Since 1986, domestic sewage treatment plants have installed and operated biogas plants that produce biogas (digested gas) using food, livestock manure and sewage sludge as part of the use of alternative energy for energy independence. Despite concerns about safety accidents and risks of large-scale accidents due to the continuous expansion of biogas plants, the Ministry of Environment has managed and supervised biogas plants to be environmental plants, focusing on environmental management. There is a lack of safety awareness of workers' processes. Only recently has the process safety management (PSM) system been implemented in biogas plants, but workers' perceptions of process safety have changed. As there is a difference in the degree of safety process management and safety awareness among workers, it is necessary to establish clear and systematic safety management standards. Therefore, The purpose of this study is to examine whether the application of the plant safety management (PSM) system to biogas plants is effective for workers' safety awareness in order to ensure safe operation of biogas plants and prevent workers' safety accidents in advance.

Keywords: Biogas, Process Safety Management, Improving Safety Awareness.

1. INTRODUCTION

1.1 Background

In the case of organic wastes (food waste, livestock manure, etc), direct landfill has been completely banned since 2005, and sea dumping has been also completely banned (January 2013) in accordance with the London Convention, which came into force in 2006[1]. Therefore, sewage treatment facilities (biogas plants) installed with digestion tanks have been operated as an alternative. In addition, the Ministry of Environment has established the "Measures for Waste Resource and Biomass Energy(08)" and has been promoting projects to expand biogas facilities[2]. The relevant facilities have been established as facilities to produce new & renewable energy in South Korea, where energy resources are insufficient[3].

Despite concerns about safety accidents and large-scale accidents due to the continuous expansion of biogas plants (Table 1)[4], until recently, biogas plants have been limited to environmental plants and the Ministry of Environment had been managed and supervised biogas plants focusing on environmental management. As a result, workers' safety awareness in relation to processes and their consciousness about industrial safety are insufficient.

As a result of the previous studies, only biogas research has been conducted on production or composition,

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and no research on safety management of biogas plant workers has been conducted.[5]

Biogas plants began to implement the process safety management (PSM) system[6] only recently, and workers' awareness of process safety has changed accordingly. However, in the case of biogas plants, the level of workers' operation of the process safety management (PSM) system and safety awareness varies with the operator of the sewage treatment plant, that is, whether the sewage treatment plant is directly managed by the local government or operated by a private operator on commission. Therefore, clearer and more systematic standards for safety management should be prepared.

Members with high safety awareness are well aware of specific risk factors and have a high ability to control them, thus reducing the risk of safety accidents. On the contrary, lack of safety consciousness creates negative safety climate in the organization, induces careless behavior of employees and increases the risk of safety accidents.[7] The causes of accidents or disasters can be divided into physical, human and environmental factors. Human factors account for the largest proportion, over 88%. This can be attributed to low safety awareness, poor safety management system and lack of safety and health education.[8]

Table 1. Organic Waste Resource Biogas Facility Status.

Year	No. of Biogas Facility	Year on Year Increase Rate(%)
2011	55	10.0
2012	57	3.64
2013	61	7.02
2014	71	16.39
2015	88	23.94
2016	90	2.27
2017	98	8.89

1.2 Purpose

In this study, The purpose of this study is to examine whether the application of the plant safety management (PSM) system to biogas plants is effective for workers' safety awareness in order to ensure safe operation of biogas plants and prevent workers' safety accidents in advance.

2. STUDY METHOD

In this study, a survey was conducted to examine the opinions of workers working at biogas plants regarding changes in their safety awareness following the introduction of the process safety management (PSM) system.

The survey was conducted at sewage treatment plants located in Seoul and Gyeonggi-do, and the questionnaire in which a total of 84 workers participated was analyzed.

The questionnaire consisted of 30 questions comprising six general questions, 11 questions about safety management and safety awareness, and 13 questions about the implementation of the process safety management (PSM) system. Among the questions, some of those that are regarding safety awareness or safety management were used in the analysis.

3. STUDY FINDINGS

3.1 Present Situation of Domestic Biogas Plant Facilities and Production

As for biogas plants, beginning with the operation of Gwacheon Environment Affairs Agency in 1986, the number of facilities that use organic wastes increased to 98 as of the end of 2017, and biogas treatment facilities are expected to increase continuously hereafter too. (Table 1)[4]

Table 2. Biogas Production and Use by Year.unit: 1,000m³/year, (%)

Year	Total Output	Usage by Use			Unused Quantity
		Electricity Generation	External Supply	Self-Use	
2011	173,918 (100)	27,387 (15.8)	15,364 (8.8)	98,078 (56.4)	33,089 (19.0)
2012	178,510 (100)	27,706 (15.5)	16,928 (9.5)	97,207 (54.5)	36,669 (20.5)
2013	205,435 (100)	27,925 (13.6)	27,211 (13.2)	103,414 (50.3)	46,885 (22.8)
2014	248,805 (100)	32,408 (13.0)	31,689 (12.7)	111,927 (45.0)	72,781 (29.3)
2015	284,382 (100)	43,177 (15.2)	52,349 (18.4)	122,729 (43.1)	66,127 (23.3)
2016	304,293 (100)	53,199 (17.5)	72,205 (23.7)	115,153 (37.9)	63,736 (20.9)
2017	321,062 (100)	55,839 (17.4)	100,603 (31.3)	111,585 (34.8)	53,035 (16.5)

As of 2017, 83.5% of the total biogas production is consumed for power generation, external supply, and self-use, and the 16.5% of the biogas, which was not used, is disposed of by burning. Among the uses of the biogas, the frequency of self-use is the highest followed by external supply and power generation in order of precedence. The yield of bio-gases has been increasing. (Table 2)[4]

3.2 Application of the Process Safety Management (PSM) System in Biogas Plants

After the introduction of the Process Safety Management (PSM) system under the Occupational Safety and Health Act of 1995, the PSM system has been in force since 1996[9]. Despite that biogas plants are subject to the Process Safety Management (PSM) pursuant to Article 33-6 of the Enforcement Ordinance of the Occupational Safety and Health Act because they manufacture and handle hazardous and dangerous substances in quantities exceeding the stipulated quantity (Table 3)[10], the Occupational Safety and Health Act has been applied since 2017 to only those sewage treatment plants that had been operated from the past among biogas plants. Therefore, biogas plants are introducing the Process Safety Management (PSM) later than other manufacturing, gas, and power generation industries.

Table 3. Quantity of Harmful or Dangerous Substances.

No.	Chemical Name	Stipulated Quantity(kg)
1	Flammable Gas	Manufacturing · Handling : 5,000
2	Flammable liquid	Storage : 200,000

3.3 Process of Biogas Plants

The processes of biogas plants in sewage treatment plants import organic wastes, undergo pretreatment,

and generate bio-gases in the anaerobic digestion plant (Fig. 1).

The main components of the generated bio-gases vary according to digested states, but they are generally composed of methane, carbon dioxide, hydrogen, nitrogen, and hydrogen sulfide. Among them, the content of methane is in a range of 55 ~ 70% (Table 4)[3]. The bio-gases as such are used as energy sources for boilers, surplus gas combustion equipment, and power generators.

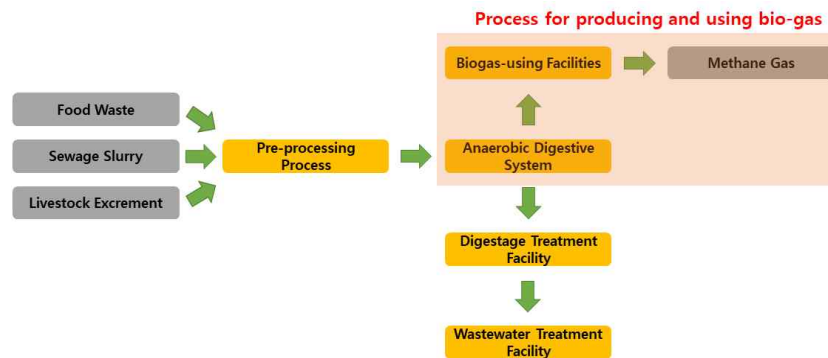


Figure 1. General process diagram of integrated processing biogas facilities.

Table 4. Example of a biogas component.

unit: v/v, (%)				
Methane	Carbon dioxide	Hydrogen	Nitrogen	Hydrogen sulfide
55 ~ 70	25 ~ 35	0 ~ 2	0 ~ 6	0.01 ~ 0.1

3.4 Questionnaire Survey and Analysis

The findings of analysis based on the questionnaire survey in which 84 workers participated are as follows.

In the case of most of the biogas plants in sewage treatment plants, the ratio of male workers was overwhelmingly higher at 97% of the workers who participated in the survey because of the nature of work that should be performed at the site. In addition, on reviewing the career of service at biogas plants, it could be seen that 39.3% of the workers had at least 10 years of careers. Meanwhile, in the case of biogas plants operated by the local government, 60.0% of the workers had long service careers not shorter than 10 years. This indicated the characteristics of workers who work in local governments. In the operation of a sewage treatment plant, the highest priority was given to the sector of environmental management by 43% of the workers followed by the sector of safety management by 32% and the sector of facility maintenance by 25% indicating that emphasis is placed on environmental management rather than worker safety.

In particular, in the case of sewage treatment plants operated firsthand by local governments, 40% of worker gave the highest priority to environmental management, 40% to facility maintenance, and 20% to safety management indicating that interest in safety was remarkably low.

As for the workers' opinions on whether the implementation of the Process Safety Management (PSM) system helped the improvement of the management's awareness, 25% of the workers answered 'very much so' and 57% answered 'yes' so that the ratio of positive opinions became 82%(Table 5). In addition, as for the workers' opinions on whether the implementation of the process safety management (PSM) system helped the safety awareness of the entire workplace, 36% of the workers answered 'very much so' and 50% answered 'yes'

so that the ratio of positive opinions became 86%(Table 6). Therefore, it could be seen that the introduction of the process safety management (PSM) system directly helped the management and workers in improving their safety awareness.

Table 5. The extent to which the process safety management (PSM) has contributed to the improvement of the employer's sense of safety.

No.	Answer	Rate(%)
1	Not at all so	0
2	Not so	11
3	Neutral	7
4	yes	57
5	Very much so	25

Table 6. The degree to which the process safety management (PSM) has contributed to the improvement of the workplace's safety awareness.

No.	Answer	Rate(%)
1	Not at all so	0
2	Not so	3
3	Neutral	11
4	yes	50
5	Very much so	36

However, as for the workers' opinions on whether all employees in the workplace were interested in the process safety management (PSM) system, 11% of the workers answered 'not at all so' and 14% 'not so' indicating that a total of 25% of the workers believed that workers were interested in only some of processes of the biogas plants out of the entire processes of the entire sewage treatment plant(Table 7).

In addition, as for the same question asked to only those workers working at sewage treatment plants that are operated by local governments, 20% of the workers answered 'not at all so' and 20% 'not so' indicating that workers' interests in the process safety management (PSM) system was lower than sewage treatment plants being operated on commission by private enterprises(Table 8). This is judged to be not unrelated to the characteristics of long service of workers working in local governments.

Table 7. The degree of interest of all employees in Process Safety Management (PSM).

No.	Answer	Rate(%)
1	Not at all so	11
2	Not so	14
3	Neutral	18
4	yes	43
5	Very much so	14

Table 8. The degree of interest of all employees in the process safety management (PSM) of sewage treatment plants operated by local governments.

No.	Answer	Rate(%)
1	Not at all so	20
2	Not so	20
3	Neutral	20
4	yes	40
5	Very much so	0

4. CONCLUSION AND DISCUSSION

The purpose of this study was to examine whether the process safety management (PSM) system was effective for safety awareness in biogas plants in sewage treatment plants. According to the results, whereas the level of interest in and awareness of safety of workers who were implementing the process safety management (PSM) were improved, but those of workers working at other processes or unrelated departments were hardly improved.

The conclusions obtained through this study are summarized as follows.

(1) Due to the nature of the work termed sewage treatment, the operation of biogas plants in sewage treatment plants was divided into firsthand operation by local governments and operation by private operators on commission. Since the administrating departments of local governments are environment-related departments, matters for intensive management cannot but be eventually concentrated on environment management. Therefore, new discussions on the division of overall works of the administrating departments of local governments related to occupational safety, including the process safety management (PSM) system should be necessary so that the workers' safety awareness can be inspired.

(2) It could be seen that the level of safety awareness of the management was improved through the process safety management (PSM) system and this is considered attributable to not only the effect of the introduction of the system but also the accompaniment of administrative punishments such fines in the case of most sewage treatment plants because they submitted process safety reports while they were operating their facilities despite that they should submit the report before installing the facilities pursuant to the Occupational Safety and Health Act.[8]

In the situation where interest in new & renewable energy will increase hereafter, biogas plants in sewage treatment plants cannot but be expanded, and environment and safety are not to be managed separately but should be managed comprehensively and mutually cooperatively. In such a situation, the role of the relevant departments of local government is important because very dangerous biogas plants must be designed so that the process safety management (PSM) system is reflected so that the worker's safety awareness is safer than now.

In addition, all the sewage treatment plants currently in operation should be investigated to see if any of them is not implementing the plant where the process safety management (PSM) system so that a safe environment system can be established in each sewage treatment plant.

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