ISSN: 0975-766X
CODEN: IJPTFI

Available Online through ***Research Article***
www.ijptonline.com

A SURVEY ON UNDERSTANDING OF GUIDLINES FOR HANDLING NANOMATERIALS AND ATTITUDES REGARDING SAFETY AND HEALTH

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Received on 14-07-2016 *Accepted on 11-08-2016*

Abstract:

This study is to measure understanding and attitudes about safety and health related to nanomaterials in work sites. A survey questionnaire was designed that included the general questions regarding nanomaterials, the contents of the guideline, and understanding of nanomaterial-related safety and health. Out of the 41 nanotechnology workplaces surveyed, 29 manufactured or used nanomaterials and 12 did not handle nanomaterials. There were a total of 133 respondents including 59 employees, 52 managers and 22 business owners (employers). Simple logit regression analysis was carried out to assess the difference in understanding of safety and health of the Guideline according to the characteristics of the respondents. Only 33.8% of the 133 respondents understood the "Nanomaterials Technical Guideline", while 59.4% did not. About 41.5 % of the respondents from 'nanomaterials field" workplaces were aware of the Technical Guideline, which is 8 times

higher than in respondents from 'Other fields like nanoprocess' (OR=8.16) (95% CI 1.83~36.42). While 65.4% of the managers responded that they would seek some consulting, this rate was 2.2 times higher than among employees and statistically significant (95% CI 1.04~4.82). It is necessary to provide training and education to reinforce accurate understanding of the Technical Guideline and thus fill the gap between the accurate information delivery and the understanding level of the contents of the Technical Guideline.

Keywords: Nanomaterials; Guidline; Awareness level; Health effects; Questionnaire.

Introduction

Worker's perceptions of nanotechnology and its potential hazards can be an important driver for protection of their health and safety and the sustainable advance of the technology. Multiple studies in a variety of fields have shown that there are significant differences in the perception of risks by the public and experts [1, 2)]. There is no significant

relationship between nanoscientists' attitudes and their citations of nanotechnology environmental, health, and safety publications [3].

Besley et al (2008) studied risk perceptions of US nanoscientists and found that support for regulations is strongest in the fields where the scientists' risk perceptions are highest [4]. Lee et al. (2008) reported that 74% of the public (N=599) have not heard about the potential risks of nanotechnology and 77% expected that nanotechnology/nanomaterials don't have harmful effects on human or ecological health. 74% of experts (N=165) realized the potential hazards by nanomaterials [5]. Thus, the perception levels of workers, managers and owners were much lower than those of experts.

Systematic safety control of nano products is urgently required in Korea. From 2005, the Ministry of Knowledge Economy has promoted the Integrated Plan for Safety of Nano Products for safety evaluation, establishing control systems, and internationally recognized standards.

Since it is likely that the safety of nanomaterials will be of global concern in the future, and could potentially lead to trade and technical barriers between countries, in 2011 the Ministry of Environment together with the Ministry of Employment and Labor, the Ministry of Knowledge Economy, the Ministry of Science, ICT and Future Planning and the Ministry of Food and Drug Safety, has implemented the "First Nano Safety Management Master Plan" [6].

Currently, there are 32 kinds of nanomaterials including TiO_2 and CNT (carbon nanotubes) that are distributed in Korea, and about 59,000 tons of nanomaterials are manufactured or imported into Korea annually. TiO_2 and SiO_2 are a majority of these nanomaterials [6].

Artificially manufactured nanomaterials (hereafter "manufactured nanomaterials") and various nanotechnologies are expected to have huge influence on our ordinary life. However, there are concerns regarding potential health effects in workers and the general population because of exposures to such materials. These concerns are partly driven by the lack of knowledge regarding the exposures and the related health effects.

As manufacture and production increases, the potential exposures of workers in the production and research facilities will increase. While active studies on nanomaterials are being carried out with government support, there is lack of data on exposure conditions and exposure evaluation.

This paper is part of an ongoing effort in Korea to develop methods to ensure safe use of these materials during handling and production. It is important to generate the necessary data regarding the types, amounts and exposure levels of nanomaterials, safety and control measures, and the infrastructure to implement these strategies.

Materials and Methods

1. Survey target and questionnaire

A survey questionnaire was developed by simplifying the nanomaterials safety and health guideline (hereafter "guideline") into ten questions. It included questions on sealing, isolation, personal protective equipment use, and safety and health education for business owners and employees. The questionnaire for working environment assessment were distributedamong 596 respondents in 184 manufacturers through health personnels of each manufacturer by post mail. The questionnaires were collected 3 to 5 weeks after distribution by the health personnels, and examined for the whole subject.

The target business workplaces included any enterprises engaged in the handling of nanomaterials or using nanotechnology (N = 184) according to the Yearbook of Nano in 2014[7]. Analyzed were data from 133 respondents out of the 596 (22.3%), who fully completed the questionnaires. The respondent companies have theprocess that handlenanomaterials andnon-respondent companiesdoes mainly not handle them.

The questionnaire included basic demographic questions, followed by a survey of the respondents' understanding of various aspects of the guideline. The questionnaire used in this study is presented in Appendix 1.

Analysis

To measure understanding and attitude on the safety and health on nanomaterials, a 5-point scale for scoring was used, with higher scores indicating higher understanding and better attitudes regarding safety and health. Multiple responses for 5 itemswas designed so that the sum of scores can be converted to 100-point scale. Simple logit regression was used to analyze the differences between various groups in their perception of safety and health of the guideline. The significance level for all statistical tests was 0.05. All statistical analyses were conducted using SPSS for Windows (IBM, 18.0k).

Results and Discussion

Responses to the questionnaire survey were received from 41 workplaces. Out of the 41, 29 manufactured or used nanomaterials and 12 were nanotechnology workplaces that did not handle nanomaterials. Five workplaces were engagedin both manufacture and use of nanomaterials. There were 34 nanomaterial handling places in Korea in 2012 according to the Ministry of Environment. Thus, we can assume that the 29 who responded to the survey are representative of of all workplaces. There were a total of 133 respondents including 59 employees, 52 managers, and 22 business owners (employers).Theresultsincludedan analysis ofthenanotechnology workplaces that did not handle

nanomaterials.

In terms of regional distribution, 59 respondents were from Gyeonggido (44.4%), followed by Daejeon 26 (19.6%), and Chungnam 12 (9.0%), and other areas 36 (27.1%). Around 31.6% of the workplaces had 10-29 employees, 23.3% of workplaces had 5-9 employees, and 13.5% of workplaces had 1-4 employees. Thus, a total of 68.3% of workplaces were small-scale industries with less than 30 employees, the rest were medium and large scaleindustries.

A majority of the respondents - 103 (77.4%) - worked with nanomaterials, followed by nano-measurement with 17 (12.8%) respondents and others with 13 (9.8%). The highest use of nanomaterials was nanometals with 33.3% followed by nanoparticles such as nanosilver with 32.6%, CNT (carbon nanotubes) with 20.7% and nano instruments with 13.3%.

Table 1 shows some of the demographic characteristics of the respondents – the vast majority were male (88.6%) and in the age group 30-49 years (73.7%); 33.6% had worked at their current place workplace for 3~5 years, and 24.4% had worked for 6~10 years.

Of the respondents, 28.2% had tasks described as "Work handling nano-structured powders", 20.2% had tasks with "Risk of skin exposure by liquid nanomaterials", 14.5% had tasks described as "Maintenance work in nanomaterials production facility" and 14.5% had tasks with "Risk of inhalation by mixing and rapid agitation of liquid medium nanomaterials."

73.8% of the respondents worked in a facility with less than five employees. Thus, the nanotechnology industry is dominated by small scale facilities.

Table 1. Characteristics of Study Subjects by Occupations.

Variable	Class	Worker	Manager	Employer
Age (year)	≤19	0	0	0
	20~29	11(8.2%)	0	0
	30~39	40(29.9%)	25(18.7%)	1(0.7%)
	40~49	4(3.0%)	26(19.4%)	5(3.7%)
	50~59	3(2.2%)	3(2.2%)	16(11.9%)
	≥60	0	0	0
	Missing	1	0	0
Sex	Male	46(34.8%)	50(37.9%)	21(15.9%)
	Female	10(7.6%)	4(3.0%)	1(0.8%)

	Missing	3	0	0
Present employment duration (year)	≤1	12(9.2%)	1(0.8%)	0
	1~2	17(13.0%)	4(3.1%)	3(2.3%)
	3~5	19(14.5%)	22(16.8%)	3(2.3%)
	6~10	8(6.1%)	20(15.3%)	4(3.1%)
	≥11	1(0.8%)	6(4.6%)	11(8.4%)
	Missing	2	1	1
Similar work duration (year)	≤1	18(15.0%)	8(6.7%)	0
	1~2	13(10.8%)	4(3.3%)	1(0.8%)
	3~5	14(11.7%)	9(7.5%)	3(2.5%)
	6~10	5(4.2%)	16(13.3%)	3(2.5%)
	≥11	1(0.8%)	13(10.8%)	12(10.0%)
	Missing	8	4	3
Task	1. Risk of skin exposure by liquid medium nanomaterials	10(8.1%)	11(8.9%)	4(3.2%)
	2. Risk of inhalation by mixing and rapid agitation of liquid medium nanomaterials	9(7.3%)	6(4.8%)	3(2.4%)
	3. Work forming respiratory nano aerosol	1(0.8%)	0	0
	4. Work causing gas type nano particle in an unsealing condition	4(3.2%)	2(1.6%)	0
	5. Work handling nano structure powders	15(12.1%)	12(9.7%)	8(6.5%)
	6. Maintenance work in nanomaterial production facilities	8(6.5%)	8(6.5%)	2(1.6%)
	7. Cleaning of nano particle collecting devices	4(3.2%)	5(4.0%)	1(0.8%)
	8. Others	6(4.8%)	3(2.4%)	2(1.6%)
	Missing	2	5	2

General understanding of the guideline

Table 2 shows that for the question on whether there was adequate guidance provided on the "nanomaterials guideline", 48 of the 133 respondents answered "Yes" (36.1%) which is significantly lower than the 85 respondents who said "No"(63.9%).

Thus, it reinforces the need for better promotion of the guideline as well as more meaningful guidance on its use. As for the route of acquiring the information of the guideline, 27.4% of respondents acquired it via training, or during inspection or supervision by related organization, 25.4% via government leaflet, 14.8% via the Internet, and 8.5% via Korean OSHA's leaflet. Questioned if they thought nanomaterials were dangerous, 29.5% "Agreed" or "Strongly Agreed" compared to 36.5% who "Disagreed" or "Strongly Disagreed" and 34.1% answered "Average".

Table 2. Characteristics of Perceptions of Study Subjects.

Variable	Class	Worker	Manager	Employer
Adequate Guidance on Guideline	Yes	15(11.3%)	24(18.0%)	9(6.8%)
	No	43(32.3%)	30(22.6%)	12(9.0%)
	Missing	1	0	1
Dangerous	Strongly agree	3(2.3%)	2(1.6%)	0(0.0%)
	Agree	16(12.4%)	14(10.9%)	3(2.3%)
	Average	20(15.5%)	17(13.2%)	7(5.4%)
	Disagree	11(8.5%)	13(10.1%)	6(4.7%)
	Strongly disagree	7(5.4%)	6(4.7%)	4(3.1%)
	Missing	2	2	2
Possible diseases caused by nanomaterials	Skin disease	8(6.8%)	9(7.6%)	1(0.8%)
	Respiratory disease	28(23.7%)	30(25.4%)	11(9.3%)
	Circulation system	4(3.4%)	1(0.8%)	1(0.8%)
	Endocrine system	2(1.7%)	0	0
	Do not know	11(9.3%)	8(6.8%)	4(3.4%)
	Missing	6	4	5
Factors influencing exposure	Handling amount nanomaterials	7(5.9%)	7(5.9%)	4(3.4%)
	Use and exposure time of nanomaterials	12(10.1%)	12(10.1%)	3(2.5%)

Concentration of nanomaterials in the air	12(10.1%)	10(8.4%)	2(1.7%)
Particle size, type and cohesion level of nanomaterials	11(9.2%)	9(7.6%)	6(5.0%)
Exposed part of body	10(8.4%)	11(9.2%)	4(3.4%)
Missing	7	3	4

Respiratory disease (cough, asthma, rhinitis etc) was thought to be caused by exposure to nanomaterials by a majority (59.5%) of the respondents, skin disease (eczema, atopy etc) by 17.6%, and smaller percentages for circulatory system and endocrine system diseases. Thus, respiratory disease was considered the most likely disease outcome. Factors perceived as influencing exposures to nanomaterials "Use and exposure time of nanomaterials" (22.7%), "Particle size, type and cohesion level of nanomaterials" (21.8%), "Exposed part of body to nanomaterials" (21.0%), "Concentration of nanomaterials in the air" (20.2%), and "Amount of nanomaterials handled" (15.1%). It shows they understood the relevant exposure factors for nanomaterials relatively well.

In terms of their interest in health and safety during the handling of nanomaterials, 56.1% answered "Very high" or "High", compared to 12.1% who answered "Low" or "Very low". Asked about the frequency of safety and health checklist assessments of nanomaterials, the responses were as follows: 1) Weekly assessment according to checklist (14.0%), 2) Monthly assessment according to checklist (16.3%), 3) Routine assessment with checklist (10.1%), 4) Routine assessment without checklist (44.2%), 5) No intermittent assessment and no checklist (15.5%). Over 80% had routine inspection. The following reasons were provided for not observing the guideline : 1) Ignorance of the guideline (50.4%), 2) To reduce cost (2.4%), 3) Not complying with the Guideline will not lead to any problems (36.2%), 4) Complying with the guideline will be problematic (8.7%), 5) Unrealistic to implement (2.4%), and 6) Others (0.8%).Asked about their intention to consult with experts on this matter, 57.6% of the respondents said "Yes" and 22% said "No".

Vulnerable group and risk factor on the guideline

The sizes of the enterprises were classified on the basis of the number of employees as small (5-49), medium (50-499) and large (> 500). There was no clear difference in the awareness level of the guideline by size of workplaces. However, the larger enterprises tended to have higher rates of awareness of the guideline (Table 3).

Table 3. Awareness level of the Guideline.

	No. of employees	Yes	No	Rates	Odds ratio	lower	upper
Company size	1-4	5	7	41.7%	-	-	-
	5-49	7	19	26.9%	0.52	0.10	2.57
	50-499	3	3	50.0%	1.40	0.17	11.38
	≥ 500	5	4	55.6%	1.75	0.27	11.54
	Kind	Yes	No	Rates	Odds ratio	lower	upper
Nano technology	Reference category	2	28	8.0%	-	-	-
	Nanomaterials	44	62	41.5%	9.94	2.25	43.90
	Nanoprocess	0	4	0.0%	0	-	-
	Nano measurement	1	16	5.9%	0.88	0.07	10.43
	Nano element	0	0	0.0%	0	-	-
	Nano bio	0	1	0.0%	0	-	-
	Type of work	Yes	No	Rates	Odds ratio	lower	upper
Nano work	Reference category	15	49	23.4%	-	-	-
	Nano manufacture	31	36	46.3%	2.81	1.33	5.97
	Nano use	22	34	39.3%	2.11	0.96	4.65
	Other	3	23	11.5%	0.43	0.11	1.62
	Year	Yes	No	Rates	Odds ratio	lower	upper
Similar work duration	<1	2	21	8.7%	-	-	-
	1~2	5	5	50.0%	10.50	1.56	70.76
	3~5	10	14	41.7%	7.50	1.42	39.52
	6~10	14	9	60.9%	16.33	3.06	87.18
	>10	7	18	28.0%	4.08	0.75	22.19
employment	Title	know	do not	Rates	Odds	lower	upper

position	well	know		ratio		
Employee	1	14	6.7%	-	-	-
Manager	9	13	40.9%	9.69	1.07	87.44
Owner	5	4	55.6%	17.50	1.56	196.33

As for the awareness level of the guideline by types of nano technology, among those answered ‘nanomaterials’ workplaces had 41.5% of awareness rate at logit regression analysis, which is 10 times higher than reference category (OR=9.94, 95% CI 2.25~43.90)(OR:Odd Ratio). The reference category means non-nano technology. This result seems to be caused by the fact that ‘nanomaterial’ is the main area of nano treatment. As for the evaluation of awareness level of the guideline in either manufacturing or using nanomaterials, the rate of nanomaterials manufacturing place was 46.3% which was 3 times higher than reference category, which is non-nano work(OR = 2.81, 95% CI 1.33~5.97). This demonstrates manufacturing places of nanomaterials had higher awareness level of safety and health than nanomaterial using places. As for the awareness level by years in similar work, the rate for experience of 1~2 years was 50.0%, that of 3~5 years was 41.7%, that of 6~10 years was 60.9% and that of 11 years and more was 28.0%. Thus, compared with less than one year, it had about 10 times, 7 times, 16 times and 4 times higher awareness levels using logit regression analysis. This suggests that higher experience leads to higher awareness levels of theguideline. Except for those working more than 11 years, all other cases were statistically significant (95% CI 1.42~87.18).

Education and consulting participation rate

As for the intention of accepting consulting support from experts for issues such as nanomaterials exposure evaluation, larger enterprises tended to have lower intention of seeking consultation. While this may be read as small enterprises wished more consulting or education, it was not statistically significant(95% CI 0.10~2.57). As for evaluation by types of nano technology, ‘nanomaterial area’ which was related to nanomaterials had lower participation on the consulting support. While the awareness level of nanomaterials was higher because every area treating nanomaterials belonged to ‘nanomaterial’, the rate of seeking consultation was lower, but it was not statistically significant. As for the consultation seeking by employmentposition(Table 4), based on employees, managers had a rate of 65.4% which was 2.2 times higher than employees and statistically significant (95% CI 1.04~4.82). Those with longer employment duration tended to have lower rates of seeking consultation, but it was not statistically significant(95% CI 0.75~22.19). It seems those with longer experience with nanomaterials tended not to seek consultation assistance.

Table 4.Consulting participation level of the Guideline by employment position.

Title	Consulting participation		Rates	Odds ratio	lower	upper
	Yes	No				
Employee	27	32	45.8%	-	-	-
Manager	34	18	65.4%	2.24	1.04	4.82
Employer	13	9	59.1%	1.71	0.64	4.62

Awareness level of the health effects of nanomaterials

The level of the understanding of the guideline for managers and owners were 40.9% and 55.6% respectively which were about 9~17 times higher than employees (95% CI 1.07~196.33)(Table 5). There were significant differences in the awareness level of health effects of nanoparticle exposures by workplace size. The levels of awareness were 8 to 48 times greater than for very small scale facilities. However, the awareness levels decreased for very large facilities. Awareness levels were much greater in manufacturing workplaces than in other types of workplaces. Managers had much greater awareness levels than owners and employees.

Table 5.Awareness level about the health effects of nanomaterials.

	No. of employees	is dangerous	is not dangerous	Rates	Odds ratio	lower	upper
Company size	1-4	2	16	11.1%	-	-	-
	5-9	10	20	33.3%	4.00	0.76	20.92
	10-29	6	33	15.4%	1.45	0.26	8.03
	30-49	4	2	66.7%	16.00	1.69	151.12
	50-99	6	1	85.7%	48.00	3.65	631.79
	100-299	5	5	50.0%	8.00	1.17	54.73
	300-499	1	1	50.0%	8.00	0.35	184.38
	500-999	0	5	0.0%	0.00	-	-
	1000 or more	3	7	30.0%	3.43	0.47	25.27
Nano technology	Item	is dangerous	is not dangerous	Rates	Odds ratio	lower	upper
	Reference category	2	23	8.0%	-	-	-
	Nano materials	35	67	34.3%	6.01	1.34	26.97

	Nano measurement	1	16	5.9%	0.72	0.06	8.62
	No response	1	6	14.3%	1.92	0.15	24.87
Nano work	Type	is dangerous	is not dangerous	Rates	Odds ratio	lower	upper
	Reference category	10	53	15.9%	-	-	-
	Nano manufacture	27	37	42.2%	3.87	1.67	8.94
	Nano use	18	38	32.1%	2.51	1.04	6.04
	No response	1	24	4.0%	0.22	0.03	1.82
Disease	Item	is dangerous	is not dangerous	Rates	Odds ratio	lower	upper
	Reference category	8	54	12.9%	-	-	-
	Respiratory disease	29	36	44.6%	5.44	2.24	13.23
	Circulatory disease	2	1	66.7%	13.50	1.09	166.57
	Endocrine system	4	3	57.1%	9.00	1.69	47.86
	Skin disease	6	10	37.5%	4.05	1.15	14.21
	Don’t know	4	30	11.8%	0.90	0.25	3.24

The terminology in thid study can define as follows ; Perception is the ability to see, hear, or becomeaware of something through the senses. Awareness isthe knowledge or perception of a situation or fact. Understanding isthe ability to understand something; comprehension. Andattitudeis asettled way of thinking or feeling about something in Oxford dictionaries.

Twenty-six companies (65%) of 41 companies that produced engineered nanomaterials indicated that they did not perform any risk assessment of their nanomaterials and 13 companies (32.5%) performed risk assessments sometimes or always. Helland et al, (2008) recommended the development of risk and safety decision frameworks in industry to ensure that the potential risks of engineered nanomaterials are managed appropriately [8, 9].

This study revealed that perceptions of nanotechnology health and safety were affected by factors such as years of

employment, use of safety and health checklists, and consulting or training by government, but not by factors such as job category, sex, age, harmful effects, and company's level of interest on safety and health.

Only ~34% of the respondents were aware of the guidelinepublished by Korea. Only ~36% of the respondents felt that the guideline provided useful guidance. The awareness levels of managers and owners on the Technical Guideline were twice higher than workers. The understanding levels of the Technical Guideline for managers and owners were 40.9% and 55.6% respectively and they were ~9 to ~17 times more likely than employees to have better understanding. Companies manufacturing nanomaterials had 3 times higher awareness than companies using nanomaterials.

Conclusions

This survey showed that the awareness of the workers (employees) of the risks of nanomaterials is not high compared with the awareness levels of managers and owners. The difference between these groups can potentially be an obstacle to improving health and safety issues relating to nanomaterials, as well as imroving compliance.

These results underline the need to consider the perception of workers about nanomaterials and its potential risks, and provide accurate and objective information about the potential hazards of nanomaterials. It is necessary to provide training and education to reinforce accurate understanding of the Technical Guideline and thus fill the gap between the accurate information delivery and the understanding level of the contents of the Technical Guideline.

There is also a need to increase the types of industries in which such training and education needs to be provided. Since managers report a better understanding than employees of the Technical Guideline, the training needs to also focus on employees. The results reinforce the need for better promotion of the Technical Guideline as well as more meaningful guidance on its use.

Acknowledgments

This study was supported by the intramural research fund of the Occupational Safety and Health Research Institute (OSHRI), Korea Occupational Safety and Health Agency (KOSHA).

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