

Original Research Article

Social Impact of Odor Induced by Municipal Solid Waste Treatment Facilities in Ho Chi Minh City

ABSTRACT

Landfills are mostly used to manage solid waste in Ho Chi Minh City, Vietnam. Due to inappropriate administration, there have been numerous issues over the years relating to odor and leachate. The purpose of this study is to explore the impact of odor stemming from Da Phuoc landfill site on surrounding areas. A questionnaire survey was administered through face-to-face interviews with 409 residents living in the affected areas. The findings of this study indicate that the odor perception of residents significantly influences their attitudes towards waste disposal sites. The results show that odor affects not only the region around municipal solid waste (MSW) treatment facilities but regions more than 7 km away as well. The data indicates that the odor emanating from the MSW disposal site negatively affects the daily life of many residents. This study is an effort to finding a solution to reduce the impact of odor generated from the landfill site on nearby residential areas.

Keywords: Odor perception; landfill site; municipal solid waste; Vietnam

1. INTRODUCTION

Municipal solid waste (MSW) management centers have an adverse impact on the environment [1,2,3]. They contaminate the environment in two main ways: (i) contaminated gas and metals seep into the air, water, and soil from the degradation and treatment of wastes; (ii) garbage disposal causes many problems like noise, litter, dust, vermin, odor, and damage to productive agricultural and historic sites. Therefore, evaluating the influence of MSW management on the environment is a critical task. This task is challenging as many factors such as odor dispersion on nearby landscape, meteorology, and atmosphere, the residence size and educational level of the residents, and weather per season need to be considered.

Gas emissions from the MSW, such as bacteria, odor, and particles, can significantly disturb the neighboring inhabitants. Hence, a few studies on the odor effect of MSW centers were carried out in many territories such as the US, Europe, Japan, and Korea [4,5,6,7]. Qualitative evaluation of the odor effects on residences is often performed by using survey questionnaires to give a standardized assessment [8,9,10,11]. Recently, some surveys targeted three critical points, including the odor effect on health, wellbeing, and how the odor effects are influenced by residents' recognition.

However, such studies have not been conducted intensively in Ho Chi Minh City (HCMC), Vietnam, where the waste degradation is much faster and has a more significant impact on the environment due to the tropical weather. HCMC is the largest city in the south of Vietnam, not only in terms of population but also economy. The HCMC population was approximately 8,444,600 people in 2017, living within an area of 2,061.2 km². The HCMC

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39 residents produce 8,175 tons of solid waste per day that contains 6,700-7,000 MSW with
40 1.02 kg/capita/day [12]. The amount of MSW annually increases by 98,338 tons. A
41 significant portion of the MSW originates from households, schools, hotels, and restaurants.
42 The MSW treatment in the HCMC is mostly landfilling. Around 86% of the solid waste is
43 treated at the two main landfills, Da Phuoc and Phuoc Hiep, and the remaining 14%, which
44 mainly consists of paper, plastic, and metal, is recycled. Unfortunately, the MSW treatment
45 at the HCMC centers, especially in the area shown in Fig. 1, currently causes many
46 environmental consequences such as leachate and bad odor. However, these
47 consequences have not been adequately addressed in order to find solutions for them.

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49 Human reactions to the odors are subjective and changeable. The odor perception is
50 influenced by several personal factors (such as awareness, sensitivity, ability to cope, and
51 previous experience with odors). Personal perception also has a connection to other
52 environmental stressors, socio-economic conditions, and disruption in the activities of
53 residents [13,14]. Moreover, the responses of people are influenced by the characteristics of
54 the odor, such as frequency, intensity, duration, and odor quality [13]. The odor dispersion,
55 concerning odor emissions, wind direction, topography, weather conditions, and the distance
56 from odor sources, affects the load of the environmental odor in a particular area [15,16,17].
57

58 Residences close to the waste disposal area probably have broader concerns about the
59 health and environmental impacts [18]. There is a growing awareness of the environmental
60 impact of MSW disposal facilities. Additional reported evidence of the effects on the health of
61 MSW management zones could result in an increased perception of the risk to nearby zones
62 [19]. Therefore, the public's concerns, perceptions, and attitudes about the MSW treatment
63 play an essential role in the final decision on the plant and the location of a new SWM facility
64 [20,21]. When given sufficient information on the possible impacts and benefits of new MSW
65 facilities on the environment, residents readily support their construction [21]. Otherwise,
66 they raise a strong opposition which cannot be avoided [6].
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68 Besides, the effects of distance to hazardous waste sites have been studied in developing
69 countries. Non-sanitary waste treatment centers were classified into two different groups: (i)
70 those within 50 meters of residences and (ii) those outside 50 meters of residences in a site
71 in Sierra Leone [22]. In their study, Al-Khatib (2014) asked the interviewees whether they
72 were opposed to the building of a MSW management facility within one kilometer of their
73 homes [23]. Another questionnaire study examined how interviewees, living within and
74 beyond 250 meters of a dump site in Nigeria, perceived the health impacts of solid waste
75 dumping [24]. The effect of the distance and the changes in the perception of communities
76 through the distance of a site were investigated in Thailand [25]. The results of this study
77 indicate that younger people are more interested in the impact of the sites than elderly
78 respondents, and respondents with higher education are more aware of the impact.
79

80 Furthermore, the distance of the living area from the sites has a significant influence on how
81 much the odors of landfills impact the residents. A study addressed the concerns of the poor
82 communities living near the landfill in Hanoi, Vietnam [26]. Their findings indicated that
83 financial compensation should be paid to residents living within a 1 km radius of the landfill
84 instead of only within a range of 500 m, as referenced in a policy applicable in Japan. This
85 study suggests that environmental law in Vietnam should allow residents to join the process
86 of landfill siting in order to have a better understanding of their concerns related to the
87 surrounding landfills. However, previous studies have not focused on the maximum distance
88 of perceived odor or the odor irritation reported by the communities surrounding MSW
89 management facilities. Therefore, the objective of this study is to investigate the odor effects
90 with regard to the concerns and perceptions of the residences in the HCMC, as well as the
91 residents' attitudes and reactions to the waste treatment facilities in the HCMC by distance.

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2. MATERIALS AND METHODS

2.1 Characteristics of the MSW facility

The study area is described in Fig. 1. The Da Phuoc waste treatment facility was built in 2007 in the southeast area of the HCMC. This waste treatment facility was designed with three functions: (i) a recycling processing plant with advanced technologies, (ii) a composting plant, and (iii) sanitary landfilling. The waste treatment facility receives 5,200 tons of waste every day.

2.2 Study area

The questionnaire survey was conducted through face-to-face interviews with households in the four areas located near the waste treatment site, with a distance of less than 3 km (area 1), 3-5 km (area 2), 5-7 km (area 3), and over 7 km (area 4) from the border of the waste disposal facility. As shown in Fig. 1, area 1 is located in the Da Phuoc commune of Binh Chanh District, area 2 is located in the Nhon Duc commune of Nha Be District, area 3 is located in the Phuoc Kien commune of Nha Be District, and area 4 is located in Phu My Ward of Phu My Hung urban area (district 7).

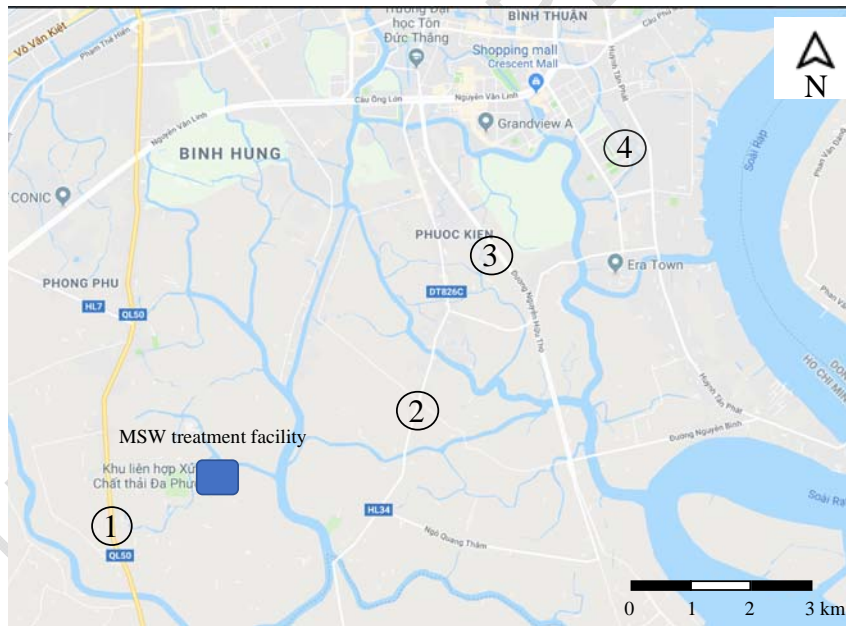


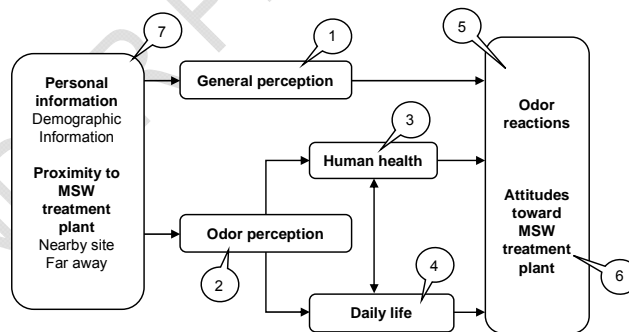
Fig. 1. Location of study area. Source: Google map.

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2.3 Data collection and analysis

121 The survey questionnaire consists of 7 main sections. The questionnaire structure is shown
 122 in Fig. 2. These factors include the general perception of environmental pollution (Q1-Q3),
 123 perception of odors (Q4-Q13), health (Q14-Q17), assessment of the impact of daily life
 124 activities (Q18-Q23), people's actions to cope with odors (Q24-Q28), attitudes towards MSW
 125 facilities (Q29-30), and questions regarding demographic status. Questions 1-3 focus on the
 126 general perception of environmental pollution: "Are there any pollution-related issues in your
 127 residential area?" (yes, no, don't know); "If yes, what is the principal source?" (industrial
 128 activity, landfill site, vehicular traffic, construction activity); and "What problems do you
 129 face?" (odor, noise, dust/gas emission from vehicles, flies, others). Questions 4-13 are
 130 concerned with the odor perception; "time of year the odor becomes worse," "frequency,
 131 duration, type of odor," "odor level," "factors affecting odor emission," and "intensity of odor
 132 emission." Questions 14-17 are concerned with health issues that include the following
 133 aspects: "concerns" about odor, "health affected," and "symptoms" at the time the
 134 respondents noticed the odor. Questions 18-23 cover the annoyance felt by residents due to
 135 the odor affecting their daily life in "daily activities," "studying/working," "business activity,"
 136 and "outdoor activities" (not at all, a little bit, moderately, very, extremely). Questions 24-28
 137 are concerned with the residents' reactions to the odor emission posed in the fourth part.
 138 Information is thus collected with respect to "measures to reduce odor effects," "used face
 139 mask for outdoor activities" (yes, no), "inform government staff about odor problem," "inform
 140 landfill manager about odor problem," and "if respondents were to move, would they move"
 141 (to another location in this area, to another location outside this area, don't know). The
 142 survey was conducted from October to December, 2018. [The total populations of areas 1, 2,
 143 3, and 4 were 16,388, 11,179, 24,765 and 24,270, respectively [27,28,29,30]. The sample
 144 size for this study was calculated by using Cochran's sample size determination technique
 145 with 5% confidence interval and 95% confidence level. The optimal sample size for this
 146 study was 382. Then we used the proportional allocation method to calculate sample size for
 147 individual study areas. The optimal samples for areas 1, 2, 3, and 4 were 82, 56, 123, and
 148 121, respectively. However, a total of 409 questionnaires were administered, which
 149 consisted of 82, 70, 112, and 145 questionnaires corresponding to areas 1, 2, 3, and 4,
 150 respectively.

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 154 **Fig. 2. Hypothetical diagram of cause-impact structure**
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156 Chi-square test was performed to test significant relationships between
 157 questionnaire components. Factor analysis was used to investigate the correlation
 158 between variables and find latent factors. All the analysis was performed in SPSS version 25
 159 and MS Excel software.
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161 **3. RESULTS AND DISCUSSION**

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163 **3.1 Demographic profile**

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165 The socio-demographic profile results of the respondents are described in this section.
166 There is no significant difference between the number of male and female respondents. In
167 terms of the level of education, the people residing in a region over five kilometers from the
168 MSW treatment facility have a higher education level (undergraduate degree or above), as
169 compared to the people within a five-kilometer range. Respondents over the age of 30
170 accounted for 85.8%. In respect to the number of years the respondents have lived in an
171 area, 50% of the respondents stated that they had been living in area 1 for over 10 years.
172 On the other hand, more than 50% of respondents from areas 2, 3, and 4 stated that they
173 had been living there for less than 5 years. With regard to the type of dwelling, the results
174 show that 90.2% and 80% of the respondents of areas 1 and 2, respectively, lived in
175 detached houses. Meanwhile, 67.9% and 69% of the respondents of areas 3 and 4 lived in
176 apartments.
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178 **3.2 Odor perception**

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180 The human nose is able to recognize odors at a lower concentration than gas
181 chromatography for some elements [31]. Odor perception depends on several conditions
182 such as atmospheric conditions, subjective awareness, and influence of different odors
183 [32,33,34]. The one also depends on the personal physical state [35]. In this subsection, the
184 overall results of the questions concerning odor perception, such as frequency, duration,
185 level, intensity, and factors affect odor emission are discussed. We found that odor
186 perception was influenced by wind direction and seasonal changes in the study area. These
187 results revealed that 46.2%, 33.3%, and 20.5% of the respondents noticed that the worst
188 odor occurs from June to August, from September to November, and from March to
189 December, respectively. The respondents stated that odors become worse by distance to
190 the landfill site, depending on the time of year, as shown in Fig. 3. It may explain that the
191 studied area, which has a tropical monsoon, has two typical weather characteristics that
192 directly influence the odor dispersion. The first one is the high temperature throughout the
193 two distinct seasons: the dry season from November to April and the rainy season from May
194 to October. The second one is the wind direction, which changes from month to month: (i)
195 Southeast or in the southern direction from January to May, (ii) West or Southwest direction
196 from June to September, and (iii) Northeast direction from October to December. Due to the
197 change in the wind direction, it is easy to understand why a part of the respondents agreed
198 that the odors became worse from June to November.
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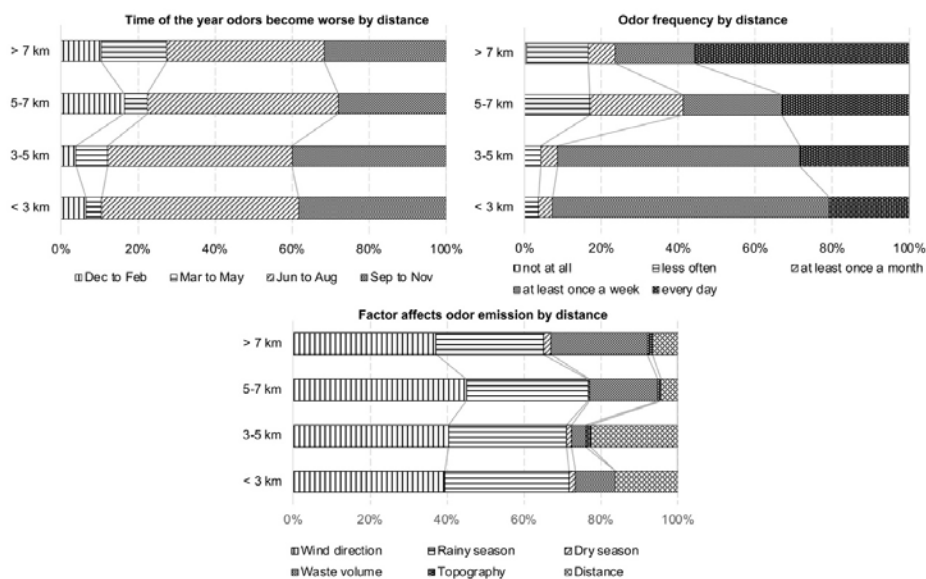


Fig. 3. Odor perception: time of the year odors become worse by distance, odor frequency by distance, factor affects odor emission by distance (Source: compile from field survey 2018)

The odor frequency of “at least once a week” ranked the highest (39.6%), followed by “every day” (33.3%), “less often” (11.7%), “at least once a month” (10.5%), and “not at all” (0.2%). For odor duration, the results indicated that the highest rank was “1–4h” (32.5%), followed by “30 min–1h” (26.2%), “> 4h” (24.7%), “10–30 min” (13.9%), and “< 10 min” (2.7%). The impact of the odor frequency by distance to the landfill site is shown in Fig. 3. The most affected factor was wind direction (40.1%), followed by rainy season (30.1%), waste volume (16.8%), distance (10.7%), dry season (1.4%), and topography (0.7%). During the survey, 41.8% of interviewees reported that they felt “extremely annoyed” by the odor, and 57.7% reported that the intensity of odor had increased over the past two years. Furthermore, 63% of respondents reported that the odor type was offensive. This is consistent with the findings of previous studies [15,16,36,42]. The impact factors of the odor emission by distance to the landfill site is shown in Fig. 3.

3.3 Annoyance of daily life and human health effects

Odor emission from MSW treatment facility potentially adopts a negative effect on human health [37,38]. Odor level strongly influences the relationship between exposure and annoyance. It also affects the association between exposure and symptoms [13]. The previous studies indicated that odor causes a large number of complaints from the community related to industrial [39,40]. It is suggested that odor annoyance instead of perception causes symptoms [41]. The characteristic odor contributes to the formation of annoyance, resulting in headache, respiratory problems, eye, nose and throat symptoms, nausea, etc. The results of this study are consistent with previous studies [15][22][36]. In particular, the results showed that a majority of the respondents (86.1%) thought that the MSW treatment facility reduced their quality of life. Their daily activities, business activities, studying or working activities, and outdoor activities were “extremely” affected, accounting

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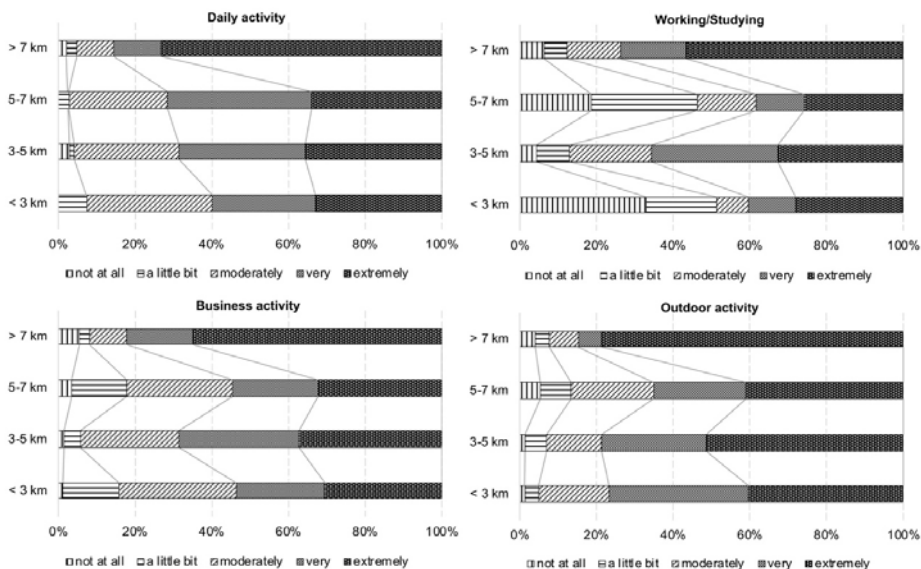
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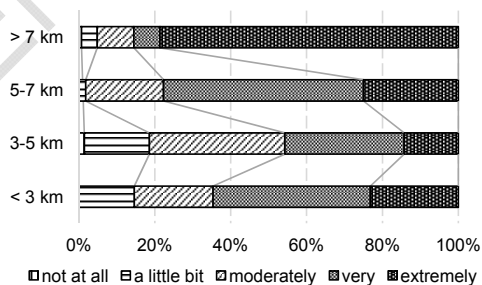
232 for 47.9%, 38.4%, 44.3%, and 56%, respectively. The concerns regarding daily life activities
 233 by distance to the landfill site is indicated in Fig. 4. Around 53.3% of respondents "extremely"
 234 expressed their feelings towards the odor. The results indicate that up to 82.9% of the
 235 respondents had health-related concerns, and 84.6% of them reported that the odor affected
 236 their entire family. The symptoms that people encountered were predominantly nausea
 237 (15.7%) and shortness of breath (15.5%). Surveed communities of this study perceived
 238 greater concerns and health issues in comparison with a previous one [42]. The odor
 239 concerns of respondents by distance to the landfill site is shown in Fig. 5.
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Fig. 4. Daily life concerns (Source: compile from field survey 2018)



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Fig. 5. Odor concern by distance (Source: compile from field survey 2018)

248 It is clear to say that the odor effects decrease due to increasing distance [6,11,23,24,40,41].
 249 However, the results of this study show that people felt more annoyed in zone 4, as seen in
 250 Fig. 5. This might be because the odor dispersion is from MSW management facility to zone
 251 4 (cluster of high-rise buildings). Odor dispersion does not occur in lower floors of the high-
 252 rise building areas because the wind speed is proportional to the height of the buildings [39].

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253 In the meantime, odor dispersion is easier on the higher floor due to high wind speed.
 254 Therefore, odor effect does not decrease within this area. The above observation can be
 255 explained by residents' awareness, educational level, and dwelling type. Because
 256 differences of demographics and lifestyle may generate changes of reactions to
 257 environmental odors except at very high or very low concentrations [44,45]. It is possible that
 258 the respondents of area 1, due to being exposed to the odor perpetually, may have gotten
 259 used to it since long-term exposure of odors may lead to decrease the ability to detect them
 260 [46]. The concerned ones are mostly farmers and workers who have to earn money for a
 261 living. Meanwhile, most respondents in area 4 have higher incomes and are interested in
 262 environmental issues. They also are worse at detecting odors, which leads to aversion and
 263 negative behaviors when they detect odors [35].
 264

265 3.4 Odor reactions and attitudes toward MSW management facility

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 267 Perception of odor does affect what response that odor probably evokes, and, on the
 268 contrary, odors induce changes in behavior and feeling when a person believe to smell
 269 them despite their presence [47,48,49,50]. Table 1 indicates the results of the people's
 270 reaction towards the waste treatment facility. About 58% of the respondents close their
 271 windows when they notice the odor, while 0.3% (2 out of 409) of them leave their home for a
 272 while. A total of 74.8% of people use masks when they need to go outside and 60.6% of
 273 respondents inform the government staff about the odor impacts. Also, 21.8%, 12%, and
 274 5.6% of respondents answered "plan to inform," "not inform," and "no idea." Regarding the
 275 question of informing the landfill manager about the odor impacts, 49% of respondents
 276 selected "inform," followed by 28.1%, 18.8%, and 3.2% of respondents who selected "plan to
 277 inform," "not inform," and "no idea," respectively.
 278

279 **Table 1. Odor reactions**

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Items	Frequency (%)
Used a face mask for outdoor activities	
Yes	306 (74.8)
No	96 (23.5)
Don't know	7 (1.7)
Inform government staff	
Inform	248 (60.6)
Plan to inform	89 (21.8)
Not inform	49 (12.0)
No idea	23 (5.6)
Inform landfill manager	
Inform	204 (49.9)
Plan to inform	115 (28.1)
Not inform	77 (18.8)
No idea	13 (3.2)

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 282 The results relating to people's attitude towards the waste treatment facility are shown in
 283 Table 2. When asked about the merits and demerits of the waste disposal site, a majority of
 284 respondents rated "bad" (67.2%) while only 21% of them rated "good." Also, 52.3% of the
 285 respondents stated that the assessment result of the management of the garbage disposal
 286 facility is "very bad."
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Table 2. Attitude towards MSW management facility

Items	Frequency (%)
Positive or negative aspects	
Good	86 (21.0)
Bad	275 (67.2)
Don't know	48 (11.7)
Landfill management rating	
Very good	2 (0.5)
Good	11 (2.7)
Fair	64 (15.5)
Bad	118 (28.9)
Very bad	214 (52.3)

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3.5 Relationships between the cause – impact structure

296 A series of chi-square tests were implemented to determine significant relationships between
297 the questionnaire components. The inter-connected lines of questionnaire sections in Fig. 6
298 imply the characteristics of their relationship. Significant relationships were observed
299 between the residents' daily life and their odor-related reactions and attitudes towards the
300 MSW treatment plant via chi-square tests. The solid lines in Fig. 6 indicate these
301 relationships. Moreover, there is an insignificant relationship between the odor level of the
302 odor perception section and the distance to the landfill site of the demographic status
303 section. The round dotted line represents the relationship between the two sections
304 mentioned above. Furthermore, the square dotted lines were used to denote significant
305 relationships of residents' odor perception, daily life, odor reactions, and attitudes towards
306 MSW treatment plant with human health. That is because only two questions regarding
307 human health (odor concern and health affected) were correlated with those sections.
308 Finally, there is an insignificant relationship between residents' general perception and
309 demographic profile, odor reactions, and attitudes towards the MSW treatment plant. The
310 long dashed-dotted lines denote the relationships.

311
312 Fig. 7A shows the relationship between odor frequency and the residents' annoyance levels
313 in daily affairs. The results revealed that residents' annoyance is strongly related to the odor
314 frequency. The result of the relationship between residents' annoyance and their given rating
315 of the landfill site is shown in Fig. 7B. The respondents who experienced extreme
316 annoyance poorly evaluated the landfill site.
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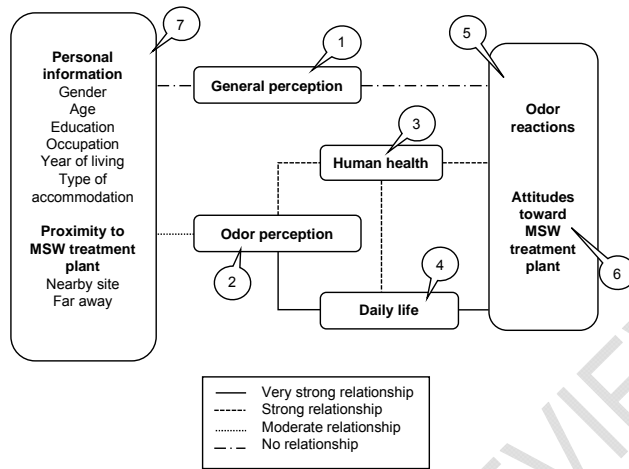


Fig. 6. The relationship between questionnaire parts

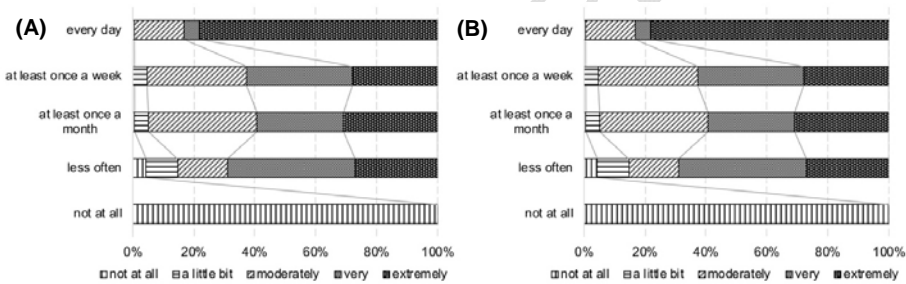


Fig. 7. Relationship between odor frequency and residents' annoyance of daily activity (A), and relationship between residents' annoyance of daily activity and rating of landfill (B) (Source: compile from field survey 2018)

3.6 Factor analysis

Factor analysis was used to explore the potential structure of the variables in questions 1-30, based on the correlation criteria. It is used to discover, validate, and compare the number of factors in the research model with the actual data. The purpose of this analysis is to investigate the correlation between variables and find key factors for future research. In the exploratory factor analysis, the extraction method used is the Principal Component Analysis method and Varimax rotation method with Kaiser Normalization. As a result, there are four components shown in Table 3.

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Table 3. Component loadings of concerned items by factor analysis (N=197)

Item	Component			
	1	2	3	4
Work or studying	0.86	0.29	0.04	0.11
Business activities	0.82	0.17	0.03	0.04
Daily activities	0.78	0.37	0.05	0.11
Outdoor activities	0.78	0.32	0.08	-0.03
Worried about the odor	0.77	0.30	0.04	0.16
Property value	0.69	0.16	0.08	0.05
Odor frequency	0.64	-0.03	0.20	0.08
Used a face mask for outdoor activities	0.59	-0.14	0.02	-0.14
Positive or negative aspects	0.30	0.73	0.02	-0.08
Landfill management rating	0.32	0.71	0.09	0.21
Deterioration of environmental quality	0.03	0.65	0.30	0.07
Inform landfill manager	0.11	0.07	0.87	0.00
Inform government staff	0.11	0.21	0.82	0.08
Odor intensity	0.21	-0.12	0.01	0.85
More odor or more sensitive	-0.10	0.28	0.08	0.79
Eigenvalue	5.79	1.75	1.34	1.08

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The first component is named “nuisance” due to the high loadings, including the annoyances of “work/studying,” “business activity,” “daily activities,” “outdoor activities,” “odor frequency,” “worried about odor impact,” “property value,” and “used a face mask for outdoor activity.” “Attitudes toward MSW treatment facility” is the second component that consists of “positive or negative aspects,” “landfill management rating,” and “deterioration of environmental quality.” “Action to cope with odor impacts” is the third component consisting of “inform landfill manager” and “inform government staff.” The fourth component is termed “perception of odor intensity,” which includes “odor intensity” and “more odor or more sensitive.”

The standard error of regression (REGR) factor score 1 and 2 by distance, the standard error of REGR factor score 1 and 3 by distance, the standard error of REGR factor score 1 and 4 by distance, and the standard error of REGR factor score 3 and 4 by distance are indicated in Fig. 8. The results showed that respondents in area 4 (> 7 km) had a higher awareness of perception of odor intensity and attitude toward MSW treatment facility than other regions in terms of a nuisance as seen (Fig. 8A, 8B). Meanwhile, respondents in zone 2 had the lowest results of the nuisance, attitude toward MSW treatment facility, perception of odor intensity, and action to cope with odor impacts as seen Fig. 8.

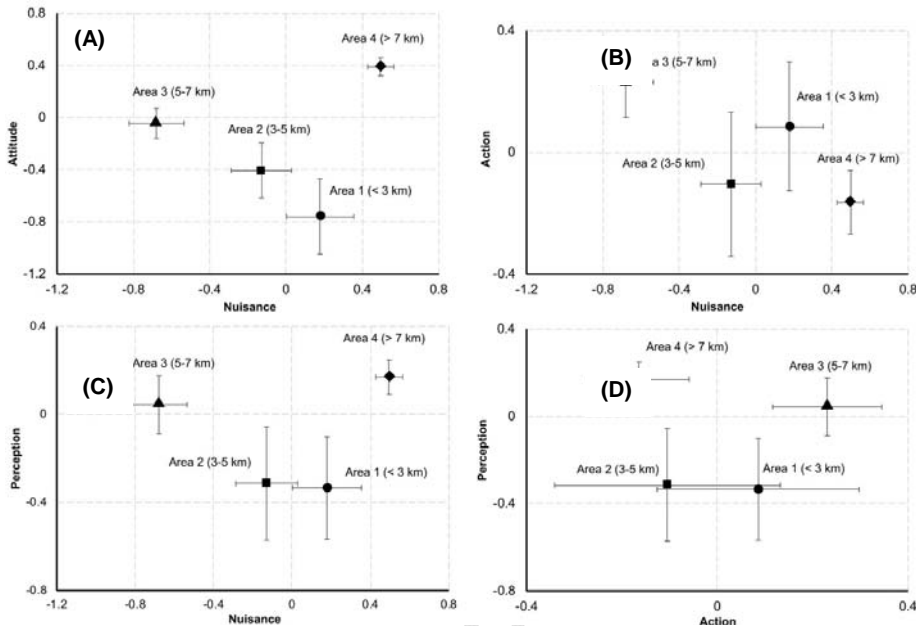


Fig. 8. The standard error of REGR factor scores: nuisance and attitude (A), nuisance and action, nuisance and perception (C), action and perception by distance (D) (Source: compile from field survey 2018)

4. CONCLUSION

In this study, we have investigated the impact of the odor emission on the residents as well as their perceptions, reactions, and attitudes towards the MSW treatment facility. There are several findings which have been observed in our study. Firstly, it can be seen that residents' attitudes toward the landfill site are strongly influenced by their perception about odor. This perception is affected by weather conditions, such as season, wind and rain. Secondly, it is found that not only are the area near the MSW management facility influenced by the odor effects but also areas more than 7 km away. In other words, most residents living more than 7 km away from the landfill site felt more annoyed than those living less than that. Thirdly, the collected data provide insights into how the odor from the MSW disposal site negatively changes the residents' daily life. Particularly, the respondents who experienced more annoyance tend to poorly evaluate the landfill site. This is a good start to find solutions for odor improvement in order to reduce its impact on residences. Finally, four principal components have been obtained by using factor analysis. They are identified as "nuisance," "attitudes towards MSW treatment facility," "reactions to deal with odor impact," and "perception of odor intensity." The combination of questionnaire survey and measurement of odor can be considered in future research to achieve greater efficiency in assessing the impact of odor on the community.

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391 **ETHICAL APPROVAL**

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393 This work was approved by Tokyo Institute of Technology Research Ethics Committee.

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395 **COMPETING INTERESTS**

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397 Authors have declared that no competing interests exist.

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399 **REFERENCES**

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