

Odor intolerance and proposed off-site limit under the Thailand public health provision

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proposed
off-site limit

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Received 16 January 2020

Revised 31 March 2020

20 April 2020

Accepted 26 May 2020

Abstract

Purpose – This study aimed to determine the initial odor concentration which commonly urges Thais to make complaints and to propose an off-site limit for odorous emissions.

Design/methodology/approach – Odor concentrations measured by Nasal Rangers® and face-to-face survey interviews were simultaneously conducted with 122 residents located near 101 manufacturing centers in 20 provinces of Thailand. Along with the measured values and odor strength verbally rated by trained assessors, the number of complaint intentions, annoyance levels and health symptoms of residents were reported.

Findings – The odor concentrations in the inspected houses were <2, 2, 4, 7, 15, 30 and 60 D/T. The trained assessors stated that at the concentration of 4D/T, most odors were likely to be objectionable and unbearable when odor concentrations were higher. Correspondingly, about 80% of residents exposed to odors at this level felt some annoyance and reported health symptoms and therefore intended to register a complaint. At lower concentrations, the annoyance level as well as the decision to complain likely depended on other factors such as hedonic tone and exposure frequency.

Practical implications – The proposed off-site reference value for odor complaint assessment was 4D/T. However, in the case of lower concentrations, additional relevant factors were crucially required to investigate the complaint.

Originality/value – This finding will help local authorities diminish subjective discretion on whether or not an odor constitutes a nuisance.

Keywords Environmental nuisance, Odor, Odor annoyance, Objectionable level, Odor complaint, Thailand

Paper type Research paper

Introduction

As a result of economic and technological development without careful contingency planning, a large proportion of the population has been exposed to various kinds of environmental nuisances. Among these, objectionable odor has been ranked as the highest complaint in many countries including Thailand [1]. To investigate the problem, four factors affecting nuisance occurrence, i.e. frequency, intensity, duration and odor offensiveness, called FIDO factors, have been applied worldwide. Nevertheless, difficulty in decision-making on whether a statutory nuisance could be established usually occurs. This is because



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Journal of Health Research
Vol. 36 No. 1, 2022
pp. 37-45
Emerald Publishing Limited
e-ISSN: 2586-940X
p-ISSN: 0857-4421
DOI 10.1108/JHR-01-2020-0018

odor is a subjective experience and depends on many factors such as physical health, psychological state, socioeconomic status and education, thus varying from person to person. To make the judgment less subjective, objectionable odor is mostly defined by many state and local governmental agencies. For instance, in the USA, several states such as Wyoming, Illinois, Colorado and Missouri have defined their standard objectionable odor by the level of odor concentration [2–5]. This definition can also be observed in other countries such as Australia and Germany, but different measurement techniques have been applied [6, 7].

In Thailand, the Public Health Act of 1992 does not define objectionable odor but generally states that any premises or activities generating malodor so as to be injurious to health or likely to be deleterious to health constitute a statutory nuisance [8]. Although the World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” [9], this statement has been interpreted differently by the local authorities obliged to investigate nuisance complaints. Furthermore, the confounding factors, both physical and nonphysical, often create confusion concerning whether an odor complaint meets the declaration of a statutory nuisance. Therefore, requests for clearer guidelines have been received from local administrative organizations [10]. For this reason, the study mainly aimed to determine objectionable odor concentrations which would urge Thais to register a complaint. This value could be used as a reference value for odor nuisance investigations which would help responsible officers make all-inclusive and confident judgments on nuisance complaints.

Methodology

This research investigated odor intolerance among Thais residing around odorous sources. Along with interviewing residents, off-site odors at the affected houses were measured by trained inspectors. To determine the sampling sites, a total of 101 sources with a complaint history from 2016 to 2017 were purposively selected as case studies because their emitted odor characteristics were acceptably tested by human sensory reception. These included 46 animal farms, 35 food manufacturers, 12 animal product manufacturers and eight other manufacturing businesses in 20 provinces in Central, Northern, Southern and Northeastern Thailand. At each site, a purposive sampling technique was used to determine the amounts of inspected houses and participants. To select houses for odor assessment, two criteria were established, i.e. they had to be located downwind of the odorous sources and odor in housing areas had to be perceived long enough to complete each measurement. Subjects comprised representatives of each household, aged from 18 to 70 years, having no respiratory diseases and regularly residing in that house and who were willing to participate. Additionally, odor concentrations in public areas with the same criteria were assessed but no subject was interviewed. A total of 151 measurement points (122 points in housing areas and 29 points in public areas) and 122 respondents were available at the arrival time of the assessors to the selected areas.

To select a panel of odor assessors, a group of public health personnel was tested for their odor sensitivity using an odor sensitivity test kit. Then, eight persons with a normal sense of smell, whose ages were from 25 to 35 years old, were trained to use a field olfactometer, Nasal Ranger®. This equipment quantifies the odor concentration in terms of the volume of odor-free air required to dilute a certain volume of odorous air to the point at which the assessors can detect the odor. Therefore, concentration is expressed as a dilution to the threshold (D/T). The greater the odor-free air volume required, the higher the odor concentration was.

Before measuring the odor concentration, odor characteristics, categorized into eight groups, i.e. medical, floral, fruity, vegetable, earthy, offensive, fishy and chemical (Table 1), were recorded by the assessors. In addition, the verbal odor strength rated from 0 to 5 points following the scale of the State of New Jersey as shown below was evaluated. Then, three

		Odor intolerance and proposed off-site limit
Group	Odor characteristic	
Medical	Alcohol, ammonia, anesthetic, camphor, chlorinous, disinfectant, menthol, soap, vinegar	
Floral	Almond, cinnamon, coconut, eucalyptus, fragrant, herbal, lavender, perfumy, rose-like, spicy, vanilla	
Fruity	Apple, cherry, citrus, cloves, grapes, lemon, maple, melon, mint, orange, strawberry	
Vegetable	Celery, cucumber, dill, garlic, green pepper, nutty, onion	
Earthy	Ash, chalk-like, grassy, mold, mouse-like, mushroom, musky, musty, peat-like, pine, smokey, stale, swampy, woody, yeast	39
Offensive	Blood, burnt, decayed, fecal, garbage, manure, putrid, rancid, raw meat, rotten eggs, septic, sewer, sour, urine, vomit	
Fishy	Amine, dead fish, perm solution	
Chemical	Car exhaust, cleaning fluid, creosote, gasoline, kerosene, molasses, mothball, oil, paint, petroleum, plastic, solvent, sulfur, tar, turpentine, varnish, vinyl	
<i>Verbal odor strength</i> [12]		
0:	Odor not detectable; no odor perceived by the sense of smell	
undetectable		
1: very light	Odor present, which activates the sense of smell, but the characteristics may be indistinguishable	
2: light	Odor present, which activates the sense of smell and is distinguishable and definite but not necessarily objectionable in short durations but may be objectionable in longer durations	
3: moderate	Odor present in the outdoor air, which easily activates the sense of smell, is very distinct and distinguishable and may tend to be objectionable and/or irritating	
4: strong	Odor present, which would be objectionable and cause a person to attempt to avoid it completely and may cause physiological effects during prolonged exposure	
5: very strong	Odor present, which is so strong, to be overpowering and intolerable for any length of time and causes physiological effects	

Table 1.
Odor descriptors [11]

concurrent measurements at intervals of not less than 15 minutes apart within a period of two hours were made by at least two trained assessors at each affected house. An identical reading from more than one-half of the assessors in each series of three determinations was recorded, and the highest value was selected to serve as the exposed odor representative. Along with the measurement, weather data, i.e. rainfall, temperature, relative humidity, wind speed and direction, were recorded.

While the inspectors were measuring odor concentration, the residents were asked for a verbal description of their exposure duration, frequency, annoyance level and physical health symptom effects from odor exposure, e.g. headache, dizziness, respiratory tract symptoms and eye/nose/throat/skin irritation. Based on a five-point scale, the annoyance was labeled as follows: 1 = not annoying, 2 = a little annoying, 3 = moderately annoying, 4 = very annoying and 5 = extremely annoying. Importantly, the decision to complain was explored using one key question: “At this current exposure level, are you going to file a complaint form?” When any respondent said “no,” we then asked for the reasons because nonphysical factors might involve a nuisance complaint. For example, some individuals did not want to complain because they felt no action would be taken by the responsible officers. Moreover, some were unsure whether their complaints would remain confidential [13]. Therefore, the answer was reconfirmed again by asking whether they were going to file a complaint form regardless of those factors.

All data were descriptively analyzed. Frequency distribution was mainly used to describe the number of residents who intended to complain at each exposure level. The verbal odor strength rated by the odor assessors and the annoyance level expressed by the nearby residents were presented in proportion. The response categories of “moderately annoying,” “very annoying” and “extremely annoying” were combined and calculated as a percentage of

“some annoyance,” while the percentage “highly annoyed” (%HA) was calculated from the categories “very annoying” and “extremely annoying” combined.

Ethical considerations

The Ethics Review Committee for Human Research at the Ministry of Public Health granted ethics approval (no. 0928.06/200) for this study on April 26, 2016.

Results

Based on the odor descriptors, odors from 101 investigated sites were divided into six groups, i.e. medical (1%), floral (2%), vegetable (1%), earthy (2%), offensive (67%) and fishy (25%). Among these, the majority comprised offensive and fishy smells mostly detected from swine farms and dried seafood manufacturers, respectively.

During odor concentration assessment, approximately 97% of the selected sites had no precipitation with a wind velocity of <0.4 to 2.2 m/s, while temperature and relative humidity ranged from 25.9 to 34.4°C and 54.8 to 79.6, respectively. Notably, most meteorology data were rather homogeneous, so it was not possible to explore its influence on odor complaints. Regarding the odor concentrations at the inspected sites, <2, 2, 4, 7, 15, 30 and 60 D/T were recorded, of which 83% of all respondents were intermittently exposed to these odors. Although the concentrations of 4, 7 and 15 D/T were mainly observed as shown in Figure 1, the concentrations of less than 2D/T initially agitated some people to complain. Among these observed values, it was evident that decision-making on nuisance complaints was unanimous at the concentration of ≥4D/T. Corresponding to the residents’ annoyance and health effects, greater than 80% of the residents, exposed to these levels, felt some annoyance. Additionally, their physical health effects from odor exposure during the past six months such as headache, burning sensation in the nose, runny nose and itchy skin were reported (Figure 2). All intended to complain at the concentration of ≥30D/T, for which 100% of residents were highly annoyed and adverse health effects were entirely observed.

Similarly, trained inspectors initially perceived odors at the concentration of <2D/T and verbally rated their strengths from nondetectable to light (Figure 3). Almost all perceived odors with a concentration of 2D/T were classified as objectionable when frequently exposed. At a concentration of 4D/T, approximately 60% of the odors either tended to be or would be considered objectionable. The higher the concentrations the inspectors were

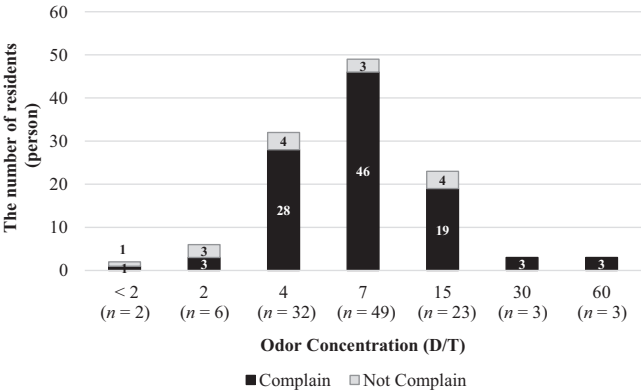


Figure 1.
Complaint amounts at
each
concentration (n = 118)

exposed to, the stronger the given rating scales were (Figure 3). All odors were unbearable at the concentration of 30D/T, which aligned with the complaint intention of exposed residents.

Considering the lower concentrations as shown in Figure 2, one-half of the respondents intended to file a complaint form at ≤ 2 D/T. To provide some explanation, the complaint derived from two main odor characteristics, i.e. offensive and fishy smells, were compared as shown in Figure 4. Although only small amounts of the sample were observed during the study period, this figure implied that at low concentration, residents living near manufacturers with a fishy smell were more tolerant than those living near manufacturers discharging offensive smells. This result was confirmed by the higher percentage of highly annoyed (%HA) responses of residents from offensive smells, especially at low concentration (Figure 5). However, when it came to 4D/T, almost all respondents who were exposed to both odor characteristics intended to complain.

Discussion

According to Sucker *et al.* [14], odor annoyance could occur when odors were recognized. In our study, some people started complaining at the concentration of ≤ 2 D/T, from which it could be noted that only offensive odors received complaints. This was because hedonic tones

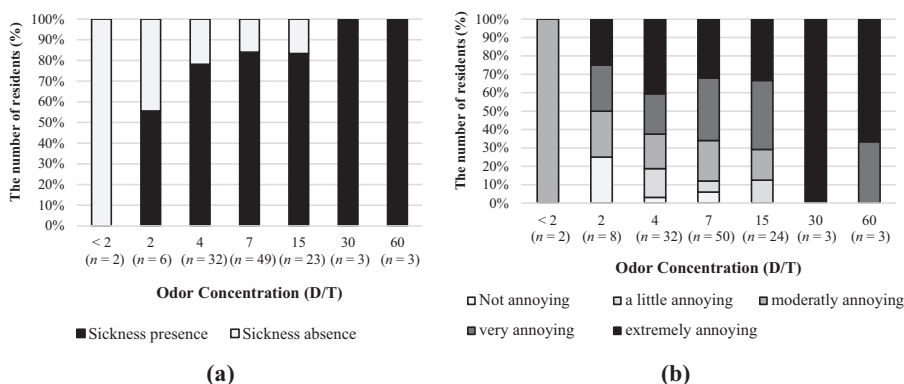


Figure 2.
The number of
residents with various
outcomes: (A)
annoyance ($n = 122$);
(B) health
effect ($n = 118$)

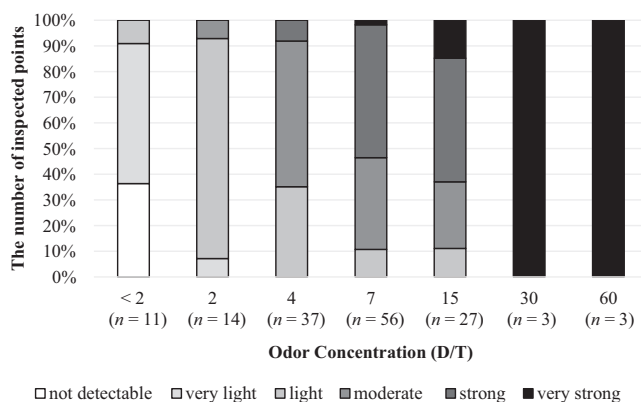


Figure 3.
Perceived odor
strength at each
concentration ($n = 151$)

play an important role for complainants' decision-making as seen by the big gap between the percentage of highly annoyed (%HA) responses of residents exposed to offensive and fishy smells, especially at lower concentrations. Although both offensive and fishy smells are classified as unpleasant odors by several countries, this odor characteristic from dried seafood manufacturing is not considered an unpleasant odor in Thailand, as long as the concentration is not too high. Likewise, the odor characteristic of dried fish was rated as unpleasant by Germans but neutral by the Japanese due to the influence of cultural eating habits [15]. Consequently, no complaints were recorded regarding fishy smells at lower concentration because of its small degree of unpleasantness.

Considering offensive odor, only one-half of the residents intended to complain at the concentration of $\leq 2D/T$. This possibly depended on individual and other factors including the frequency to which inspectors confirmed the possibility to be an objectionable odor when frequently exposed. Unfortunately, the frequency–duration criterion among Thais could not be explored due to the lack of available information. Nevertheless, a significant influence of these factors on nuisance complaints was inevitably recognized and even some governmental agencies with objectionable odor criteria were not overlooked. An example appears in Section 22a-174-23 of the regulations of Connecticut State Agencies [16]. Although the state determined the objectionable level at $\geq 7D/T$, the violation in case of an odor concentration lower than the odor limit may still be determined by the commissioner. Additionally, Sucker's work supported that the dose–response relationship between odor frequency and annoyance was strongly affected by the hedonic tone and unpleasant odors had a greater potential to

Figure 4.
Complaint amounts
from different odor
characteristics: (A)
offensive ($n = 75$); (B)
fishy ($n = 37$)

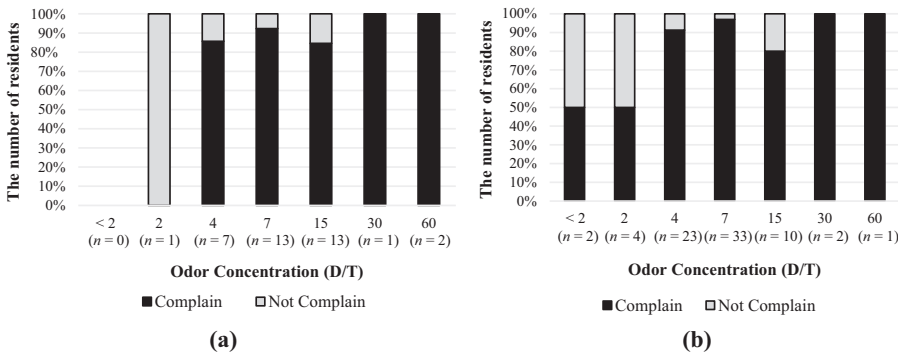
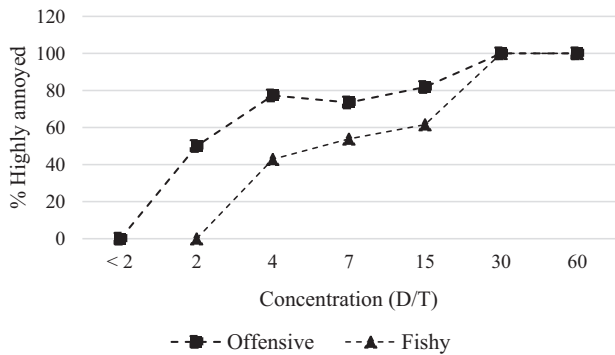


Figure 5.
Percentage of highly
annoyed responses
from different
hedonic tones



induce annoyance than pleasant odors [14]. Therefore, hedonic tone and other FIDO factors, e.g. frequency and duration are seriously required to be taken into account for odor complaint investigation at low concentrations.

At higher concentrations, it could be seen that no matter what the odor characteristics were, the trigger level of odor concentration urging most residents to complain was 4D/T. Correspondingly, a study near six industrial sources in Germany indicated that the hedonic tone of the residents decreased with increased intensity, regardless of pleasantness or unpleasantness [17]. Wherever the odor concentration was $\geq 30\text{D/T}$, all residents intended to complain, and inspectors said they could not tolerate these smells. The approximate level (31D/T or higher) was also described by Huey *et al.* as a serious nuisance when persisting for any length of time [18].

To propose the objectionable level in Thailand, the information from many state agencies in the USA as shown in Table 2 was compared. For example, a violation in the state of Colorado occurs when the odor concentration of 7D/T or higher is detected outside the property line of the emission source in predominantly residential or commercial land uses [4]. Several states and municipalities such as Connecticut, Kentucky and Las Vegas also defined their objectionable criteria using 7D/T but in nonspecific areas [16, 19, 20]. Although this number was categorized as objectionable by Huey's work in the early years of a field instrumental development [18, 21], California's South Coast Air Quality Management Districts stated that odor concentrations from 5 to 10 D/T can drive people to register complaints [22]. Apart from individual factors, the influence of cross-cultural and geographic variations on olfactory performances might explain this diversity [23–26]. Therefore, various numbers determined as odor standards have been seen from many state and local agencies. For Thailand, we would like to propose the odor concentration of 4D/T as an off-site reference value for odor complaint investigation under the Thai Public Health Act. This was because the common intolerance level for problem odors among Thais was likely to be 4D/T and the inspector's perceptions also pointed out its possibility of being an objectionable odor.

Conclusion

Based on data available in this study, odor shall be deemed to constitute a nuisance in a residential area when four odor concentration units or higher are detected. Nevertheless, in the case of malodor with frequent exposures, odor complaints at lower concentrations could

Authorities	Land use	Odor regulation
Colorado	Residential/commercial	7 D/T outside the property line
	Other land uses	15 D/T outside the property line
	Any receptor	2 D/T off-site
Connecticut	n.s	7 D/T
Kentucky	n.s	7 D/T
Las Vegas	n.s	7 D/T
Wyoming	n.s	7 D/T at the property line
BAAQMD	n.s	4 D/T at or beyond the property line
St. Louis**	Residential, recreational, hotel, institutional or educational premises	No objectionable odor
	Industrial premises	20D/T
	Other premises	4D/T

Note(s): n.s. = not specified; BAAQMD = Bay Area Air Quality Management District; *applied to odor from swine farm only; **not applicable to odorous matter emitted from the raising and harvesting of a crop, the feeding, breeding and management of livestock or domestic animals or fowl

Table 2.
Examples of odor
regulation in some
authorities [2, 4, 16, 19,
20, 27, 28]

have occurred. Therefore, insightful and comprehensive data collection was essential to establish this reliable judgment.

Conflict of interest: There is no conflict of interest.

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