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ODOR, ANNOYANCE AND HEALT
RESIDENTIAL COMMUNITY
INDUSTRIAL ODO

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ODOR, ANNOYANCE AND HEALTH SYMPTOMS IN A RESIDENTIAL COMMUNITY EXPOSED TO INDUSTRIAL ODORS

Preliminary Technical Report Submitted to South Camden Citizens in Action

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SUMMARY

A study was conducted to investigate the prevalence of reported odors and their relationship to annoyance, sensory irritation, health symptoms and avoidance behaviors among residents in South Camden, a community in the city of Camden, New Jersey which has a long history of complaints of significant odor pollution from industrial sources. A total of approximately 200 adults were recruited to participate -- half from South Camden and half from a North Camden community not reporting significant exposure to industrial odors. All participants completed environmental and health symptom surveys and were given standard tests of olfactory function, to evaluate their sense of smell and their perception of "sewage-smelling" malodors.

Reports of odor, annoyance, sensory irritation and health symptoms were more frequent and more intense among South Camden residents than among North Camden residents. In addition, South Camden residents also reported more frequently that they engaged in behaviors designed to avoid odors and that environmental odors disrupted their normal activities. No differences were observed between the two groups in the general ability to smell a control odorant, but the South Camden residents were significantly more adapted to the lowest concentration of a "sewage" test odorant than were the North Camden residents. This suggests that repetitive exposure to a background level of similar environmental odors has produced olfactory adaptation among these individuals. Although participants were self-selected and not randomly sampled from each community, the large sample size and magnitude of differences in sensory responses, self-reported health symptoms and daily behaviors indicate that a significant community problem exists in South Camden. This problem is correlated with the presence of frequent and unpleasant environmental odors.

INTRODUCTION

Currently, a significant controversy exists between the residential community of South Camden, the Camden County Municipal Utilities Authority (CCMUA) - the local waste treatment plant - and various other industries that exist side-by-side in this residential neighborhood. The close proximity of the CCMUA and other industries to the residential areas of South Camden has heightened the issue of the possible effects of odorous emissions on the health and well-being of local residents. Residents claim that bad odors and health effects from the emissions are commonplace, and that their quality of life is being diminished. Community concerns over the past ten years regarding the foul odors and possible health effects culminated in the

establishment of a citizens group, South Camden Citizens in Action (SCCA), in January 1997. A member of the Rutgers University-Camden Task Force on Environmental Justice brought the concerns of SCCA to the attention of the task force in late May. Dr. Pamela Dalton, a researcher at Monell Chemical Senses Center who studies the human perception and response to odors, proposed conducting a study in conjunction with Rutgers University's Science Preparation Alliance of Rutgers-Camden (SPARC), to provide some systematic data pertaining to the concerns of the SCCA. The study took place in July and August of 1997. Residents from South Camden and from a matched-control community in North Camden were surveyed regarding their environmental odor perceptions and annoyance issues and their acute health problems. Additionally, residents were tested for their olfactory sensitivity. This latter is particularly important as considerable research suggests that chronic exposure to chemicals can alter olfactory function (Ählstrom et al., 1986; Amoore, 1986; Schwartz et al., 1989).

The purpose of the research was to examine the relationships between exposure to the reported odorous emissions in South Camden and several quality of life issues and health effects. Specifically, the relationships between exposure and one's reported level of odor annoyance (psychological experience), irritation (physical experience), odor intensity, health symptoms and behavior were examined.

BACKGROUND

Odor and Annoyance. Research suggests that environmental stimuli, such as noise and odors, can have significant effects on an individual's psychological and health status (Staples, 1996; Berglund et al., 1996; Dravnieks & O'Neill, 1979). If the exposure is prolonged or the intensity increased, the feeling of unpleasantness can develop into a feeling of annoyance. Annoyance has been defined as a feeling of displeasure associated with any agent or condition believed to adversely affect an individual or group (Lindvall, 1974; Punter, 1987). According to this definition, the environmental agent or condition has an effect upon the psychological state of the individual but need not have a direct effect upon his or her health. For example, two recent papers examined the determinants of odor annoyance in populations exposed to industrial emissions in Germany and The Netherlands. Both Winneke (1992) and Cavalini (1994) found that odor exposure was the single most important predictor of annoyance.

In addition to annoyance from the perceived odor, however, volatile chemicals can produce sensory and respiratory irritation (Cain et al., 1986; Frechen, 1994; Koren et al., 1992; Warren et al., 1992; Warren et al., 1994). Thus, although most environmental odors are not considered to be health hazards because they are usually present in low concentrations, they can nonetheless cause a number of unpleasant physical reactions in people, such as nausea, vomiting, headaches, disturbances of sleep, appetite loss, and irritation of eyes, nose and throat (National Research Council, 1979). In other words, if there is a bad smell in the air, it does not have to directly produce a health effect to be a detriment to the individual. Even when compounds are at levels that are not necessarily a clear health risk, the smell can actually be intense enough to cause psychological annoyance and physical irritation, often

manifested by feelings of nausea, headaches and general malaise.

Volatile Chemicals and Health Symptoms. The literature suggests that there are two main plausible mechanisms for adverse community health effects from exposure to industrial-related pollutants: direct toxicological mechanisms based on exposure to specific pollutants at determined toxic concentrations and indirect odor annoyance-mediated mechanisms which result in stress-related symptoms or heightened symptom awareness (Neutra et al., 1991). With respect to toxicity from odorous pollutants, evidence from methodologically rigorous studies indicates little support for a direct toxicological effect (Axelsson & Molin, 1988; Dales et al., 1989; Schecter, 1990).

In contrast, there is strong support for an odor annoyance-mediated association between exposure and symptom reporting. Neutra et al. (1991) identified odor complaints as a powerful modifier in several studies of self-reported symptom rates around hazardous waste. Additionally, in a re-analysis of three cross-sectional studies of symptoms reporting around hazardous waste sites, Shusterman and colleagues (Shusterman, 1992; Shusterman et al., 1991) reported that both odor perception and concern about environmental health effects from the site were strongly related to symptom reporting and that the combined effect of odor perception and concern was even stronger. For various physical symptoms (e.g., headaches, nausea, and throat or eye irritation), those who frequently perceived an odor related to the site were four to five times as likely to report the symptom as those who did not; those who were very concerned were five to 11 times as likely to report the symptom as those who were not concerned; those who perceived an odor frequently and were very concerned were 12 to 37 times as likely to report the symptom as those who did not perceive the odor and did not exhibit concerns. The authors concluded that odor perception may act as a cue that either triggers stress-related illness or heightens awareness of underlying symptoms.

Additional support for the relationship between annoyance, odors and health comes from a three-stage study that was conducted to investigate the community health impacts of a petroleum refinery in Canada (Taylor et al., 1997). The study was designed to examine the association between self-reported somatic and/or psychological symptoms and exposure to odorous refinery emissions in families living near the refinery. The survey results showed strong associations between zone of residence and odor perception and annoyance, which, in turn, were strongly associated with the reporting of primary and general health symptoms in adults and children.

Odor and Respiratory Problems. An association between "odors" and respiratory problems, such as asthma, was described as early as 1698 by Sir John Floyer in his classic "A Treatise of the Asthma". He noted, "any strong smells such as 'candles put out' or those associated with certain occupations (for example, soap making, wine fermenting, or work associated with fumes of metals such as quicksilver) are harmful" (as quoted by Sakula, 1984). A variety of odors that appear to trigger asthma symptoms have been described in more recent publications. For example, research has found that people with underlying reactive airway disease (RAD) can have their asthmatic symptoms triggered by an irritant or other stimulant (Sandler, 1996).

Such irritants can include nuisance dusts, fumes, odors, stress, cold, and exercise. The first step in preventing RAD, according to Sandler, is a comprehensive safety and health program to reduce or eliminate the potential for exposure to sensitizing agents or potent irritants (Sandler, 1996). Similarly, other investigators (Shim & Williams, Jr. 1986) have found that odors can be common elicitors of asthma symptoms. The odors that commonly triggered asthma in their study were insecticides, household cleaning agents, perfume and cologne, cigarette smoke, fresh paint smell, automobile exhaust or gas fumes, and cooking smells. They advised that sensitive asthmatic patients should eliminate odors from their environment as much as possible (Shim & Williams, Jr. 1986).

In a review of the health significance of odor pollution, virtually all of the studies indicated a strong association between symptom reporting and odor exposure. The present study adds to this literature by a detailed examination of odor exposure, annoyance, and health symptoms in a community that reports frequent exposure to industrial odors, through a combination of quantitative and qualitative methods.

METHODOLOGY

Two areas within Camden City were studied -- South Camden (defined as the experimental group) and North Camden (defined as the control group). All other factors being judged roughly equal (e.g., gender, age, race, education, socioeconomic status), these two areas differed on three criteria: (1) distance from the odor-emitting industries, (2) location with respect to prevailing wind patterns, and (3) history of odor related complaints. Thus, South Camden residents were considered to be at 3 levels of exposure proximity to industrial odors (very high, high or intermediate), while North Camden residents were considered to be at low or minimal exposure proximity to industrial odors.

Subjects were recruited from the respective neighborhoods by means of announcements posted and distributed in the neighborhood. Testing took place at the Hynes Center in South Camden and at the Cooper-Waterfront Homes in North Camden. Each subject was compensated $5.00 for their time (approximately 30 minutes). One hundred and ninety four subjects (92 from South Camden and 102 from North Camden), ranging in age from 18 to 79 years old, participated (See Table 1 for demographic details). Each subject was asked to complete two self-administered questionnaires (Environmental Survey and Health Symptom Survey) and to participate in two tests to evaluate their sense of smell (Olfactory Sensitivity Test and Environmental Odor Standard Test). The Environmental Survey asked a series of questions including ones on sociodemographic characteristics, environmental annoyance issues, responsibility for controlling environmental annoyances, number of hours spent in or near the home, frequency of smelling bad odors, odor irritation, and effects of odors on behavior. The Health Symptom Survey, asked subjects to identify which, if any, of 56 health symptoms they had experienced in the previous month. Health symptoms included neurological problems, cognitive/mood problems, visual and hearing problems, gastrointestinal problems, physical problems, sensory and respiratory problems. This survey was designed to examine the

relationship between odor exposure and self-reported health symptoms. Both surveys were based on previously used surveys (i.e., Bowler et al., 1996; Miedema & Ham, 1988; Otto et al., 1990; Otto et al., 1992) but were modified slightly for the present study.

We also tested each individual's general olfactory sensitivity using phenyl ethyl alcohol (PEA), a rose-smelling odorant that is used in many consumer products but is not regularly experienced as an industrial environmental odor. At the Monell-Jefferson Chemosensory Clinical Research Center, this test is part of the standard clinical evaluation for the diagnosis of smell dysfunction (Cowart et al., 1997). Participants were asked to sniff and compare plastic bottles containing different concentrations of PEA with a bottle containing odorless glycerol and to indicate from which bottle they smelled an odor. Repeated trials with different concentrations allowed us to determine an individual's olfactory sensitivity (i.e., the lowest concentration of PEA that they could reliably discriminate from the odorless blank) and thereby to identify any general problems with the sense of smell that any participant exhibited.

The final olfactory test required participants to sniff each of three dilutions of a mixture that simulated some of the volatiles emitted from sewage-treatment facilities. A wide variety of volatile, odorous compounds are produced at sewage-treatment works as a result of the incomplete degradation of organic compounds. These volatiles include ammonia, amines, hydrogen sulphide, mercaptans, alkyl sulphides, aromatic hydrocarbons, chlorinated organic compounds, aldehydes, alcohols, fatty acids, skatoles, indoles and terpenes (Brennan et al., 1996). The mixture contained roughly equal parts of dimethyl disulfide, dimethyl trisulfide, and ethyl mercaptan. These three compounds were selected because they are frequently present in the odorous emissions from sewage treatment facilities (Heuer & Kaskens, 1997) and have particularly low odor thresholds, such that individuals can smell them readily even at very low concentrations.

Ratings of the perceived intensity of this mixture were used to provide a way to assess whether individuals were showing changes in odor perception related to repetitive exposure. Individuals who are regularly exposed to a volatile chemical often show a reduction in the perceived intensity of that specific odor, a phenomenon known as "olfactory adaptation" (Cain, 1970; Cometto-Muñiz & Cain, 1995; Dalton & Wysocki, 1996; Dalton et al., 1997). Thus, differences between residents of North and South Camden in their ratings of the standard "sewage" malodor could provide indirect evidence of exposure to those or related compounds. Participants were asked to indicate how strong the odor in the bottle was and how it compared with their average and their strongest environmental odor.

FINDINGS

Overall Odor Evaluation. Significantly more South Camden residents reported smelling bad odors both indoors and outdoors than did their North Camden counterparts. Specifically, nearly half of the South Camden residents reported smelling bad odors indoors 2 to 5 times per day or more. Similarly, nearly three-quarters of the South Camden residents report smelling

bad odors outdoors 2 to 5 times per day or more (see Figures 1 and 2).

When evaluating outdoor environmental odors, we observed a significant difference between the South Camden and North Camden residents' perception of their "average" neighborhood odor. For example, North Camden residents perceived the lowest concentration of the "standard sewage odor" to be similar to their "average" environmental odor. In contrast, South Camden residents perceived the middle concentration of the "sewage odor" to be more similar to their "average" environmental odor.

Overall, South Camden residents reported both a higher frequency and a greater intensity of malodors in their environment as compared to North Camden residents.

Odor and Annoyance. In order to examine the relationship between proximity to the odor-emitting sites and quality of life issues, we first looked at differences between the South and North Camden residents. We found, on average, that residents in South Camden reported a significantly higher level of annoyance and irritation from odors than did residents in North Camden.

In a separate analysis, we divided the South Camden neighborhood into three zones, based on proximity to the CCMUA facility (see Figure 3). Based on this division, it appears that exposure to malodors in the neighborhood is predictive of the level of annoyance and the level of irritation from environmental odors. For example, among the South Camden residents, we found that the closer the individual lived to the CCMUA, the greater their level of reported annoyance or irritation from environmental odors.

Olfaction Tests. We did not find a difference between the two groups of residents (South and North Camden) in their ability to detect the rose-scented odorant (the "PEA" test.) We interpret this to mean that the potentially greater exposure to neighborhood odors among South Camden residents has not produced any general deficits in their ability to smell most odors. However, we did see an interesting difference in the ratings of odor intensity given to the three "sewage odor" bottles. As shown in Figure 4, the South Camden residents perceived the lowest concentration of the "sewage odor" bottle to be significantly less intense than did the North Camden residents. The ratings of the other two concentrations were not different for the two groups. This difference is similar to the pattern of intensity ratings observed in many laboratory studies when individuals are exposed to an odor for a period of time and become "adapted" to a certain concentration of an odor (Ählstrom et al., 1986; Dalton & Wysocki, 1996; Wysocki et al., 1997). In other words, one interpretation of this difference is that South Camden residents are adapted to "sewage-like" odors at low to moderate intensities because of their repeated exposure in the neighborhood. This observation was anecdotally supported on a number of occasions when members of the study team (non-residents) would report smelling malodors in the South Camden testing facility at times when the residents did not and, in fact, claimed they were having a "good air day".

Health Symptoms. In our survey of health symptoms, participants were asked to indicate whether they suffered from allergies or asthma. The incidence of self-reported asthma was

significantly greater in South Camden than in North Camden (33% vs 15%), but no significant difference between areas was found with respect to allergies.

Results from the health symptom survey revealed that South Camden residents reported a higher incidence of many health symptoms, especially those in the following categories: neurological, cognitive/mood, gastrointestinal, physical, and sensory (See Table 2). It is important to recognize, however, that we did not randomly sample from either the South or North Camden residents to obtain these data. Thus, it is possible that we tested a biased sample-- in other words, that individuals who had more health problems were more likely to come to be tested. However, the relatively large sample size and the number of individuals reporting health symptoms, particularly in the South Camden community, suggests that a community health study, in which the survey participants are randomly chosen, may be warranted in the future.

Respiratory Symptoms. From the health symptom survey, we specifically isolated and examined those symptoms that were associated with respiratory problems, such as asthma (See Table 3). The frequency of reported respiratory symptoms was significantly higher among South Camden than North Camden survey participants.

Odors and Behavior/Activities. Levels of reported environmental odor exposure were found to be predictive of behavioral changes in response to those odors. Specifically, significantly more South Camden residents reported the following behavior alterations as a result of odor exposure: "don't like to be at home", "lose appetite", "breathe less deeply", "sleep is disturbed", "children won't play outside", "feel sick", "distracted from what I am doing", and "embarrassed to invite friends over" than did their North Camden counterparts (Table 4).

CONCLUSIONS

In summary, the research has revealed that residents in South Camden do report a greater number of malodors in their neighborhood than do the residents from a comparable community in North Camden. Additionally, there is evidence, based on the South Camden residents' responses to the "sewage odor" test, that such exposures occur frequently enough to "adapt" them to low-levels of some sulphur compounds. When the levels rise above those concentrations, however, South Camden residents are frequently annoyed and irritated by the odorous emissions. South Camden residents surveyed also reported a higher incidence of health problems, including respiratory symptoms, than the North Camden residents, but due to the nature of the sampling process, no firm conclusions can be drawn about the health status of the South Camden community as a whole at this time. Nonetheless, the significant and on-going presence of malodors in the South Camden community appears to be strongly correlated with higher levels of reported health symptoms, sensory irritation and environmental annoyance.

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Table 1

Demographic Characteristics of Study Population

Category	N. Camden		S. Camden
Age in years (Mean)	39.5		35.8
Age in years (Median)	40.0		32.0
Racial Composition (%)			
White	4		2
Black	71		76
Hispanic	25		22
Asian	1		0
Native American	0		0
Gender (%)			
Male	60		46
Female	41		54
Smokers (%)	75		68
Employment Status (%)			
Student	6		9
Full-time	12		18
Part-time	13		10
Unemployed	54		37
Homemaker	15		26
Residential Statistics			
Months resident at present address	81.2		90.8
Hours spent at home (weekdays)	13.8		19.8
Hours spent at home (weekend)	14.5		18.4

Table 2

Percent of Respondents Reporting Health Symptoms

SYMPTOM	North Camden	South Camden
Neurological	(%)	(%)
Faintness or dizziness	35	61
Trembling	25	39
Hot or cold spells	27	56
Feeling confused	31	47
Numbness or tingling in body parts	29	39
Feeling weak in body parts	35	57
Heavy feelings in arms or legs	26	53
Loss of coordination or balance	27	46
Drowsiness	31	54
Cognitive/Mood		
Nervousness or shakiness inside	40	47
Trouble remembering things	38	58
Feeling easily annoyed	59	73
Feeling low in energy or slowed	49	71
Difficulty making decisions	26	44
Mind going blank	24	39
A lump in your throat	23	36
Trouble concentrating	34	52
Feeling tense or keyed up/anxious	43	57
Thoughts of death or dying	29	37
Feeling everything is a physical effort	35	51
Spells of terror or panic	26	40
Feeling something bad is going to happen to you	36	57
Feeling something serious is wrong with your body	34	68
Feeling tired more easily	54	72
Feeling irritable	56	73
Feeling depressed	53	65
Sleeping more than usual	36	42
Noticeable change in personality	32	47
Visual/Hearing		
Reduced/poor vision	24	44
Reduced/poor hearing	25	27
Gastrointestinal		
Nausea or upset stomach	54	72
Vomiting	25	47
Diarrhea	26	46

Table 2 (cont'd)

Percent of Respondents Reporting Health Symptoms

SYMPTOM	North Camden (%)	South Camden (%)
Physical		
Headaches	62	84
Pains in heart or chest	30	49
Pains in lower back	45	56
Heart pounding or racing	35	57
Soreness of muscles	42	63
Trouble falling asleep	48	65
Trouble getting breath	36	61
Sleep that is restless or disturbed	51	68
Tightness in chest	23	48
Heart palpitations even at rest	25	34
Perspiring for no particular reason	22	52
Joint pain or swelling	24	49
Weight loss (excluding diet)	27	35
Nose bleeds	11	24
Skin rashes	24	37
Sensory		
Dry mouth/throat	44	64
Poor appetite	38	60
Coughing	39	61
Throat irritation	31	60
Bad taste in mouth	46	66
Nasal congestion	38	52
Sneezing	42	63
Nose irritation	31	49

Table 3

Percent of Respondents Reporting Respiratory Symptoms

Respiratory Symptom	North Camden (%)	South Camden (%)
Pains in heart or chest	30	49
Trouble getting breath	36	61
Tightness in chest	23	48
Coughing	39	61

Table 4

Effects of Odors on Behavior and Activities

Behavior/Activity	N. Camden (%)	S. Camden (%)
Don't like to be at home	26	54
Lose appetite	35	62
Breathe less deeply	33	56
Sleep is disturbed	27	46
Children won't play outside	7	41
Close windows	48	57
Feel sick	33	67
Distracted from what you are doing	26	47
Don't invite friends over	19	55
Other	5	15

Figure 1

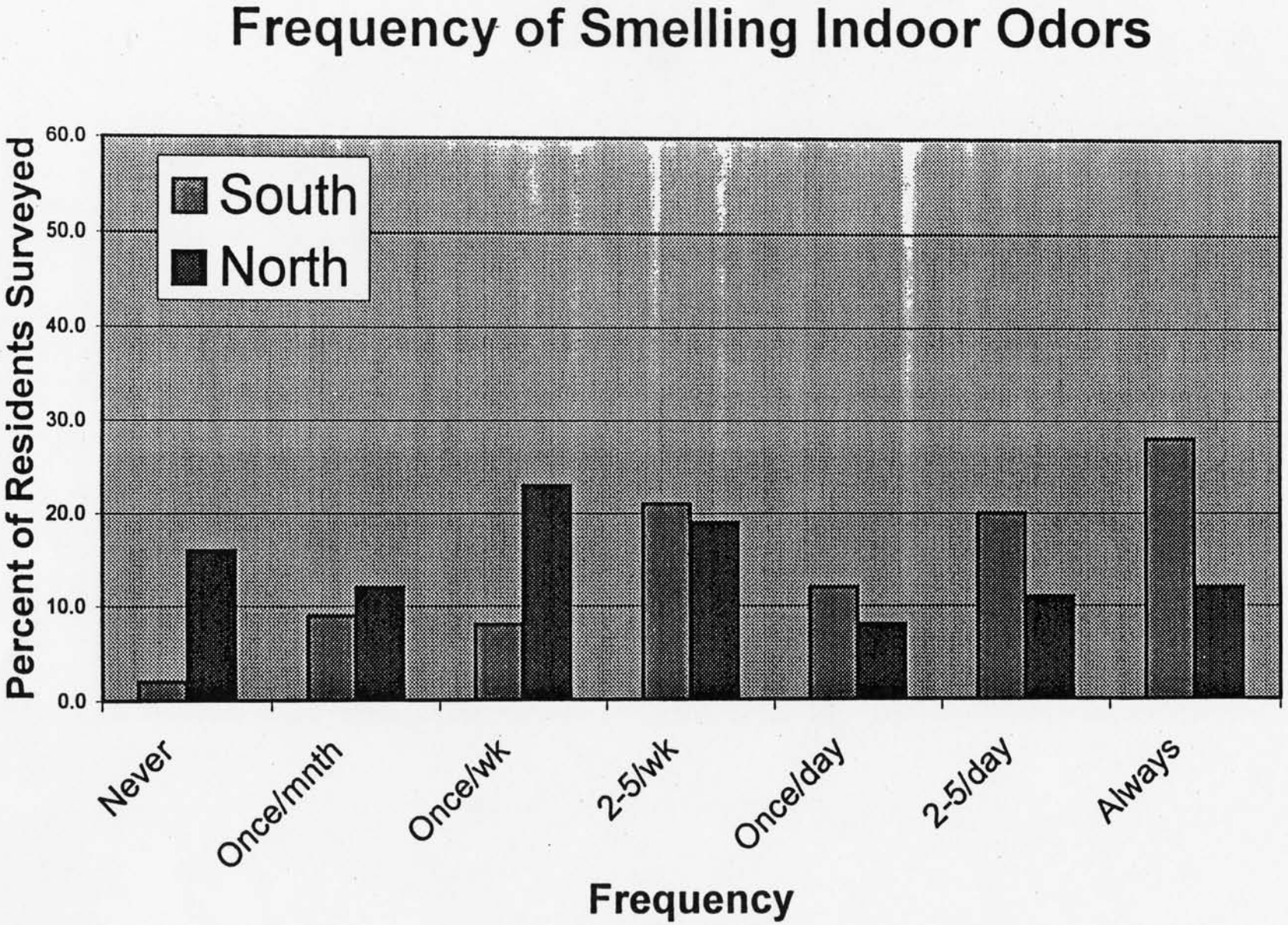

Frequency of Smelling Indoor Odors
Percent of Residents Surveyed
60.0
50.0
40.0
30.0
20.0
10.0
0.0
South
North
Never
Once/mnth
Once/wk
2-5/wk
Once/day
2-5/day
Always
Frequency

Figure 2

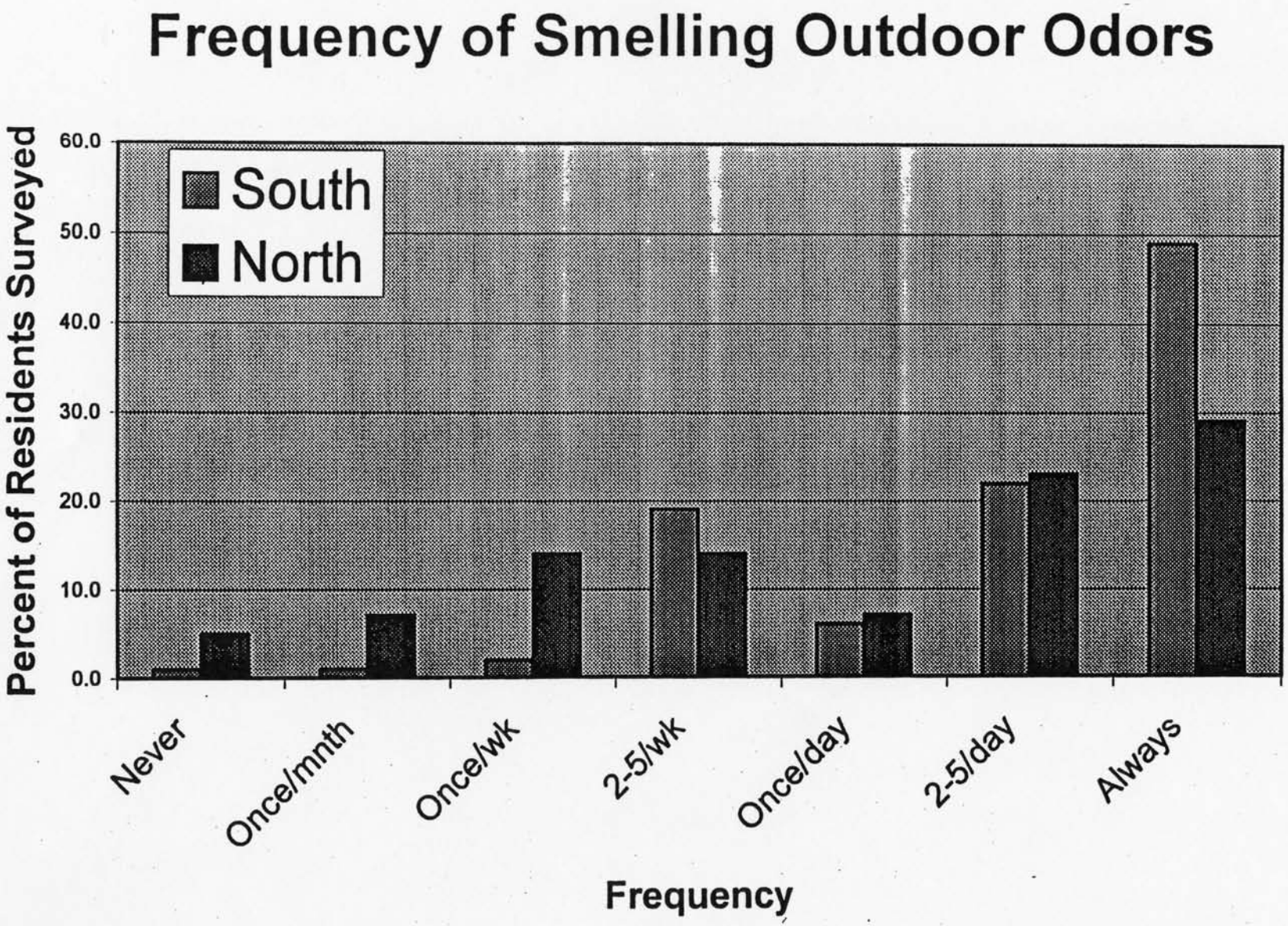

Frequency of Smelling Outdoor Odors
Percent of Residents Surveyed
60.0
50.0
40.0
30.0
20.0
10.0
0.0
South
North
Never
Once/mnth
Once/wk
2-5/wk
Once/day
2-5/day
Always
Frequency

Figure 3. South Camden Zone Map

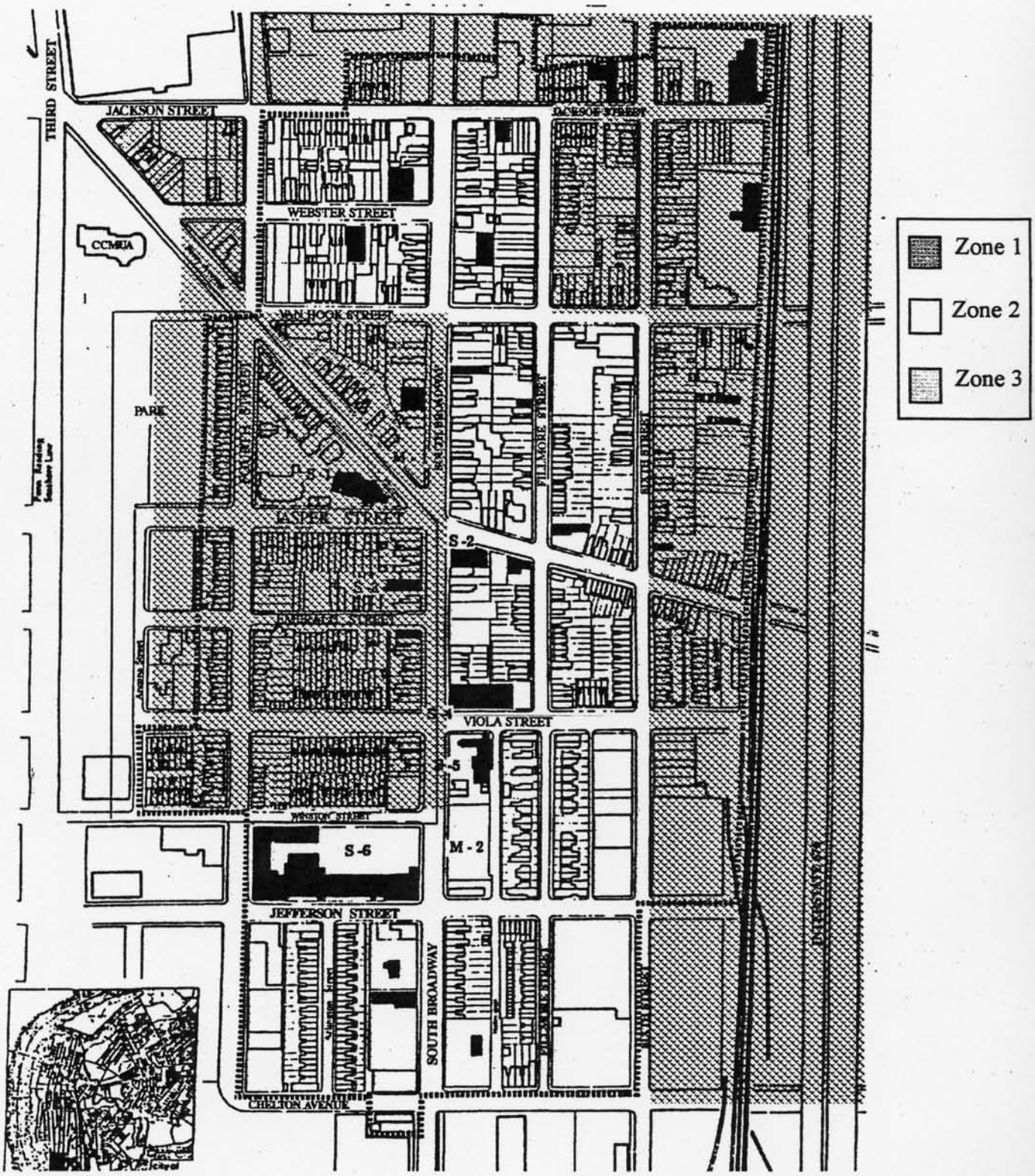
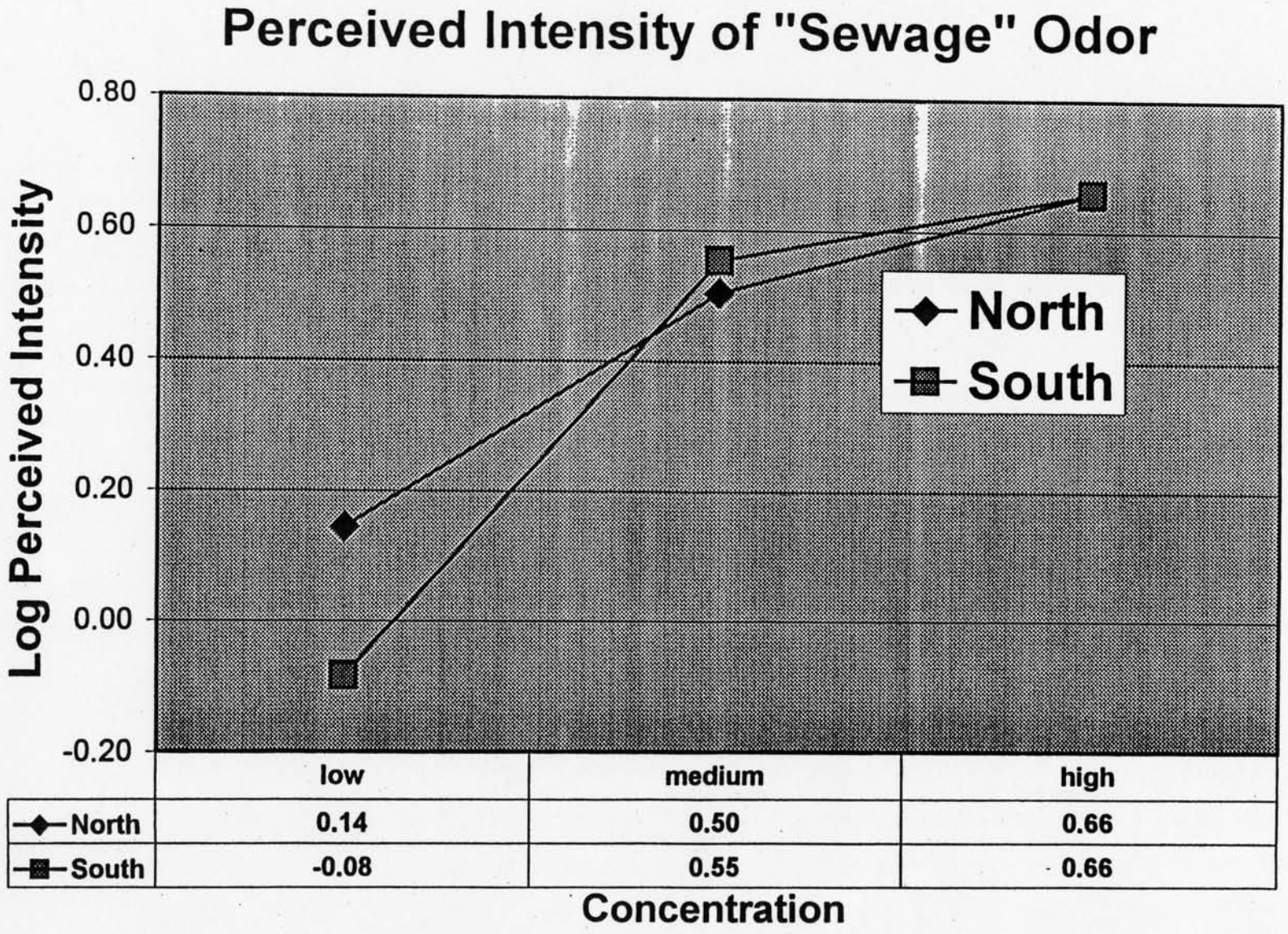


Figure 4


Perceived Intensity of "Sewage" Odor
Log Perceived Intensity
0.80
0.60
0.40
0.20
0.00
-0.20
North
South
low
medium
high
North
0.14
0.50
0.66
South
-0.08
0.55
0.66
Concentration