Assessment of Wastewater Treatment Plant Workers Exposed to Biosolids
Pilot Test of a Newly Developed Health Survey

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RESEARCH ABSTRACT

The purpose of this study was to develop and pilot test a health survey for wastewater treatment workers exposed to biosolids, using an upstream framework for environmental health. The questionnaire included items about health status, symptoms, frequency of contact with biosolids, use of personal protective equipment, and demographic data. A majority of workers regularly exposed to biosolids reported at least one health-related symptom, although some attributed their symptoms to contact with materials other than biosolids. All 11 participants took unnecessary health risks such as periodically neglecting to wear masks, respirators, gloves, or goggles to protect themselves from potential exposure to biosolids. However, those who reported symptoms were the least compliant with personal protective equipment use. Survey results highlighted that occupational health nurses must effectively communicate to their clients the need for proper use of personal protective equipment when working with potentially hazardous material.

Occupational and environmental health nursing has evolved to encompass health promotion and disease prevention, including those illnesses due to working conditions. Many Americans are exposed to harmful toxins in the environment, some in occupational settings. To address this issue, the National Institute of Nursing Research, the Agency for Toxic Substances and Disease Registry, and the Institute of Medicine have advanced national environmental health initiatives for nursing including plans for nurses to understand environmental health hazards and exposure pathways; conduct environmental assessments; use environmental health regulations; advocate for populations at risk; and become involved in basic and applied environmental health research (Larsson & Butterfield, 2002).

As a result, the National Institute of Environmental Health Sciences, the Agency for Toxic Substances and Disease Registry, and the National Institute of Nursing Research convened a nursing and environmental health roundtable in 2002 identifying topics of concern (Nastoff et al., 2002). One of the topics was the need to study the cumulative effect of low-dose, long-term exposures to environmental toxins.

Scientists have determined that certain environmental exposures are directly related to the development of some cancers, chronic diseases, and other health-related problems. For example, Dahlgren, Warshaw, Thornton, Anderson-Mahoney, and Takhar (2003) evaluated the health status of residents living near a wood treatment plant who were environmentally exposed to prolonged low-level waste chemicals. Significantly more cancer and respiratory, skin, and neurological health problems were found in the exposed residents than in controls. Halasova et al. (2005) recently assessed the influence of occupational and environmental exposures to chromium on the incidence of lung cancer. Individuals exposed to chromium had a significantly higher rate of lung cancer than individuals not exposed. Metintas et al. (2005) investigated the frequency of asbestos-related benign pleural diseases among residents environmentally exposed to asbestos. Exposed residents had a high incidence of pleural plaques and dif-
fuse pleural fibrosis, similar to occupationally exposed asbestos cohorts. Carpenter, Morris, and Legator (2002) assessed polychlorinated biphenyl (PCB) environmental exposure among residents living near a chemical production facility. Significantly elevated levels of ear, nose, and throat; central nervous system; cardiovascular system; muscle and bone; skin; immune system; and teeth and gum diseases were found. In addition, adverse pregnancy outcomes such as low birth weight and premature birth were more common among residents living near the plant than among the control community.

Identification of any health risks associated with environmental exposure in an occupational setting is relevant to nurse researchers. Wastewater treatment personnel who work with biosolids exemplify a client population potentially at risk of exposure to environmental toxins. Dermal contact with biosolids and airborne release of biological agents during sewage sludge processing at wastewater treatment plants have been identified as potentially problematic to workers. Dorn, Reddy, Lamphere, Gaeuman, and Lanese (1985) believed that biological agents associated with biosolids are important causes of symptoms from organic dust–related diseases. Nethercott and Holness (1988) reported that sewage treatment workers exposed to drying sewage sludges exhibited impaired respiratory function and acute illness characterized by cough, fever, and sore throat. Thorn, Beijer, and Rylander (2002) assessed the risks for work-related symptoms among sewage workers in Sweden, finding significantly increased risks for airway symptoms, chronic bronchitis, and toxic pneumonitis. Additionally, the authors identified significantly more central nervous system symptoms such as headache, unusual tiredness, and lack of concentration among sewage workers compared with controls. Khuder, Arthur, Bisesi, and Schaub (1998) conducted a retrospective epidemiological study examining the prevalence of infectious diseases and associated symptoms among wastewater treatment workers. Significantly higher prevalences of gastroenteritis and gastrointestinal symptoms were found. Rylander (1999) assessed the presence of fatigue, symptoms of diarrhea, and inflammation of the Airways among employees in sewage plants and their relation to airborne bacterial endotoxins in the workplace. Results confirmed the presence of airway and intestinal inflammation among sewage treatment plant workers, suggesting the most likely cause was endotoxins.

Although health-related problems have been reported among wastewater treatment workers, exposure levels and subsequent risks have yet to be quantified (National Research Council, 2002). Assessment of this occupational cohort could identify potential health and safety risks resulting in appropriate interventions to protect workers who have direct contact with class B biosolids.

**BIOSOLIDS**

Biosolids consist of sewage sludge treated to meet the regulatory requirements for land application (and land use) described in Title 40 of the Code of Federal Regulations, Part 503 (Environmental Protection Agency [EPA], 1993). The EPA defines biosolids as “the primarily organic solid product yielded by municipal wastewater treatment processes that can be beneficially recycled” (National Research Council, 2002, p. 13). Currently, recycling of treated sewage sludge is the primary means to dispose of the 5.6 million dry tons of biosolids generated each year in the United States. Approximately 60% of this material is used for land application and the amount recycled is projected to increase in the future (National Research Council, 2002).

Two classes of biosolids are designated based on the level of pathogens present. Class A biosolids are treated to reduce pathogen concentrations to a low level (< 1,000 fecal coliform density based on MPN analysis). This material may then be used as fertilizer without any type of site restriction (Geisler & Bronstein, 2001). Class B biosolids are also treated to reduce the number of pathogens; however, after treatment, significant levels of these microorganisms remain (< 2,000,000 fecal coliform density based on MPN analysis). Therefore, the EPA has placed restrictions on application sites for class B biosolids to further reduce pathogen presence through natural attenuation processes (National Research Council, 2002).

Pathogens identified in either sewage wastewater or biosolids include bacteria, viruses, protozoans, helminthes, and parasitic worms (Centers for Disease Control and Prevention [CDC], 2002) as well as fungi and molds (Clark, Bjornson, Schwartz-Fulton, Holland, & Gartside, 1984). Additionally, the outer walls of gram-negative bacteria present in biosolids (e.g., *Escherichia coli*, *Salmonella*, *Pseudomonas*, and *Haemophilus*) break down during cell growth, division, or death to form endotoxins (Horn, 2000). Workers may inhale aerosolized endotoxins during biosolids treatment or land application processes (Burton & Trout, 1999). The bioactive organic dust from endotoxins is believed to cause various acute and chronic symptoms (Rylander, 1999).

Little research and scientific documentation exist regarding the health effects or safety risks potentially associated with biosolids treatment and subsequent land
application. The EPA commissioned the National Research Council to conduct an independent analysis of the Part 503 rule several years after its passage to investigate its effectiveness and determine whether it needed to be more stringent. The National Research Council completed an 18-month study concluding that further scientific research was needed to determine whether the current chemical and pathogen standards were consistent with current risk assessment methods (National Research Council, 2002).

CONCEPTUAL FRAMEWORK

This study was based on the upstream framework for environmental health (Butterfield, 2002), including distributive and strategic actions nurses can take to reduce environmental health risks for their clients and communities. Distributive actions include tracking exposures and diseases, embedding environmental health information into nursing practice, and translating technical information for clients. The focus is on activities incorporating environmental health principles and skills into daily nursing efforts. Strategic actions include discovery through etiologic and community-based research, advocacy for clients with environmental concerns, and reframing of environmental health issues. Strategic actions promote an environmental health agenda by means of new discovery or awareness of an existing topic. Ideally, the integration of distributive and strategic actions facilitates positive health and system outcomes (Butterfield, 2002).

Improvement in the quality and comprehensiveness of environmental health data is a positive system outcome in the upstream framework for environmental health (Butterfield, 2002). The design and administration of a questionnaire for workers exposed to biosolids is a subject well suited to etiologic research conducted by nurse scientists. The topic is relevant and timely in this era of “sustainable development” where waste materials are increasingly recycled and potential risks associated with these “resources” elevated. Systematic development and implementation of data collection instruments are first steps in conducting research studies addressing potentially harmful occupational health risks. The framework challenges nurses to be vigilant in their surveillance of possible hazardous exposures, and to gather scientific evidence to prevent disease.

SURVEY INSTRUMENTS

The survey tool for this project was based, in part, on previously developed environmental health surveys. Although only a few survey studies of workers who apply biosolids were identified (Burton & Trout, 1999; Wouters, 2003), additional studies were available of workers who process sewage sludge (Burton & Trout, 1999; Dorn et al., 1985) and residents who live near waste application sites (Lewis, Gattie, Novak, Sanchez, & Pumphrey, 2002). Research on sewage treatment worker populations was most prevalent, albeit limited (Lundholm & Rylander, 1983; Nethercott & Holness, 1988; Smit, Spaan, & Heederik, 2005; Trout, Mueller, Venczel, & Krake, 2000). Studies from these populations are included, given that class B biosolids have the same pathogens as sewage sludge before treatment (National Research Council, 2002), although at decreased levels.

Of the studies reviewed, the National Institute for Occupational Safety and Health (NIOSH) investigation conducted by Burton and Trout (1999) was the most similar to the current project in population studied. However, those researchers did not use a formal survey tool because there were few participants.

The only survey available in its entirety was a NIOSH questionnaire assessing occupational transmission of hepatitis A among wastewater workers. Some questions regarding worker practices, exposure routes, personal protective equipment use, and personal history (e.g., income, race, and education) were adapted for use in the current study (Trout et al., 2000).

Weldon et al. (2000) reported the prevalence of hepatitis A among wastewater workers and referenced a questionnaire used to assess risk factors. The questionnaire was not published but was described as containing information on socioeconomic status, educational level, job duties, health, safety practices, frequency and route of exposure to sewage, and personal protective equipment use (Weldon et al., 2000). This approach appeared similar to that used by Trout et al. (2000) in the NIOSH study.

Another investigation focused on the health effects of sewage sludge application. A human exposure form was used to assess participants’ work schedules and health histories, including information about immunizations, smoking, and chronic illnesses.

Scarlett-Kranz, Babish, Strickland, and Lisk (1987) studied the health of municipal sewage workers compared with water treatment workers. A questionnaire requested information regarding smoking, alcohol use, type of work performed, length of employment, and types of symptoms and conditions experienced in the previous month while on the job (Scarlett-Kranz et al., 1987).

After the available health survey tools were reviewed, the researchers chose the data necessary to develop a descriptive research survey instrument. The overall goal of this investigation was to describe the prevalence of health conditions that could be related to biosolids exposure at a large metropolitan wastewater treatment plant experienced by workers. The health survey tool had five categories of questions:

- Health history.
- Frequency of contact with biosolids.
- Symptoms experienced.
- Personal health and safety practices and personal protective equipment use.
- Personal information and demographics.

METHODS

Participants

Eleven white men exposed to treated sewage sludge during the recovery of biosolids at a wastewater treat-
ment plant in the southeastern United States participated. All of those surveyed attend semiannual safety training focusing on the use of personal protective equipment such as goggles, coveralls, boots, and gloves. Two of the workers reported having worked with biosolids 18 and 26 years, respectively. The mean age of the 11 workers was 50 years (range = 46 to 57 years). According to the National Institutes of Health guidelines, all 11 were overweight, with 45% considered obese (National Institutes of Health, 2005). Seven participants reported chronic health problems including hypertension, arthritis, and hyperlipidemia; one reported chronic sinus infections; and three reported smoking a pack of cigarettes each day.

Procedures

The institutional review board at the University of Tennessee approved the study. The instrument was then pilot tested with a group of nursing faculty and a group of nursing students. Unclear questions or directions were modified before the final survey was administered to the wastewater workers. To access the maximum number of workers, data collection occurred during two early morning sessions in the plant break room at shift change. Participation was voluntary and limited to workers employed in jobs with biosolids exposure. Two interviewers were available to ensure all interested workers could be surveyed in a timely manner. Interviews lasted approximately 10 minutes. Prior to providing data, each participant signed an informed consent. The interviewer read the questions from the survey tool aloud and then recorded each worker’s answers on the questionnaire.

Data Analysis

Demographics, observational notes, and verbatim responses served as data for analysis. Responses to questions within each category of the survey were noted. The research team analyzed the compiled data to determine if an exposure to biosolids could be linked to an increase in symptomatic complaints of the following:

- Skin.
- Eyes.
- Nose or sinus.
- Throat.
- Respiratory system.
- Cardiovascular system.
- Gastrointestinal system.
- Musculoskeletal system.
- Neurological system.

Data were also collected on symptoms such as fatigue and fever. Symptoms were compared with consistent personal protective equipment use, basic hygiene, demographics, and chronic health problems. The data analysis highlighted areas where the employer exceeded expectations in minimizing health risks (e.g., providing personal protective equipment and training, hygiene stations, and break rooms) and employees took unnecessary risks (e.g., periodically neglecting to wear masks, respirators, gloves, or goggles to protect themselves from exposure to biosolids particles).

Limitations

Small sample size and the possibility of a self-selection bias are study limitations. It is also possible that some interested workers could not attend either data collection session. The workers’ smoking habits, proclivity toward obesity, and unique health histories may have affected the results of the research. Additionally, information was collected at only one worksite and only in the southeastern United States. A future study addressing these issues will prove more generalizable to the entire worker population.

FINDINGS

Employee Safety Training

The employer provides health and safety training to all employees on a semiannual basis. As a result of this training, all participants recognized the importance of washing their hands after using the bathroom and before eating, drinking, smoking, or chewing tobacco or gum. Each indicated consistently complying with this behavior. All of the participants reported their personal hygiene health behaviors had improved as a result of the health and safety training.

Exposure and Health Symptoms

Eight of the 11 participants reported working with biosolids several times a week; six did so daily. Six had their skin exposed to biosolids several times a week. Of these six, three reported consistently wearing gloves. Six of the 11 participants consistently wore coveralls; the other five wore them occasionally. No symptoms involving the skin due to biosolids exposure were reported.

Although the employees recognized the importance of wearing coveralls, boots, goggles, and gloves, they did not do so all the time. Eight of the 11 reported at least one of the following symptoms: sore throat, coughing, nasal congestion, postnasal drip, sinus pain or pressure, flu-like symptoms, stomach virus, burning eyes, excess tearing, headache, nausea, or fatigue. Three reported burning eyes despite wearing goggles and mostly when exposed to ammonia during biosolids dewatering operations. Five wore glasses instead of goggles, but none of them reported burning or tearing eyes. Three never wore goggles or glasses when working with biosolids.

Nine of the 11 participants reported walking in biosolids spills and breathing biosolids particulate matter several times a week; six reported daily airborne exposure. Only five who reported breathing biosolids used respirators, and only when the treatment system was being cleaned. No distinction was made in the health survey tool between wearing a respirator versus a dust mask. One participant reported often wearing a dust mask, but not a respirator. Only five of the 11 who reported breathing biosolids had a respirator with the treatment system was being cleaned. No distinction was made in the health survey tool between wearing a respirator versus a dust mask. One participant reported often wearing a dust mask, but not a respirator. Only five of the 11 who reported breathing biosolids had a respirator.

Three reported occasional nasal congestion, with two having allergies affecting the sinuses. Of these two, one had coughing and the other had a recurring sore throat. Two of the three reported wearing glasses, but not goggles; none wore respirators when working with biosolids, but two did when working with hazardous gases such as chlorine. One had headaches after breathing re-
spiratory irritants such as ammonia and chlorine. One participant reported working with biosolids only two to three times a year when washing tanks. He wore glasses, but not a respirator or goggles, and had a sore throat and coughing after mixing the biosolids.

Questions pertaining to gastrointestinal symptoms (e.g., diarrhea, nausea, and vomiting), cardiovascular symptoms (e.g., dizziness and chest pain), musculoskeletal symptoms, fatigue, fever, and flu-like symptoms were included on the survey. The participants did not report these symptoms.

**DISCUSSION**

Wastewater treatment plants exist in virtually every community in the United States. Occupational exposure to the biosolids generated by many of these facilities is of widespread concern for these workers. Most of the employees interviewed worked with biosolids regularly. Additionally, they were repeatedly exposed to biosolids via dermal contact and inhalation of dust generated during biosolids processing. Overall, these employees worked with and were regularly exposed to biosolids.

Seventy-three percent of the employees reported at least one health-related symptom. Burton and Trout (1999), who interviewed biosolids workers involved in land application activities, found that 4 (80%) of 5 had at least one symptom, including repeated intermittent headaches and gastrointestinal complaints. The authors concluded that “while the specific component(s) of the sewage sludge responsible for the employees’ symptoms have not been determined, the nature and timing of the symptoms suggest occupational exposure by inhalation or ingestion of the biosolids as a probable cause” (Burton & Trout, 1999, p. 7).

However, Nethercott and Holness (1988), who reported the health status of 50 sewage treatment workers in Toronto, Canada, found that 50% had fatigue, throat irritation, respiratory or gastrointestinal symptoms, or various skin complaints. Although a greater percentage of workers indicated symptoms in the current study, some attributed them to processes other than direct exposure to biosolids. For example, three of the eight workers with symptoms experienced them only when working near a biosolids treatment process producing high levels of ammonia gas (dewatering). One of the project investigators visited the treatment facility and confirmed a strong ammonia odor in the vicinity of the biosolids dewatering treatment process. In effect, only 5 (45%) of the 11 workers had symptoms they attributed, in part, to biosolids exposure.

Several researchers have attributed health-related symptoms to biosolids exposure. Lundholm and Rylander (1983), in studying work-related symptoms among sewage workers, found skin disorders, diarrhea, and other gastrointestinal complaints more prevalent among six sewage treatment workers than three water treatment workers used as a comparison group. Scarlett-Kranz et al. (1987) studied sewage and water treatment workers and found significantly more symptoms among sewage workers after controlling for other confounding factors. Of the symptoms identified, headache, dizziness, sore throat, skin irritation, eye irritation, and diarrhea were most frequent. Lewis et al. (2002) studied 48 residents who lived within 1 kilometer of one of 10 biosolids land application sites. Residents complained of coughing, burning throat, burning eyes, headaches, nasal and chest congestion, difficulty breathing, nausea or vomiting, fatigue, and flu-like symptoms.

The EPA recognizes the association among poor hygiene, raw sewage, and infectious disease and that class B biosolids present a health hazard to exposed workers. NIOSH recommends that employers provide appropriate protective equipment, hygiene stations, and training to reduce the risk of work-related illnesses (CDC, 2002).

**IMPLICATIONS FOR PRACTICE**

Occupational health nurses must be adept at assessing populations at risk so that appropriate interventions can be implemented to protect workers having direct contact with class B biosolids. Occupational health nurses must sufficiently understand environmental health science to recognize the many ways workers’ health may be harmed via occupational exposure. With changing processes, exposures, and risks in the workplace, those providing health services to these employees must have a thorough knowledge base, particularly regarding biological agents in industry. In addition, occupational health nurses must develop their skills in hazard recognition and become proficient in identifying potentially harmful exposures for workers when conducting walk-through inspections of facilities. They should promote healthy working conditions as well as educate employees to protect themselves from occupational risks by wearing recommended personal protection equipment.

Occupational health nurses provide direct care to workers. They see and speak to workers often in diverse work settings, increasing their opportunities to document and track workers’ exposure to contaminants over an extended period. This unique position mandates that occupational health nurses possess an awareness and understanding of environmental exposures to substances posing potential health risks. Nurses can monitor and evaluate the health status of worker populations by conducting research on the effects of workplace exposures, collecting health and hazard data, and using the findings from both in their practice.

Evaluation of occupational exposure to hazards is difficult and often confounded by multiple agents and nonoccupational factors. Occupational health nurses must be adept at taking environmental histories, important in identifying relevant exposures and linking them to employee health problems. Occupational health nurses must know what to look for, what questions to ask, what contaminants are at issue, and which workers are at increased risk (Randolph, 2005). This health survey tool can augment the employee personal health history and provide information regarding biosolids exposure, worker safety practices, and symptoms of illness. Occupational health nurses can use survey results as a guideline for teaching
and counseling employees regarding health and safety issues.

REFERENCES


