Application of GIS in Evaluating the Potential Impacts of Land Application of Biosolids on Human Health

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Chapter 10
Application of GIS in Evaluating the Potential Impacts of Land Application of Biosolids on Human Health

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Abstract This chapter describes the development and use of a geographic information system (GIS) in an environmental health investigation of the application of Class B biosolids (sewage sludge) on agricultural fields. The research project is broad-based including field observations and modeling to investigate the presence of microorganisms, metals, and pharmaceutical and personal care products (PPCPs) in biosolids applied agricultural fields and the associated runoff. These data has been linked with remote sensing imagery and added to GIS layers for Wood, Lucas and Greene Counties in Ohio. Specifically, this project describes the way in which a GIS was developed and utilized with a mailed, epidemiological health survey to investigate the potential impact of biosolids application to agricultural fields in relation to self-reported human health symptoms, acute diseases and chronic diseases among groups of individuals living specified distances from fields where biosolids were permitted and applied. For Wood County, of the 24 symptoms in the survey, six were statistically higher near biosolids permitted fields and of the 29 diseases in the survey, five were statistically higher near biosolids permitted fields. The Lucas and Greene County surveys are still being analyzed. Our future work includes refinement of the spatial analysis and health survey to include the application of biosolids and the constituents of the biosolids to fields, distances to any farm field and to other potential relationships to health effects.

Keywords Epidemiology · Biosolids · Agriculture · Pharmaceuticals and Personal Care Products · Heavy Metals · Human Pathogens

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10.1 Introduction

Sewage sludge, also known as biosolids, is defined in the Code of Federal Regulations, Title 40, as the solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a wastewater treatment plant (WWTP) (USEPA 1994). In the United States, a significant proportion of biosolids are disposed of through application to agricultural fields. There are anecdotal reports of illness and in one case death after application of biosolids. This is a very politically-charged issue in part due to public perception and concerns over health and safety having resulted in lawsuits.

In July 2002, the National Research Council (NRC) issued a report expressing concern over the practice of applying biosolids to farm fields in the United States (Renner 2002). In the 2002 report, the NRC states:

> There is no documented scientific evidence that the Part 503 rule has failed to protect public health. However, additional scientific work is needed to reduce persistent uncertainty about the potential for adverse human health effects from exposure to biosolids. There have been anecdotal allegations of disease, and many scientific advances have occurred since the Part 503 rule was promulgated. (NRC 2002)

Across the United States as well as in many other countries, policy makers are faced with the question of whether biosolids should be land applied or not. In this chapter, we will give background on biosolids application in the United States focusing on Ohio, discuss what is known on the potential environmental health impacts of land application of biosolids, and show a recent study in which a geographic information system (GIS) is being used to investigate those potential effects.

10.2 Biosolids Application in the United States

Biosolids became a disposal issue after the Clean Water Act was enacted in 1972 which laid out regulations for waste water treatment. Since then, land application of biosolids from WWTPs, to agricultural fields has become commonplace in the United States. Over 50% of biosolids produced in the United States are land-applied with the remaining placed in landfills or incinerated (USEPA 2004). The Clean Water Act section 405 amendment in 1987 required EPA to set biosolids regulations for minimizing environmental and health risks of identified toxic pollutants while maximizing the use of biosolids (NRC 2002).

Part 503, effective in 1993, was established by the U.S. Environmental Protection Agency to oversee the national biosolids program and established treatment and use requirements of biosolids, land application management practices, and concern concentration limits and loading rates of chemicals. Apart from regulating human pathogens, USEPA has adopted what it calls a “risk-based” approach to regulating ten heavy metals in biosolids: arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Table 10.1 shows the ceiling

Table 10.1 Maximum allowable concentrations for different metals in soils

Metals	Maximum allowable concentrations (mg/Kg dry weight basis)
Arsenic	75
Cadmium	85
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

concentrations of each of these metals allowed by the USEPA, which are considered safe for human contact (OEPA 2002). Chromium was later removed from the list due to a lack of evidence of human toxicity (McBride 2003). On the other hand, pathogen levels are not risk based. Instead, through treatment and use limitations, pathogens are limited through requirements to reduce their incidence and resultant potential exposure (NRC 2002). The Part 503 establishes criteria for classification of biosolids as Class A or B dependent on the level of treatment.

10.2.1 Class A Biosolids

Biosolids that have gone through extensive treatment to reduce pathogens below detectable levels and enhance vector attraction reduction (VAR) are termed Class A biosolids, also known as exceptional quality (EQ) biosolids. Biosolids must meet both prescribed densities of either *Salmonella* sp. or fecal coliform and treatment-process control requirements to be classified as Class A. EQ biosolids can be bagged and are deemed safe to sell to the public given that they meet these requirements. They can also be applied to land if there are no pathogen-related restrictions attached to the application site. The WWTPs distributing EQ biosolids need only a facility permit for land application, not a land permit. The WWTPs are not required to keep records of land sites to which EQ biosolids are applied. EQ biosolids can be applied to land under the same restrictions of other soil amendment products or fertilizers (NRC 2002).

10.2.2 Class B Biosolids

Class B biosolids are treated, but may still contain measurable levels of live bacteria and active viruses after treatment. That means Class B biosolids contain more pathogens than Class A biosolids. Class B biosolids must meet the organism control requirements of Part 503 in at least one of seven alternatives: fecal coliform limitation, aerobic digestion, anaerobic digestion, lime stabilization, air drying, composting, or equivalent process to significantly reduce pathogens. Unlike Class

A biosolids, Class B biosolids require land permits from the EPA for application. There are several restrictions for use of this type of biosolids. It cannot be given away in bags and cannot be sold. It is also prohibited to be used at sites that are open to the public, lawns, and home gardens. However, it can be applied to mine reclamation sites, forests, and agricultural sites in bulk quantities if the biosolids meet criteria for pollutants control, pathogen requirements, vector attraction reduction, and other applicable requirements of Part 503 (NRC 2002). Pathogenic microorganisms have been found in Class B biosolids, including harmful coliform bacteria, *Esherichia coli* (*E. coli*), poliomyelitis viruses, *Shigella sonnei*, fecal streptococci, and others (Lewis et al. 2002; Brooks et al. 2005a, b; Borjesson et al. 2009).

Part 503 mandates isolation distances between the Class B applied agricultural fields and houses, waterways and drinking water supplies (Table 10.2) to reduce potential exposure to humans and animals.

In Ohio, biosolids are applied through splash method or direct injection and can vary in moisture content from 3% solids, a liquid or up to 40% solids, which is often called cake. Splashing is the most common and least costly method for biosolids application while the injection method is more costly. Injection is often used to reduce VAR. Figure 10.1 shows an injection application of Class B biosolids in Oregon, Ohio. In 2006, in Ohio, approximately 20% of biosolids (in dry tons) were disposed of in landfills, 36% were incinerated while 46% were applied to agricultural land – 35% was Class A biosolids while the remaining 65% was Class B biosolids (OEPA 2006).

Land application of biosolids is considered a beneficial use of the material. Farmers use it because it is a free source of soil conditioner relative to providing nutrients (i.e. fertilizer) and it improves soil structure. It is an innovative way to recycle biosolids derived from municipal WWTPs. Land application supplies necessary nutrients, including all of the phosphorous and part of the nitrogen needed for crop growth. It also provides trace elements such as copper and zinc among others. It is reported to increase agricultural productivity by improving soil structure, mainly due to increased stable organic matter (Eberle et al. 1994). The stable

Table 10.2 Ohio EPA set isolation distances for surface and injection applications of Class B biosolids

Land use type	Isolation distances for surface applications	Isolation distances for injection applications
Bedrock	3 ft	3 ft
Medical care facility	1000 ft	300 ft
Occupied buildings	300 ft	100 ft
Private potable water source	300 ft	100 ft
Waters of the state (excludes ground)	33 ft	33 ft
Sinkhole or UIC class V drainage	300 ft without grass buffer, 100 ft with grass buffer	300 ft without grass buffer, 100 ft with a grass buffer

Source: Ohio EPA (2002)

Fig. 10.1 Biosolids application in Oregon, OH. The left picture is the tractor and applicator and the right picture shows the field after the application

organic matter is predominantly in the form of the complex polyphenolic humic and fulvic acids. In Ohio, the typical application is in late summer after winter wheat has been harvested. The following year, corn is most often planted on the amended fields.

10.3 GIS and Human Health

Health effects basically function at the level of the individual, although research concerned with the environmental impacts (the natural, social, and built settings experienced by individuals) on health can be analyzed as area-level effects. The health of the population in relationship to the environment can be plotted to determine the presence of patterns, a potential spatial relationship between health and physical proximity to particular phenomena spatial analysis. Historically, Dr. John Snow, a British physician, was one of the first to investigate an environmental health problem in a geographical context. During a Cholera outbreak in 1854, Snow plotted the cases of Cholera on a map of London. He then identified a cluster of residences, which accounted for most of the deaths, around a public water pump. Once the pump was disabled, the incidence of cholera dropped (Schultz 2007).

The role of geography in epidemiology and public health in the present is much more robust. Within environmental health, disease ecology, and public health, GIS has become an indispensable tool. Contributing to the acceptance and expanding use of GIS within health sciences is the availability of large amounts of environmental data as well as GIS internet functionality (Kistemann et al. 2002). The greatest potential of GIS lies in its ability to clearly show the results from complex research through maps (Mullner et al. 2004).

10.3.1 Biosolids and Human Health

Due to the lack of existing substantiated studies, scientists differ in opinion on the nature and intensity of impacts of biosolids application. Some argue that US and state EPAs have arbitrarily chosen toxicity thresholds and therefore, the impacts of biosolids application cannot be validated with adequate scientific knowledge. In contrast, others opine that the impacts found by field studies are substantial because the current practice of biosolids application is strictly regulated by federal and state laws that are based on multiple procedures (Düring and Gath 2002).

Although biosolids are high in more stable organic content and plant nutrients and make a good soil amendment, they can also contain metals, organic pollutants, and pathogens. Although processing biosolids attempts to limit the number of pathogens present, previous studies have shown that pathogenic bacteria often survive the treatment process (Lewis et al. 2002; Brooks et al. 2005a,b; Borjesson et al. 2009). Direct contact of waters contaminated by runoff from nearby land application sites is one potential mode of human exposure to pathogens present in land-applied biosolids (USEPA 1999). Since infection by resistant pathogens poses a unique treatment challenge, the off-site movement of pathogens, especially those expressing antibiotic resistance, is of particular public health importance. With repeated land application over time, heavy metals can accumulate to levels that may damage agricultural soils. Arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc can be present in biosolids and are regulated in the Part 503 regulations. Both pathogens and some heavy metals are known to cause illness (ATSDR 1999; 2003; 2004; 2005; 2007; 2008).

The studies that are most commonly cited are those of STP workers (Brugha et al. 1998; Weldon et al. 2000; Trout et al. 2000; Gregersen et al. 1999; Rylander et al. 1977; Lundholm and Rylander 1983; Elia et al. 1983; Clark et al. 1984) and WWTP workers (Melbostad et al. 1994; Khuder et al. 1998). However, there are few studies on biosolids applicators and residents living in close proximity to biosolids applied fields.

Varying conclusions are present in epidemiological studies of disease in wastewater workers. Retrospective epidemiological studies have found that wastewater work presents an increased risk for a variety of symptoms. Melbostad et al. (1994) found in a study of 24 wastewater workers at Norwegian wastewater treatment facilities that workers who were exposed to rod-shaped bacteria reported significantly higher rates of tiredness after work, headache during work, nausea and respiratory symptoms. Khuder et al. (1998) found in a retrospective epidemiological study of 204 wastewater workers in Ohio that they had a significantly higher prevalence of gastroenteritis, gastrointestinal symptoms, abdominal pain and headache compared to workers in other occupations.

In the 2002 NRC report, the information from 14 studies of sewage treatment plant workers was gathered. Two studies showed that Hepatitis A increased (Brugha et al. 1998; Weldon et al. 2000) while one study showed no increase in Hepatitis A (Trout et al. 2000). Additionally, an outbreak of Pontiac Fever, which is caused by a bacteria transmitted through water, was confirmed (Gregersen et al. 1999). Among general complaints were increases in nasal irritation, tiredness, and diarrhea which are compatible with exposures to some bacterial endotoxin (Rylander et al. 1977). Increased rates of skin disorders, diarrhea, and gastrointestinal symptoms have also been reported (Lundholm and Rylander 1983). A study by Elia et al. (1983) provided evidence of pesticide absorption without reporting any health effects. However, Clark et al. (1984) reported no differences in illness rates and no isolation of viruses or bacteria.

While studies of WWTP workers and sewage plant workers suggest or document some health effects that may be related to exposure to sewage and/or biosolids, those of biosolids applicators vary. Tanner et al. (2008) estimated occupational risks through the collection of microorganism levels in air immediately downwind of land application operations. Risks from aerosolized microorganisms at biosolids land application sites were lower compared to wastewater treatment plants. Robinson et al. (2006) developed and performed a pilot test of a health survey for WWTP workers, and although eight reported at least one potentially associated symptom, personal protective equipment (gloves, goggles, respirators) were not always worn to protect from potential exposure. Workers associated with biosolids land application activities were interviewed in a study by Burton and Trout (1999) and all five had reported at least one instance of gastrointestinal illness after working with biosolids at the WWTP or during application, while four of the five reported at least one symptom of various gastrointestinal symptoms or repeated intermittent headache. However, the site in question did not comply with EPA regulations, and at times before the study, had applied biosolids that exceeded the EPA fecal coliform upper limit for Class B biosolids (NIOSH 2002).

Community exposure to biosolids has been evaluated, although findings indicate further study is needed. Dorn et al. (1985) performed a 3-year prospective epidemiologic study in three geographic areas of Ohio on families of biosolids receiving farms and control farms. No significant differences were found in general symptoms or digestive or respiratory illness between the families. Lewis et al. (2002) surveyed 48 residents in eight states reportedly affected by ten biosolids land application sites although no control group was included. Results indicated at least 25% of participants reported coughing, burning throat or burning eyes within 1-h of exposure.

10.4 Methodology

In 2004, researchers from the University of Toledo and Bowling Green State University along with collaborators from Central State University, Kent State Unviersity, Cleveland State University, Youngstown State Univeristy, the University of Michigan, Oregon, Ohio WWTP and Bowling Green, Ohio WWTP developed a project to evaluate potential impacts of land application of Class B biosolids on human health using a geographic information system (GIS). This ongoing project is very comprehensive and seeks to analyze the potential pathways in which pathogens and heavy metals, through aerosols and transport of contaminants in runoff away from application fields, could result in human exposures and cause associated health problems. Field observations and modeling were utilized to investigate the fate of pathogens, heavy metals and pharmaceutical and personal care products (PPCPs) and the pathways of these constituents off of the fields. We have identified approximately 50 compounds in wastewater influent, effluent and biosolids that are classified as caffeine, antibiotics, anti-depressants, and other pharmaceuticals, etc. (Spongberg and Witter 2008; Wu et al. 2008a,b; Wu et al. 2009a,b). Samples were analyzed for PPCPs within a GIS and PPCPs were detected on the sludge amended fields, from water exiting tile drains and in ditches downstream of applied fields (Wu et al. 2009a). We have determined the source of *E. coli* bacteria in runoff water from biosolids applied fields using DNA sequencing (Kassem et al. 2008; Esseili et al. 2008). Remote sensing has been used to identify biosolids application from satellite imagery as well as to estimate phosphorus concentrations in biosolids applied soils (Sridhar et al. 2009). Aerosol sampling has been performed using both direct reading instruments and integrated sampling in an effort to characterize farm fields during major field activities including application of biosolids. We are developing a predictive screening model to determine the concentration and risk due to aerosols released into the air on nearby residents.

This project led to the publication of an epidemiological study conducted in Wood County of people living near agricultural fields permitted to receive biosolids (Khuder et al. 2007). The GIS described herein was developed in ArcGIS in support of the Khuder et al. (2007) epidemiological study.

10.4.1 GIS Layer Development

GIS databases were created for Lucas, Wood, Greene, Mahoning, Portage and Trumbull Counties in Ohio (Fig. 10.2). A standardized state plane, Ohio North

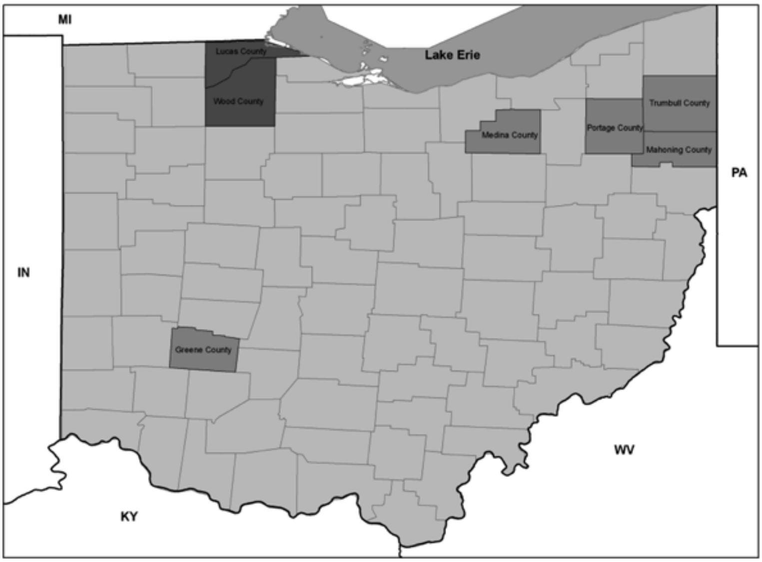

Fig. 10.2 Counties in Ohio in which the GIS and epidemiological surveys have been developed and performed

Table 10.3 Data layers and sources for the county GIS

Parcels	County auditors
Roads, railways, bike trails	ESRI, Inc. & Census TIGER files
Township boundaries	Census TIGER files
Demographic information	Census TIGER files
Soils	NRCS USDA Geospatial data gateway: http://datagateway.nrcs.usda.gov/
Hydrology	USGS NHD http://nhd.usgs.gov/
Septic tanks	County health department
Land cover	USGS/NLCD http://www.mrlc.gov/nlcd.php

(feet) coordinate system was used with the Lambert Conformation Conic projection and datum of NAD 83. Thus far, the epidemiological survey has been performed in Wood, Lucas and Greene Counties.

A base map layer was the first layer to be developed and includes parcel information, roads, railways, bike trails, schools, forests, zip codes, census tracts, township boundaries, waste water treatment plants, sewer districts, septic tanks (if available), soil classifications, hydrology, and hydrogeology (Table 10.3). Multiple sources of data were needed to collect this information including Census TIGER files, ESRI Inc. data set, County Auditors, County Engineers, and County Health Departments. After the base map, the permitted fields for Class B biosolids application were added. For the epidemiological study, permitted field locations were used to generate addresses that surveys were sent to for Wood and Lucas Counties. For Greene County, a further step was taken to attach the application information to the fields prior to generation of the addresses. This further refined the survey results and removed a confounding factor, a permitted field that never had biosolids applied, from the analysis.

10.4.2 Mapping Permitted Fields

A shapefile was created to identify the location of Class B permitted fields in each participating county. The location of Class B biosolids permitted fields (hereinafter referred to as "permitted fields") were collected from plat maps on file at the Northwest District Office of the Ohio Environmental Protection Agency for Wood and Lucas Counties and from the Dayton WWTP and local hauler for Greene County. Polygon shapes to represent the permitted fields were initially drawn freehand (Fig. 10.3). At times the description of the field was used to find the correct location of the field when plat maps were not available. Issues with polygons were observed such as overlapping of fields, the inclusion of forested areas and fields outside of parcel boundaries. A set of rules were developed to provide more accurate

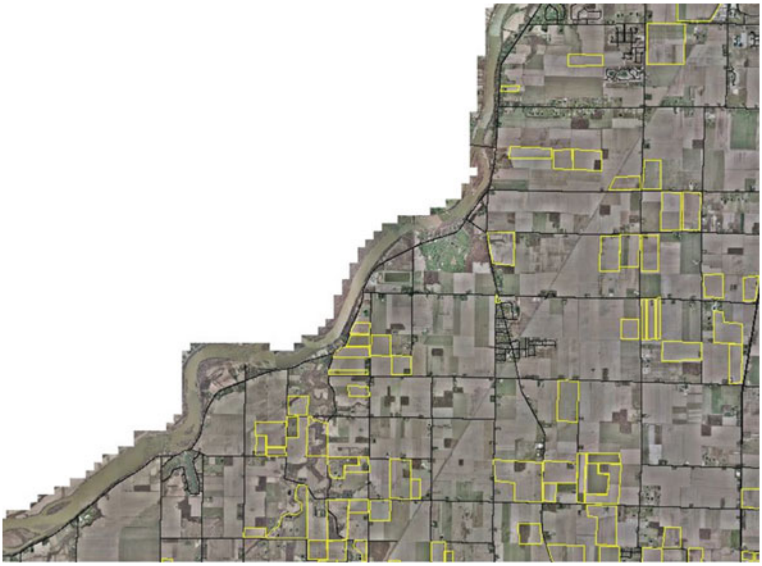

Fig. 10.3 Permitted field polygons were hand drawn from paper plat maps provided by the local EPA office over an aerial photograph. (Source: McNulty 2005)

locations and a cleaner topology of the permitted fields. The following steps were taken to ensure better accuracy.

- Aerial photographs were analyzed to verify the shape of the permitted field polygons. Heads-up digitizing was performed to match the shape of the permitted field polygon to the shape of the field.
- Permitted field polygons were compared with the parcel layer polygons provided by county auditor's offices to verify that it was within the parcel boundaries.
- Overlap of permitted field polygons with forested polygons was adjusted such that a permitted field did not include any forested area.
- A comparison of permitted field acreage listed on the EPA reports was compared to the measured acreage of the polygons produced. Substantial difference indicated an issue and the field was subsequently resolved.
- A comparison of farmer/owner name to the name listed on the parcel by the auditor was used to verify the location of the fields. Differences in owner name indicated a potential issue and the field was subsequently resolved.

The permitted fields are designated with a number and letter by the OEPA that represents the township that the permitted field is in (Fig.10.4). This leads to some confusion because a single county can have two or more fields with the same designation such as 27j. In addition, a field may be designated 27j in more than one county. The parcel ID was used as a unique identifier instead of the permitted field designation.

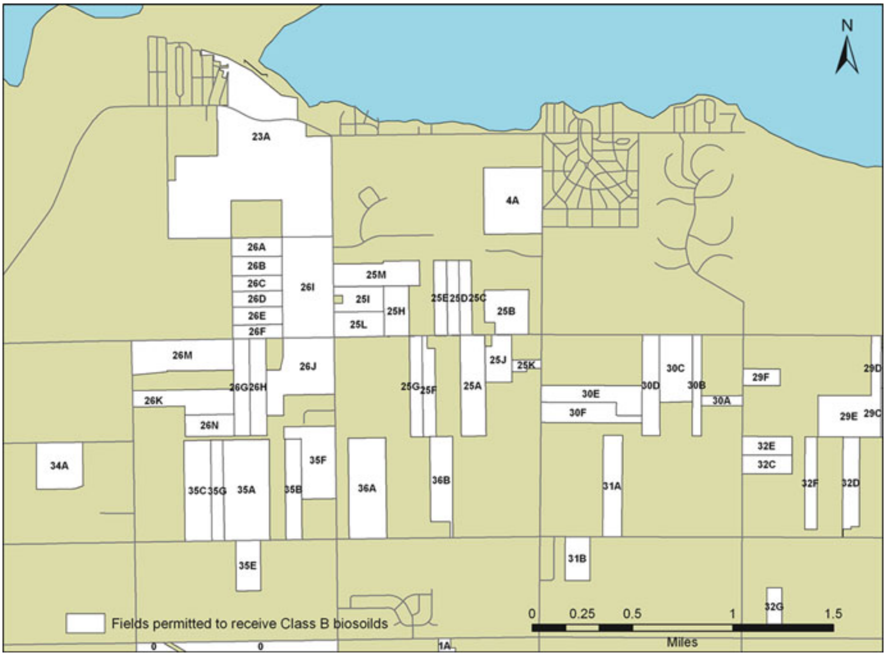

Fig. 10.4 Permitted fields in Oregon, Ohio showing the OEPA number and letter designations

After the original list of permitted fields was created for Wood County the database was continually updated in an attempt to include new permitted fields. Subsequently, the Wood County methodology was followed to develop the permitted field shape file for the other counties. The permitted fields for Wood, Lucas and Greene Counties respectively are show in Figs. 10.5, 10.6 and 10.9. The epidemiological study for Wood and Lucas Counties was performed using permitted fields only (Khuder et al. 2007).

10.4.3 Mapping Biosolids Applications

Not all fields that are permitted to receive biosolids actually have biosolids applied. Therefore, the epidemiological study in Wood and Lucas Counties had a potential confounding factor if permitted fields did not have biosolids applied to them. For Greene County, fields with known biosolids applications were used in the epidemiological study. Paper copies of submitted biosolids application reports were obtained through the Northwest District Office of OEPA for Lucas and Wood Counties and from the Dayton WWTP and sludge hauler for Greene County. Data were hand entered into data tables and joined to the parcel layer in the GIS using the parcel ID as the unique identifier. WWTPs are required to keep application reports as Part II of most NPDES permits issued to POTW and include detailed information about

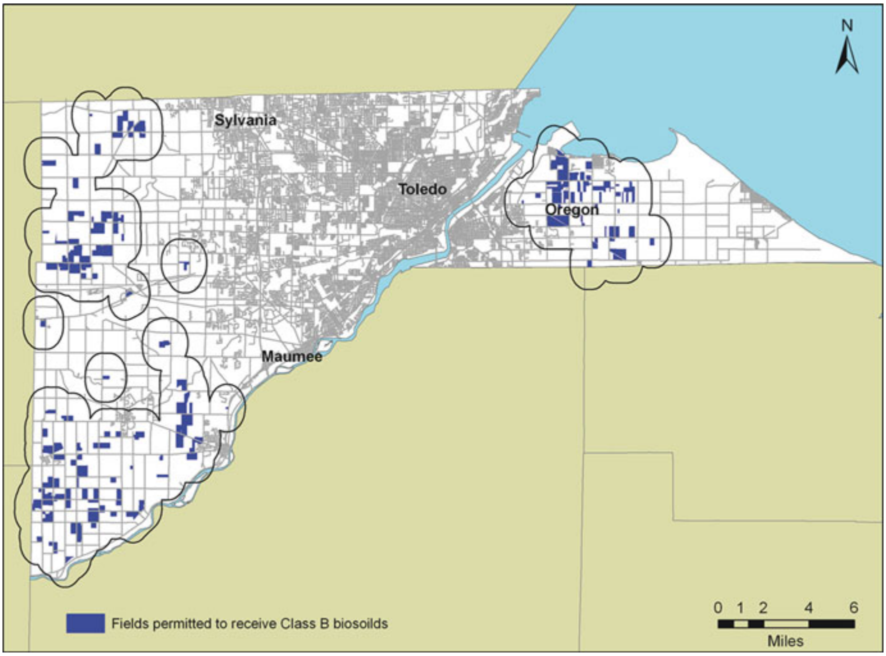

Fig. 10.5 Lucas County fields: a 1 mile buffer around permitted fields

the application site. Individual site reports vary by WWTP but often include the size of the field, gallons or dry tons applied to the field, percent solids of the biosolids, owner name, and location of the site.

The application information depicts the amount of application by year, geographic region, and amount of historical application (Table10.4). The fields that have received biosolids between 1990 and 2003 are shown in Figs. 10.5 (Lucas County), 10.7(Wood County) and 10.9 (Greene County). Once all of the data has been added, maps of the applications can be produced specifically showing the application rate of heavy metals and nutrients from the biosolids.

10.4.4 Address Generation for Epidemiological Study

The ability to look at spatial relationships was integral to the epidemiological portion of the project. The epidemiology study focused on potential health effects of residents in each county in relation to the households distance from a permitted or applied field. Households were selected to receive a mailed survey based on the distance of the house from permitted fields (Wood and Lucas Counties) or from applied fields (Greene County). A list of all households in Wood County by distance from permitted fields was created using the developed permitted fields shapefile. A

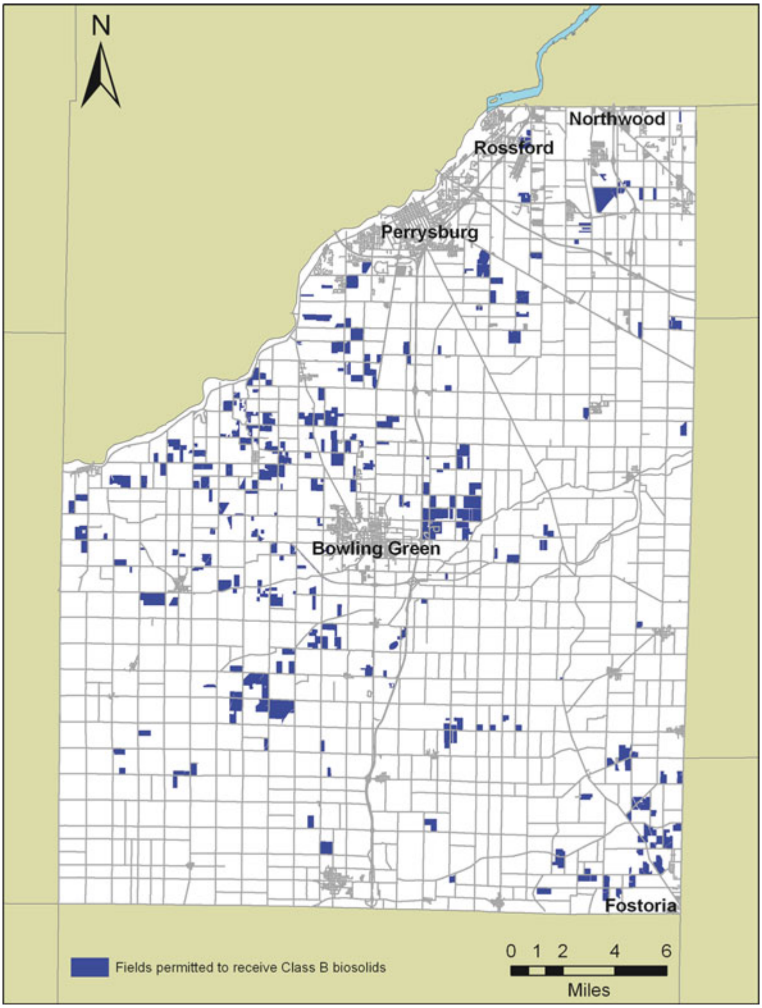

Fig. 10.6 Wood County fields permitted to receive Class B biosolids

distance buffer was generated from the edges of the permitted fields. The buffers were categorized as:

- on field,
- within 1 mile of the field,
- greater than 1 mile and within 2 miles of the field,
- greater than 2 miles and within 3 miles of the field,
- greater than 3 miles and within 4 miles of the field,
- greater than 4 miles and within 5 miles of the field, and
- greater than 5 miles of the field.

Table 10.4 Data variables recorded on biosolids application data forms

Basic information			
Date	Site	Site size	Site location
Application information			
Liquid volume applied	Percent solids	Dry lbs. material applied	Total dry tons material applied
Tons per acre	–	–	–
Nutrients (mg/Kg)			
Organic nitrogen	Ammonia nitrogen		Phosphorus
Metals (mg/Kg)			
Arsenic	Cadmium	Copper	Lead
Mercury	Nickel	Zinc	Molybdenum
Selenium	–	–	–

Participating households were selected from within these buffers. Since more health effects would be expected in areas with closer proximity and possibly higher exposure, (i.e., closest to permitted fields) all houses located on permitted fields were selected for inclusion. A similar number of houses were randomly selected from the houses within 1 mile of a permitted field and another group of houses were randomly selected from the houses greater than 1 mile of a permitted field, of which 51% were between 1 and 2 miles and 49% were between 2 and 3 miles of a permitted field. Houses more than 3 miles from a permitted field were excluded from the study due to the small number of houses in those buffers. Ultimately, the respondents were put into two groups, households up to one mile from a field and households greater than one mile from a field. These same two distance groups were used in all three studies. Figures 10.5, 10.8 and 10.9 depict a one mile buffer around the permitted fields for Lucas and Wood Counties and around confirmed applied fields for Greene County.

Survey groups for the epidemiological study were partitioned into households that were within one mile of several permitted fields (heretofore the exposed group) and households that were further than one mile away from any permitted field (heretofore the unexposed group). Epidemiological surveys were sent to the addresses chosen randomly from the generated lists. The use of GIS in the selection of survey households allowed for a random selection sample rather than a convenience sample of potentially exposed populations living near biosolids permitted fields and eventually biosolids applied fields. A convenience sample would not have guaranteed potentially exposed respondents. Additionally, the ability to verify the presence of a household on a property prior to mailing reduced the potential for returns due to bad addresses. This was especially true with dealing with agricultural areas as many properties have addresses but no one resides on the property. In addition, for Wood and Lucas Counties, many surveys were returned without delivery with *Address Unknown* on the envelope. In the process of generating addresses for the survey, we did not check to see if there was a house on the parcel. For Greene County, prior to household inclusion, a visual inspection of aerial photographs was performed to ensure that a residence was present on the parcel.

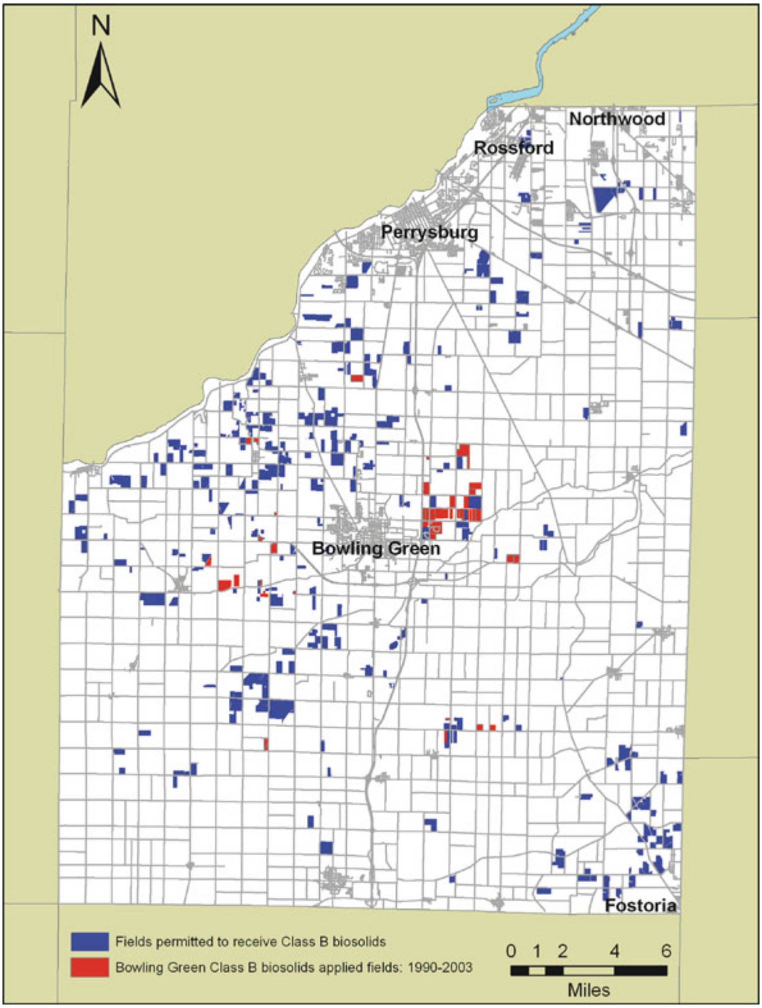

Fig. 10.7 Wood County fields that had biosolids applied between 1990 and 2003

Similar processes were used for Lucas and Greene Counties as were used for Wood County. Similar numbers of surveys were sent out for each county. The most significant difference was that fields that had biosolids applied were used for Greene County to set up the buffer (Fig. 10.9).

In the surveys, respondents were asked if they had any symptoms from a list and/or had been diagnosed with a disease by a physician. Survey respondents were asked to indicate the frequency of the following symptoms: headache, fever, excessive secretion of tears, cough, sneezing, sore throat, chest pain or discomfort, abdominal pain, abdominal bloating, nausea, vomiting, diarrhea, constipation, jaundice, skin rash, ulcer on the skin, muscle spasm, chills, dehydration, loss of appetite,

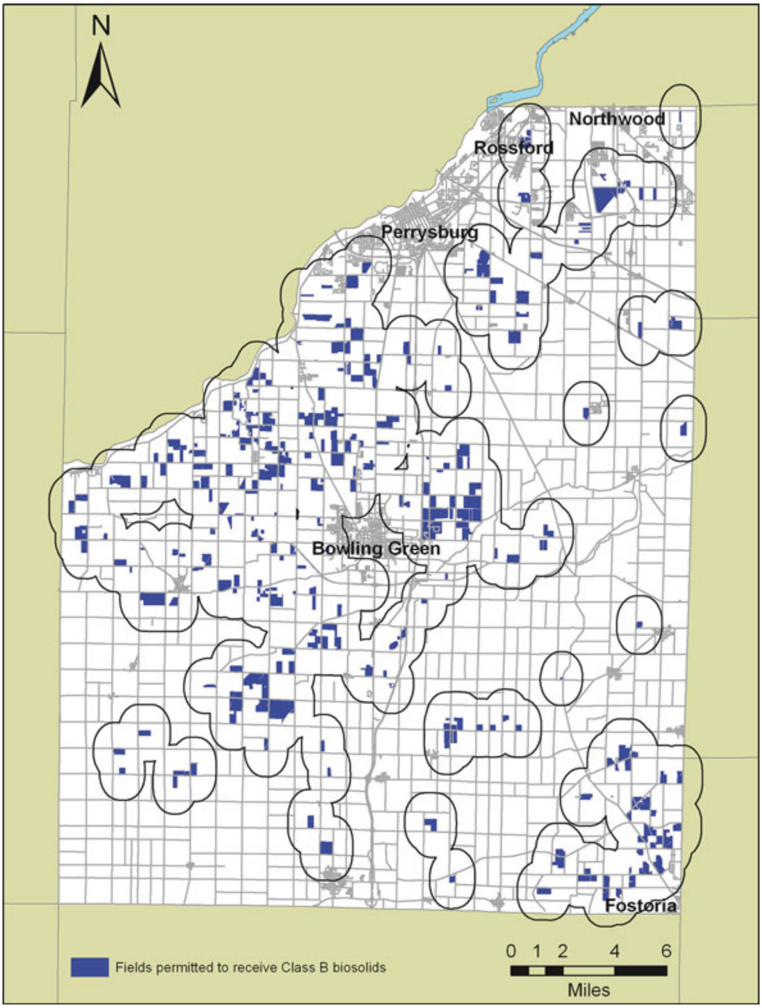

Fig. 10.8 Wood County fields a 1 mile buffer around permitted fields

weight loss, insomnia, fatigue, weakness, and general ill feeling. Respondents were asked to indicate on the questionnaire if they had been diagnosed with chronic diseases by a physician: asthma, emphysema, Crohn's disease, migraine headache, ulcerative colitis, chronic bronchitis, irritable bowel syndrome, allergies, multiple sclerosis, Parkinson's disease, scleroderma, skin disease, poliomyelitis, autism, skin cancer, and, arthritis/osteoarthritis. Lastly, physician diagnosed acute diseases listed on the questionnaire included: leptospirosis, salmonellosis, shigellosis, typhoid fever, hepatitis A, poliomyelitis, amoebiasis, bronchitis, pneumonia, upper respiratory infection, lower respiratory infection, cold, giardiasis, and gastroenteritis.

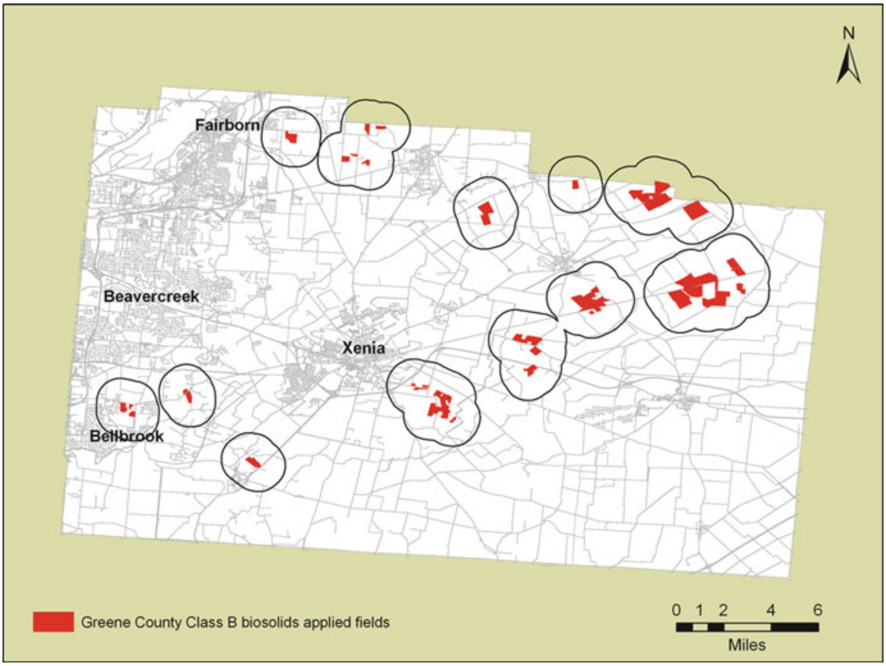

Fig. 10.9 Greene County fields a 1 mile buffer around applied fields

10.5 Results

Exposure determination in Wood County was based strictly on the distance the household was located from a permitted field. Originally, the study was designed with the intent to show a dose-response relationship, if one existed. In other words, more health effects were expected closer to the permitted fields with the number of health effects decreasing with each successive buffer zone away from the permitted fields. However, the results did not support this assumption. The symptoms and diseases self-reported from the on-field group and those reported from residents of houses within 1 mile of a permitted field were not statistically different and were combined to comprise the potentially exposed group. The control group was the sample of houses between 1 mile and within 3 miles of a permitted field. The "n" was 437 respondents from 178 households from within a mile of the permitted fields and an "n" of 176 respondents from 80 households from greater than one mile of the permitted fields.

A synopsis of the results is highlighted here with the rest of the results available from Khuder et al. (2007). Of the survey participants, there was no significant difference with regard to age, gender, length of time living on the farm, percentage of time each spent at the address, high-risk occupations, and smoking status between the participants near the permitted fields and those greater than one mile away. The findings suggest that residents living near biosolids permitted fields may be at an increased risk for certain respiratory, gastrointestinal, and other diseases. Of the 25 symptoms on the survey, seven were significantly higher for the respondents living near the fields than away from the fields at a $\alpha = 0.05$ confidence level including excessive secretion of tears, abdominal bloating, jaundice, ulcer on the skin, dehydration, weight loss and weakness. Of the sixteen chronic diseases surveyed, only emphysema was statistically higher in the group near the fields. Of the 14 acute diseases surveyed, bronchitis, upper respiratory infection and Giardiasis were significantly higher in the group close to the permitted fields. The findings show that there is some correlation between illness and proximity to permitted fields for biosolids application in Wood County, Ohio, but it is not proof that biosolids were the cause of the illnesses. This study suggests that additional research is needed.

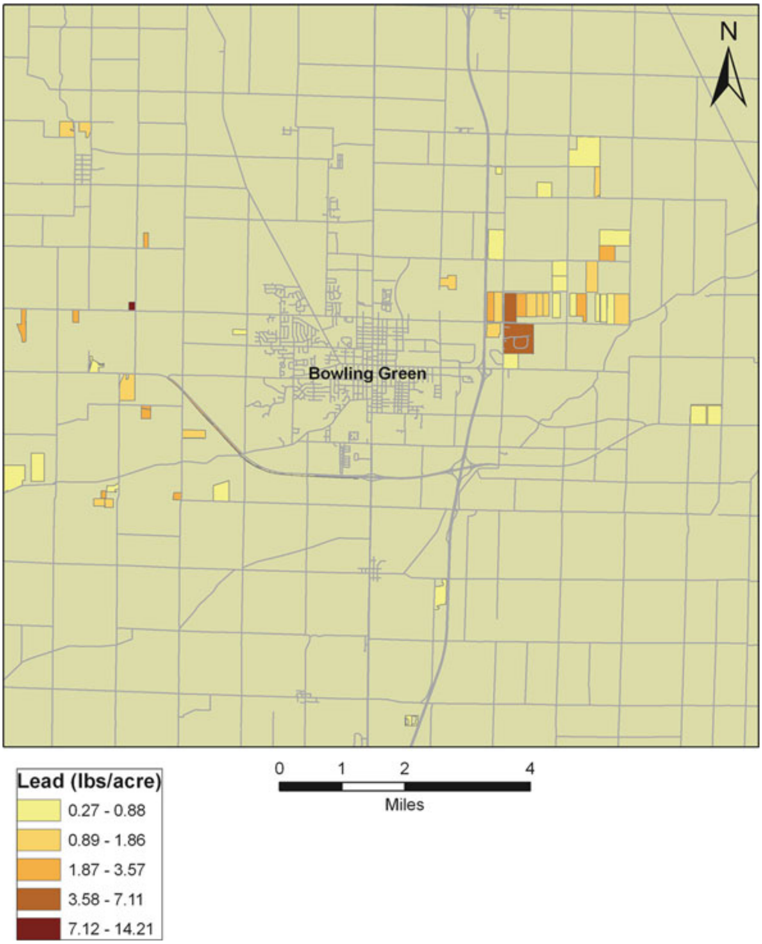

Fig. 10.10 Mass of lead applied to biosolids amended fields through 2003 in Wood County

Since the Wood County results were published, two additional health surveys have been performed in Lucas and Greene Counties in Ohio. These surveys were implemented using methods improved from the Wood County surveys. Wood County potential exposure status was defined purely by distance of the household from permitted fields. In Lucas County, the potentially exposed group was improved by selecting all of the households closest to the permitted fields. For the control households, the same procedure was used as in Wood County, a distance buffer of more than one mile but less than three miles from the nearest permitted field.

In an effort to further strengthen the epidemiological study in Greene County, the Class B biosolids application data were mapped first and then the addresses generated (Fig. 10.9). The exposed group then became the closest households to the

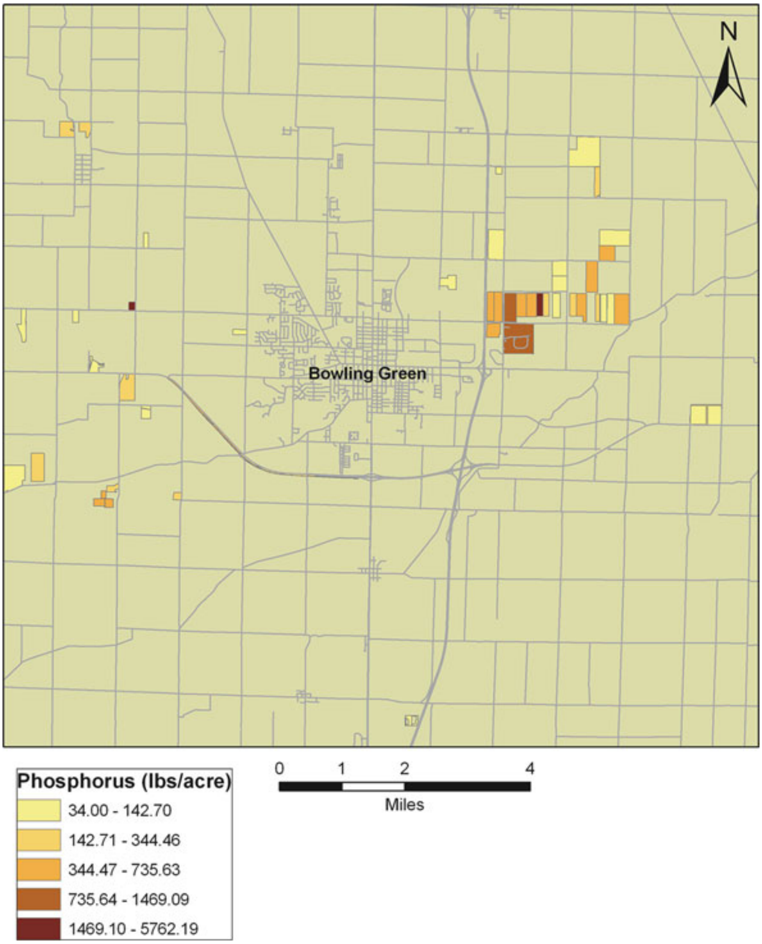

Fig. 10.11 Mass of phosphorus applied to biosolids amended fields through 2003 in Wood County

applied fields. A distance buffer was again generated, but for Greene County this buffer was set up from the edges of applied fields. The control households were then located more than 1 mile but less than three miles from the applied fields, matching the distances used in Wood County.

10.5.1 Conclusions and Future Directions

The results showed that there is some statistical correlation between illness and proximity to permitted biosolids fields in Wood County, Ohio, but it does not show a cause and effect relationship between biosolids applications to farm fields and illnesses. More work is need to further refine the epidemiological health survey data, including spatial analysis. In our study, counties that were surveyed prior to obtaining the application data will be evaluated using the obtained historical application data for a focus on biosolids applied fields, in addition to permitted fields. Application reports from WWTPs have generally been archived. Often WWTPs retain specific application information including heavy metals including arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc and nutrients including phosphorus and nitrates (Figs. 10.10 and 10.11). Comparison of the survey responses with application data has the potential to clarify the potential cause and effect relationship between biosolids and illnesses. These steps will allow for further examination of potential environmental exposure to contaminants from biosolids and relationships to human health effects.

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