Chapter 4. SMALL COMMUNITY WASTEWATER TREATMENT SYSTEMS

A. Overview

A small community has many alternatives to evaluate and select from for its wastewater collection and treatment. The choices range from the use of an individual septic tank/lateral field for each home and business, to gravity sewers and treatment plants that are miniatures of those used by larger communities. Small communities can also consider integrated combinations of more than one method.

Centralized, Decentralized, and Onsite

A centralized system usually means a central treatment plant handling wastewater collected in gravity sewers with pumping stations as needed. An onsite system treats the wastewater generated by a single-family home or one business. The wastewater is treated and returned to the environment within the property boundaries of the home or business. A decentralized system is actually centralized in the sense that it has a central coordinated administration, but may have a common collection system and treatment facility or onsite systems or both.

Discharging vs. Non-Discharging

A community needs to decide whether they want their system to be discharging or non-discharging. Discharging systems release the treated wastewater to the ground surface, usually into a ditch or stream. A discharging system requires a National Pollution Discharge Elimination System (NPDES) permit from the Kansas Department of Health and Environment (KDHE) and regular monitoring of the quality of the discharged water. A non-discharging system returns the wastewater to the soil (below surface) and to the air by evaporation or plant transpiration. Non-discharging lagoons that receive more than 2,500 gallons per day require a KDHE water pollution control permit.

Factors that are considered in making the discharging/non-discharging decision are size of the community (flow), ability of the local soils to absorb the required amount of wastewater, limitations on the stream receiving the water, and ability/desire to operate a moderately complex system. Discharging systems must use some type of treatment such as a sand filter, aeration system, package plant (pre-engineered mechanical unit), or a set of lagoons designed to be discharging systems, followed by disinfection, if needed.

Plant Size

Another issue that must be addressed early in the planning is the ultimate number of homes that are to be served. In the movie, Field of Dreams, a major league baseball field is proposed in the middle of an Iowa cornfield. The question of who will fill the stands is answered with "If you build it, they will come." The "Field of Dreams" factor applies to public works projects. If a community develops a good wastewater collection and treatment system at a reasonable cost, it will become a more desirable place to live and community growth very well may result. If the system is planned for a subdivision or a cluster of homes, the total number of available building sites will be an approximation of the ultimate size. However, if a system is to serve a community that wants or has the potential to grow, growth and the resulting requirement for oversizing and expandability need to be considered.

KDHE has a set of "Minimum Standards of Design for Water Pollution Control Facilities updated in 1978 that covers some of the community systems described here such as lagoons and systems listed in Section J., Package Plants and Other Systems. If included in the Minimum Standards, a new system should meet or exceed these requirements.

B. Treatment Alternatives

Conventional Onsite Techniques

Conventional onsite wastewater treatment methods can be adapted to small community-wide systems by increasing their size. Conventional onsite systems are those where wastewater exits the home or business and passes through a septic tank before it is treated in a soil absorption field. These absorption fields can be pipe-in-rock trenches, chambers, or beds, although beds are not recommended for large flows.

A small community that has onsite systems should give serious thought about whether their systems are failing and why. (Sanitary Surveys will be discussed in a later chapter.) Homes on very small lots in soils that are not very permeable may not be able to use onsite systems under any circumstances. However, it may be possible to use existing or repaired onsite systems with good management and careful use. It may be less expensive in both the near and long terms to make such modifications as low flow showerheads and faucets and even replacing toilets with low flow models and washing machines with front loading models that use less water, than to build a sewer system and treatment plant. It may also require lifestyle changes such as spreading out laundry washing over several days, giving up garbage disposals, turning off the shower while soaping, and regular septic tank pumping. However, community-wide cooperation in water conservation might be the only solution needed.

Another possible onsite alternative is the use of individual alternative systems such as aeration systems or sand filters. They are more expensive than conventional onsite systems, but may be less expensive than central systems. There will be later discussions of ways to manage these systems as a group to get the best performance and control costs.

Shared Facilities

It is possible that a small community is close enough to the existing wastewater treatment facility of another town that it is less expensive to convey wastewater to that treatment plant than to build a new one. If the existing plant is near capacity, they may not be able to accept additional wastewater. However, if an expansion is possible, the town may be willing to accept the small community's wastewater, if the community is willing to pay all or part of the expansion costs.

Lagoons (Wastewater Stabilization Ponds)

Lagoons, also known as wastewater stabilization ponds, are open ponds where wastewater is treated by bacteria using oxygen in air provided by wind motion, algae, and for community-sized lagoons, usually mechanical aeration equipment.

Alternative (Enhanced) Treatment Methods

Alternative treatment systems, such as sand filters and aeration systems, provide treatment for the removal of organic material and some pathogens from the wastewater before discharge or absorption. These units can be adapted and scaled to handle the full size range from single-home onsite systems through municipal plants.

Package Plants

Small package plants are commercially-made units designed for wastewater treatment that can be brought to a site and installed. Examples of systems used in package plants are rotating biological contactors and sequencing batch reactors. The package plants will include auxiliary equipment such as pumps and filters needed for operation. Package plants are usually larger and more complex than the systems described as alternative treatment. However, for larger flows or complex wastewaters, they may be more effective. They may also take up less space. They require more operator attention and higher-level operator training and commitment.

C. Conventional Soil Treatment And Subsurface Water Absorption

The individual or shared absorption fields will be sized on the basis of flow and loading rates for the soil. Thought should be given to dividing the field into sections so that if there is a problem with one part of the field, the flow can be diverted to the rest. A rotational program of section use allows part of the field to rest and rejuvenate periodically. A rule of thumb is to limit the size of any section to 1,000 linear feet or less of lateral line. The standards for field sizes, trench design, and material and construction specifications for onsite systems in *Bulletin 4-2: Minimum Standards for Design and Construction of Onsite Wastewater Systems*, pp. 10-13, are also applicable to small community absorption systems. This document can be obtained from KDHE by Calling (785) 296-4195.

D. Lagoons (Wastewater Stabilization Ponds)

Lagoons can provide both aerobic and anaerobic treatment zones of suspended bacteria. Two or more lagoons or cells are used for community systems. With three or more cells, the wastewater can flow from one cell to the next to the next (in series) or directly into two or more and from those cells into another cell (in parallel). Wastewater lagoons must be fenced. Wastewater lagoons take *relatively* little maintenance (not the same as *no* maintenance): keeping weeds out; the berms mowed and in good condition; and the mechanical equipment, pipes and valves in good operating condition. However, the lagoons should be inspected at least every two to three days to make sure that nothing has upset the processes going on in the lagoons and that the equipment is operating. Quick action to restore correct conditions is critical to prevent more maintenance problems, difficulties in restoring operations, and odors. (See Figures 1and 2)

E. Sand Filters

There are two types of sand filters, intermittent and recirculating. In an intermittent sand filter, the wastewater passes down through the sand bed once before going to an absorption field or discharge. Intermittent sand filters are further subdivided into buried and open. As a rule, intermittent sand filters for single homes or small clusters are buried and large sand filters are open. (Figure 3)

In a recirculating sand filter, part of the effluent from the filter goes to the absorption field and part is sent back to a recirculation tank ahead of the filter where it is mixed with septic tank or primary treatment effluent before being passed through the filter again. A recirculating sand filter is more expensive and complex than an intermittent unit. However, it can treat the wastewater more completely, and it can be designed to reduce total nitrogen and nitrates in the effluent, which is especially important for systems that discharge to a water-quality-limited stream. (Figure 4)

One of the most critical factors in good sand filter performance is the quality of the sand. It must be clean and sized to specific standards. Other key factors are how often and how much wastewater is applied at a time. Sand filters require dosing which is applying wastewater during several short periods of time rather than continuously. This requires a pump and a timer.

Maintenance requirements for sand filters are to care for the pumps and other mechanical equipment. Those filters that have exposed sand surfaces may have to be raked periodically to keep the surface smooth and to remove surface clogging. Over the long term, some or all of the sand may have to be replaced. The orifices (spray holes) in the distribution lines need to be checked to be sure none are plugged and cleaned, if necessary. In extreme cases, sand filters may be restored by injecting air through the sand from the bottom of the filter.

F. Non-Sand Filters

Filters using media other than sand are in various stages of development. Other media include peat, synthetic fabric strips, expanded shale, and bottom ash. So far, use of the other media has been limited to single residences or very small clusters. Research for more effective or less expensive media is ongoing.

G. Constructed Wetlands and Rock-Plant Filters

As opposed to single residential systems, all, or almost all, constructed wetlands in small community systems are used for “polishing” (additional treatment) after other treatment. Rock-plant filters are similar small-scale systems used for treating septic tank effluent.

Unless gravity flow is not sufficient and pumps are needed, rock-plant filters do not have mechanical parts except a simple manual device to control water level. Maintenance is composed of keeping the plants in good condition and maintaining the water level at an adequate level to keep the plants in good condition. Dead plant material should be removed so that it does not add to the organic load in the system. (Figure 5)

H. Mounds

Mounds are similar to sand filters in that they have dosed distribution onto a bed of sand. However, a mound has a self-contained water dispersal system because the base of the mound is in contact with the soil that accepts the treated wastewater. Mounds are alternative treatment systems suitable for areas with high bedrock or water tables. Mounds can be used for small community systems. However, because of size and construction costs, they will probably be cost-competitive only for individual homes/facilities within a larger management district or for small clusters of homes. (Figure 6)

I. Aeration

Some alternative treatment systems, most package plants, and larger systems add oxygen by adding air to the wastewater to stimulate some chemical reactions and to increase bacterial activity. A variety of blowers, bubblers, or agitators can be used. Most very small systems have a fixed “medium” that the bacteria grow on. Some are plastic grids or balls, others are fabric “socks”. Power consumption may be higher with aeration units than other systems. Noise from the equipment may also be an issue.

Aeration systems also have equipment, such as fans, that will need to be maintained. The outer part of the bacteria layer on the media will slough off periodically. This material must be removed from the system. In some units, it can be pumped out by a septage hauler. In others, mechanical cleaning devices are required. (Figures 7 and 8)

J. Package Plants and Other Systems

Wastewater treatment that does not use onsite-type technology uses some variant on a method that gradually separates the solids from the liquid and treats them. (Note that "solids" can mean anything that is solid after the water is evaporated, so wastewater contains "dissolved solids" as well as the ones that are visible.) The solids that remain at the end of the process form sludge, also known as biosolids.

Activated Sludge

There are a number of treatment methods that fall in the category of activated sludge processes. In an activated sludge process, the wastewater is treated in a tank, usually with aeration. Following this treatment, the wastewater is transferred to another unit where the sludge produced is separated from the effluent. Part of the sludge is returned to the treatment tank and the rest is removed for disposal. The returned sludge increases the concentration of active bacteria in the main treatment area.

Extended Aeration

In extended aeration, the detention time for the aeration process is 24 hours or longer versus less than an hour for some of other systems.

Contact Stabilization

In a contact stabilization process, the returned sludge is reaerated before it is added to the first aeration tank. This allows the first aeration tank to be smaller than for other processes.

Oxidation Ditch

The oxidation ditch uses a ring or oval channel instead of a rectangular tank to get a long reaction area in a small space. It is equipped with aeration devices. (Figure 9)

Sequencing Batch Reactor

Instead of series of tanks that the wastewater enters one after another, a sequencing batch reactor (SBR) performs each step in the same tank. More than one tank is used to handle larger volumes. The sequence is: fill, react (aerate), settle, draw (remove most of the wastewater), and idle. (Figure 10)

Rotating Biological Contactors

Rotating Biological Contactors (RBC) are a series of plastic disks on a rotating shaft mounted over a tank of wastewater. During rotation, a point on a disk will alternately dip into a tank of wastewater and rise into the air. The disks are covered with a film of bacteria that treats the wastewater. Aeration occurs by direct exposure to the air when the disks leave the wastewater. (Figure 11)

Trickling Filters

A trickling filter is a bed of media, traditionally rocks, but more recently plastic grids or balls. Wastewater is applied to the top of the filter, usually by spraying from a rotating arm. The spraying adds air and a bacterial film on the media treats the wastewater. (Figure 12)

K. Special Soil Absorption Systems

In addition to conventional dispersal systems, wastewater can be pumped into the soil on a dosed basis. Dosing provides two main advantages: it allows the soil to "rest" or to not be covered by effluent part of the time which allows the system to be more aerobic, and it covers the entire field area with effluent each time a dose is applied so all the area is used to the maximum.

Low Pressure Pipe

Low pressure pipe (LPP) systems typically use plastic pipes 1 to 2 inches in diameter with orifices (small spray holes) spaced 2.5 to 7.5 feet apart. A pump delivers effluent throughout the system on a regular basis as determined by a timer or the pump tank capacity.

Drip Irrigation

In drip irrigation, treated and filtered effluent is applied through shallow, flexible small-diameter tubing. The spacing of the tubing is about 2 feet apart and the very small orifices are also spaced two feet apart. Dosing is similar to LPP. Because of the flexible tubing and the shallow depth, drip irrigation is useful where the absorption field is an odd shape or if a restrictive layer is relatively high.

L. Reasons for Failure

Time and time again, the reason for failure of wastewater treatment systems, whether onsite or central plants, is lack of maintenance. Other reasons are inadequately trained or careless operators, poor design, poor quality of equipment or construction, and changes in the flow rate or content of the wastewater that is not adjusted for by the treatment facility.

M. Factors for Success

Success can be achieved by taking the reasons for failure individually and correcting them**:**

Maintenance

Whether the treatment system is based on single-unit conventional onsite systems or central treatment plants, maintenance must be performed on a regular basis, or systems will deteriorate both in physical terms and in performance. Maintenance items can include:

System	Typical Inspection and Maintenance Items
Septic Tanks	Check sludge and scum depths (to determine need for pumping), repair or replace damaged baffles, clean or replace effluent filter, check and repair other damage or leaks
Absorption Fields	Protect from damage and traffic, alternative fields if using more than one section.
Lagoons	Remove vegetation from edges of lagoon, mow berms, check and repair erosion at edges, remove trees or shrubs shading lagoon, check and repair fence, check and repair equipment.
Pumps	Test pump cycle through full range of levels; test float controls; check pump and wiring for corrosion; clean grease or debris from floats, pump, screens, etc.
Other Mechanical Equipment	Follow Manufacturer's instructions and Designer's Operation and Maintenance Manual (When contracting for design of facilities and purchase of equipment, specify that these be supplied.) Check for corrosion, wear, or damage. Repair or replace parts as needed. Be sure that equipment is clean.

Personnel

Operators must be adequately trained to do their jobs. For the simpler onsite systems, inspections, pumping, and repairs can usually be learned by on-the-job training, assuming someone knowledgeable is there to teach it. This includes Local Environmental Protection Program or County Health Department personnel. More complex plants require trained and state-certified operators. KDHE administers the certification program and information can be obtained by calling (785) 296-5511.

Design and Construction

Before an engineer is hired and all the way through the design and construction process, the community needs to know what their goals are in terms of construction costs versus ongoing costs, simplicity versus complexity of operation, flexibility in the system, etc. These must be communicated to the engineer and the contractor and they must be monitored to be sure that the goals are being met as well as possible. Hiring a construction inspector who does not work for the contractor and who understands how a plant should be run can help in getting a system built well.

Keeping Up with Changes in Wastewater and Regulations

Being handed the key to the new plant by the contractor is not the end, but the beginning of successfully handling the community's wastewater. Among the biggest challenges in managing a small community wastewater system are staying current with changes in the community and the resulting changes in its wastewater, and learning about and responding to changes in regulatory requirements. As the population grows or declines, or if new kinds of businesses connect to the system, changes in the operation of the system may be required. Monitoring the performance of the system and keeping good records will help identify when changes are required. However, advance planning is even better. Additional water quality tests or even higher quality effluent may be required a regulatory agency. Someone needs to stay on top of these things.

Other Factors

In addition, there are other less tangible factors for success. Long-term commitment of the community to providing good quality wastewater treatment is perhaps the most important. The monetary costs must be met and personnel must be found and properly trained. These challenges will last as long as the community provides wastewater service.

Imagination and cooperation will be useful tools. If ways of sharing equipment or personnel with other agencies can be found, the community's share of the costs can be reduced. For instance, it may be possible to contract with a rural water district or a rural electric association to do the billing. Another possibility is to have a "circuit-riding" operator who can work at more than one community's wastewater system. Usually a full-time operator is not needed at each plant, so the same person can handle several plants if they are fairly close to each other. Similarly, water plant operators for a water district could also be certified as wastewater plant operators. At the least, cooperative agreements could be reached to back up other operators during emergencies or vacations.

N. Selection Criteria

The following factors need to be taken into consideration when selecting a wastewater treatment process for a community:

1. Effluent Water Quality Requirements (for Discharging Systems)
2. Flow Rate
3. Cost
4. Available Space
5. Availability of Equipment and Parts
6. Availability of Operators and Repairmen
7. Discharging vs. Non-discharging
8. Flexibility for Process Changes or Expansion
9. Preference
10. Local Topography/Geology

O. Special Considerations in Design

Flow Rates/Plant Sizing

Among the factors to be considered in selecting a method of treatment, are the flow rate (average and minimum/maximum) and the strength (chemical composition/concentration) of the wastewater. There are typical assumptions used in engineering calculations. However, small communities may have special situations, such as the type of collection system, that will require making sure these assumptions are correct for that community. If a community has businesses or industries that are large water users, or if it has an unusually high number of businesses or industries for its size, detailed flow calculations should be made to account for them.

If the collection system has a conventional gravity sewer, a factor for infiltration and inflow (I & I) must be added in. Infiltration is water that enters the collection system through loose pipe connections, broken pipes or manholes. It is usually highest after rain or snow melt. If the water table is high, it may be a continuous problem. Inflow is water from sources such as foundation and roof drains, cooling water from air conditioners, and drainage from outdoor paved areas that have been connected into the sewer system. The KDHE requirement for new gravity sewer that is less than 24 inches in diameter is a maximum infiltration of 250 gallons per day (gpd) per mile of pipe for each inch of pipe diameter. (As an example, an 8 inch diameter pipe that is 2 miles long could have a maximum infiltration rate of 8 inches x 250 gpd x 2 miles = 4,000 gpd.) Older sewers can have much higher levels of infiltration. Inflow is possible with systems having septic tanks or grinder pumps, but it would probably be more noticeable in terms of overload or failure.

A pressure sewer, in order to stay pressurized, must be constructed more tightly than a gravity sewer. Therefore, infiltration should be minimal. However, past experience with alternative collection systems indicate that I & I can still be an issue if the system is not constructed well. Sources of infiltration can include septic tanks and pump chambers that are not watertight, loose connections on the pipe between the house and the septic tank, and leaky manholes. If assumptions about reduced wastewater flow because of the use of pressure sewers are to be valid, special attention during construction and maintenance must be paid to eliminating sources of infiltration.

Strength of Wastewater

The strength of wastewater varies from home to home and with time of day. This is a challenge for onsite systems that is dealt with by making conservative assumptions for typical wastewater to be used in design. In a community situation, the wastewater streams combine and the differences level out. However, the type of collection system influences the strength. As was described above, a conventional gravity sewer will have an I & I component. A pressure sewer will have to be tighter so the infiltration will be less. A substantial portion of the organic load is removed by a septic tank, so the strength of wastewater in a STEP (Septic Tank Effluent Pump) system would be lower than total household wastewater. On the other hand, the effluent from a grinder pump system will contain all material from household's wastewater. Because it will have lower I & I, it will be stronger than the wastewater from a gravity sewer. The design of a plant will need to be checked to be sure that it can handle the organic load as well as the hydraulic load.

Denitrification

A water quality standard that may become increasingly important for wastewater plants is the nitrogen level of the effluent. The important nitrogen compound in groundwater is nitrate and the important one for surface water is ammonia. Some systems reduce nitrogen levels as part of the process such as some recirculating sand filters and some commercial aeration units. Other systems can have an additional treatment unit added to the facility to remove nitrogen. If nitrogen control may become an issue, a system should be selected that reduces nitrogen compounds or that can be easily modified to handle them.

Septic Tank Abandonment

If a decision is made to replace or abandon septic tanks, the existing tanks must be cleaned and properly abandoned, usually by breaking the bottom, and possibly the sides, and filling with compacted soil or other inert material. Other inadequate or illegal systems such as cesspools and “ratholes” must also be abandoned. In some circumstances, additional measures may be required. The costs of this procedure must be included in the project costs.

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Research Article

Impact on the Quality of Life When Living Close to a Municipal Wastewater Treatment Plant

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The objective of the study was to investigate the impact on the quality of life of people living close to a municipal wastewater treatment plant. A case control study, including 235 inhabitants living within a 500 m radius by a municipal wastewater treatment plant (cases) and 97 inhabitants living in a different area (controls), was conducted. A standardized questionnaire was self-completed by the participants which examined the general health perception and the overall life satisfaction. Also, the concentration of airborne pathogenic microorganisms in aerosol samples collected around the wastewater treatment plant was investigated. Significant risk for symptoms such as headache, unusual tiredness, and concentration difficulties was recorded and an increased possibility for respiratory and skin diseases was reported. A high rate of the cases being irritable and moody was noticed. Significantly higher gastrointestinal symptoms were also reported among the cases in relation to the controls. The prevalence of pathogenic airborne microorganisms originating from the wastewater treatment plant was reported in high numbers in sampling points close to the wastewater treatment plant. More analytical epidemiological investigations are needed to determine the cause as well as the burden of the diseases to inhabitants living surrounding the wastewater treatment plant.

1. Introduction

Air quality and its pollution (physical, chemical, and biological) significantly influences the health and good living of humans, animals, or plants inhabiting it [1, 2]. Despite the fact that the air is an unfavourable environment for microorganisms to grow, it is merely a place which temporarily occupy and move in. The air is very often called "transport environment" because microorganisms may be present and often can be transported over considerable distances [1]. Microorganisms move in the air as a consequence of wind movement, which "sweeps" them away from various habitats and surroundings (soil, water, waste, plant surfaces, animals, and other), or are introduced during the processes of sneezing, coughing, or sewage aeration [2].

Wastewater treatment plant (WTP), due to its working conditions, is considered as a major source of aerosols and may constitute an important health risk for plant workers as well as the surrounding inhabitants [2–5]. Various bacterial and fungal communities have been isolated from all types of aerobic and anaerobic WTPs [6]. Several studies have shown that bacteria contained in droplets of WTPs were 10–1000 times more than that in a water source, depending on the droplet size [3]. A number of atmospheric factors such as temperature, wind velocity, smog, and specific humidity influence the aerosol spread as well as the ability of microorganisms to survive in the air. At very low humidity and high temperature, microbes face dehydration, whereas high humidity may give cells protection against the solar radiation [3, 4, 7]. It has also been reported that UV radiation, oxygen content, specific ions, various pollutants, and air-associated factors are also responsible for the decrease of the biological activity in a WTP [7, 8].

Bioaerosols may contain different types of microorganisms such as viruses, pathogenic bacteria, and fungi, capable of causing skin, digestive system, respiratory, and nervous system diseases and human allergies [9]. Specifically, bioaerosols emitted by WTPs can impact the air quality. In the past, microbial concentrations in the surrounding air from the aeration tanks of WTPs, at different heights and different distances, have been reported [10–12].

Waste management facilities generate atmospheric emissions and liquid effluent, which may be hazardous to human health. The potential health hazards related to WTP aerosols are documented commonly for occupational exposure. Effects including respiratory and digestive symptoms have been reported in workers exposed to particulate matter and bioaerosols [9]. Similar health problems may occur in people living near such plants who may be exposed to this release. To guide the implementation of waste management policies, decision-makers need information about their potential effects on public health.

In the city of Patras, south western Greece, a municipal wastewater treatment plant receiving domestic sewage from approximately 250,000 citizens is located in a densely inhabited area. The WTP effluents flow to the Patraikos gulf through a submarine pipe delivering the treated effluents in approximately 100 m from the coastline. Within a radius of 100–500 m around the WTP, 800 to 1000 inhabitants are permanently living. In order to assess the impact on the quality of life of citizens living close to the WTP, an observational case control study, as well as a microbiological analysis of air close to the living areas, was performed. It is the first time that such an observational survey has been performed in Greece. It is one of the very few studies combining microbiological and epidemiological data in an area close to a wastewater treatment plant.

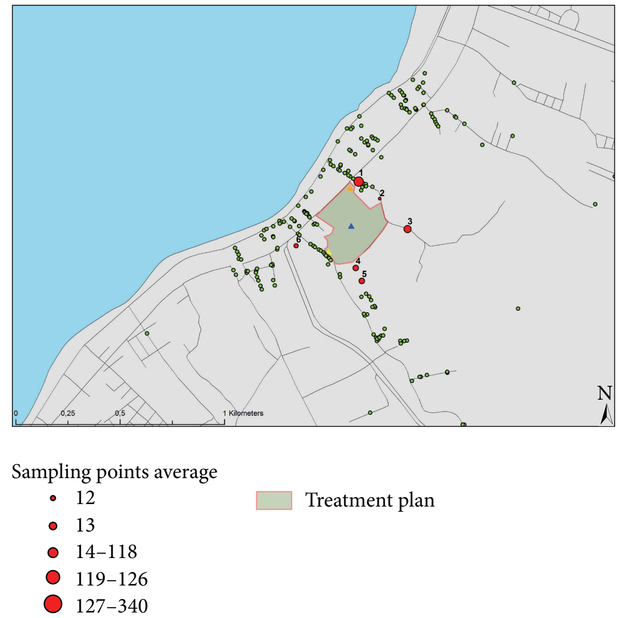

Figure 1: Microbiological sampling stations and results as well as questionnaire locations in a perimeter of a radius of 500 m.

2. Materials and Methods

The Patras' wastewater treatment plant (WTP) has a mean inflow of 45,000 m^3/d receiving municipal waste from 250,000 inhabitants. It is a secondary WTP which includes indoor pretreatment with screens and coarse bubble aerated grit clambers, outdoor primary and secondary settling tanks, outdoor chlorination, and indoor sludge processors with belt filter presses.

2.1. Study Population. The study population was comprised of inhabitants living in the surrounding area of the WTP (up to 500 m radius) considered as cases. A case included any resident, living permanently for more than eight hours per day in an area (<500 m) from the WTP. As a control was considered a resident living permanently in an area located more than 5 km from the WTP. The participants, cases and controls, were matched according their demographic, socioeconomic, ethnic, and occupational background. Inclusion criteria in the study were the permanent residency in the region, the age above 18 years, and the agreement to complete the questionnaire. Cases travelled and stayed abroad as well as individuals who were working far from their house for more than 10 hours every day or who resided in the regions for less than a year were excluded from the study (Figure 1).

2.2. Study Design. Study participants completed a structured self-administered validated questionnaire distributed at their homes [13]. Participation was on a voluntary basis. The questionnaire was divided into three parts and contained 60 questions.

The first part (23 questions) assessed baseline characteristics including sociodemographic variables such as age, sex, family status, education, occupation, place of work, socioeconomic status, life habits (tobacco and/or alcohol), and general health perception. The health status was indicated by a distinction between poor and good health. The exact wording and response option of current health question is consistent with recommendations of the WHO [14] and the EURO-REVES 2 group [15]. Participants were asked, "In general how would you describe your current health status." Those who responded "very good" "good" or "satisfying" were considered to be in good health, while those who responded "poor" or "bad" health were considered to be in poor health.

The second part (10 questions) was concerned with the medical history of participants: presence and frequency of gastrointestinal and respiratory symptoms, joint pains, and central nervous system symptoms (including headache, unusual tiredness, and concentration difficulties). Special questions were related to physician diagnosed allergy, eczema, and asthma. The grouping of symptoms was as follows: respiratory (asthma, chronic bronchitis, and chronic sinusitis), gastrointestinal (abdominal pain and bloating, nausea, vomiting, diarrhoea, constipation, and jaundice), skin (skin rash, ulcer on the skin) or systemic (headache, fever, chest pain or discomfort, muscle spasms, chills, irritability, insomnia, fatigue, weakness, and vague general discomfort or feeling of illness), allergies at last year (drugs, powder, materials, etc.), blood diseases (thalassemia, leukaemia), and musculoskeletal diseases (osteoporosis, backache).

The third part (27 questions) related to health-related quality of life and overall life satisfaction. The questions assessed the occurrence of four subjective physical and psychological health complaints, namely, being moody, irritable, bad tempered, and unhealthy.

The questionnaire has been piloted into 20 respondents before its use. Also, a test-retest system was used to assess the reproducibility of the responses, 20 subjects being required to complete a second questionnaire after one-month interval.

2.3. Air Sampling Strategy. Sampling of aerosols was performed once a week for four consecutive weeks during summer period, from 6 sampling stations in an area of 500 m radius around of the Patras' WTP. The sampling points were recorded using a GPS instrument (Magellan Explorist, Aachen, Germany). Three samplings were performed at different times of each sampling day (morning 8.30 a.m., afternoon 18:00 p.m., and night 22:00 p.m.) from each sampling station, in order to monitor the presence of microorganisms during the whole day. Microbiological investigation was carried out during ordinary workdays when biological treatment plant was normally working. Throughout the studied period, during air sampling, air temperature, relative humidity, wind direction and speed, and solar radiation were measured.

During each sampling period, an average of three readings of humidity and temperature was recorded. The temperature (expressed in °C) and the relative humidity (expressed in %) were measured with a portable instrument (Opus 10 Lufft, Germany).

Aerosol samples were collected using a sampler (International PBI Surface Air System, SAS, Italy). Petri dishes (55 mm diameter) containing 25 mL of Tryptic Soy Agar medium, (TSA Merck, Darmstadt, Germany) were placed into a special support of the sampler. The sampling flow rate was 90 L/min. A 15 min sampling time (volume of air > 1000 L) was used and samples were transported to the laboratory within 2 hours for further analysis. The air sampler was disinfected with 70% denaturized ethanol (CarloErba, Milano, Italy) after each sampling. Petri dishes were incubated at 36°C (±1°C) for 24 hours. After the incubation period, one experienced analyst enumerated bacterial colonies on each plate based on their cell morphology. Bacterial colonies were differentiated on the basis of colony morphology, Gram staining, and catalase and oxidase test. Following Gram staining, at least three characteristic and distinctive Gram negative colonies from each plate were identified using the API system (bioMerieux, Marcy I'Etoile, France). Also *Staphylococcus* spp. (ISO 6888-2:1999), *Enterococcus* spp. (ISO 7899-02:2000), and total coliforms/*Escherichia coli* (ISO 9308-1:2000) were identified. The concentration of airborne bacteria was finally expressed as colony forming units (CFU)/m^3. No major environmental problems were reported at the sampling stations during the survey period. Concentrations on a limited number of days were considered representative of the annual microbial concentrations.

2.4. Statistical Analysis. All statistical analysis was conducted with SPSS 21.0, while, for the mapping, Arc-GIS 9.2 software was applied (ESRI, USA). Data were analysed using descriptive statistics (Chi-test) and logistic regression to determine odds ratios and statistical significance. Differences in selected demographic variables, as well as smoking and health status, between the cases and the controls were evaluated by the Chi-square test. Student's t-test was used to evaluate continuous variables, including age and pack-years of cigarette smoking. Unconditional multivariate logistic regression analysis was employed to examine the association of living near the WTP and the development of health problems by estimating odds ratio (ORs) and 95% confidence intervals (95% CI).

The baseline characteristics were compared between the two study groups using the Chi-square and t-tests. Multivariate analyses, using a logistic regression model, were conducted to compare the prevalence of the investigated chronic diseases, adjusted for demographics and health-related habits. Comparisons of the questionnaire components were performed with Mann-Whitney U test, and for multivariate analysis linear regression models were computed. The independent variables for the models were demographics, health-related habits, and chronic conditions.

Nonparametric statistics were usually used to test for relationships between pathogen concentration and other factors, because total airborne bacteria (TAB) were not normally or log-normally distributed. A nonparametric Mann-Whitney test was used to determine whether there were significant differences in microorganism concentrations based on the factors evaluated in this study. Spearman's correlation analyses were used to examine the relationship between microorganism concentration and the other factors. A nonparametric Kruskal-Wallis test and analysis of variance were also performed to determine whether there were differences in microorganism concentration by sampling location and date. A P value lower than 0.05 was considered significant, for all statistical analyses. All values are expressed as mean (SD).

3. Results

3.1. Questionnaire Validation

3.1.1. Acceptability. Ten subjects (4.2%) refused to complete the questionnaire.

3.1.2. Feasibility. Three subjects (1.3%) failed to complete the questionnaire owing to poor eyesight.

The average time for completion was 15 minutes (range 10 to 20 minutes). The completion rate for the questionnaire was 90% of all questions.

3.1.3. Reproducibility. In both groups (case control) the test-retest study showed that only one answer (1.75%) was altered in one questionnaire (0.4%).

3.2. Epidemiological Survey Study. A structured questionnaire was administered to the 235 cases and 97 controls (Table 1) to obtain information on demographics, knowledge of their general health status, and determination of frequency of physical symptoms that they have experienced in the study period. All respondents were asked to give complete answers. The participants (cases and controls) self-filled in the study questionnaire and returned it anonymously indicating only the address (Figure 1).

Table 1: Demographic characteristics of the study population.

Sample characteristics	Cases (235)		Controls (97)		P value
	N	%	N	%	
Sex					0.074
Male	107	45.5	33	34	
Female	126	53.6	61	62.9	

The 86.8% of the cases were staying at home for more than 8 hours. The smoking habits of cases and controls were reported in Table 2. The 26.8% of the cases considered their healthy status as nonsatisfactory (average and bad) compared to 17.8% of the controls ($P < 0.001$). A statistically significant negative relationship ($r = -0.58$, $P < 0.001$) between cases living near the WTP and their general perception about their health status was also noted.

The incidence of allergies among the cases reached the 27.8% and most of them were allergic to dust and pollen. Questionnaires showed that 8.7% had iron deficiency anaemia and 27.5% were suffering from migraine headache. 7.2% had asthma and 12.9% gastritis. Dermatitis occurred in 9.3% and the medicine use reached 41.1%. The mood as well as the perception about their health between cases and control is shown in Table 3.

There was no increased rate of gastrointestinal disorders or myoskeletal diseases. Similarly, there were no significant increases in the rates for respiratory, allergic, and blood diseases. However, there was a significant increase in the rate of neural disorders (Table 4). The frequency of the symptoms is reported in Table 5. Almost all cases (79.6%) complained about strong odors coming from the WTP during the evening (40.4%), during the afternoon (20.8%), during the midday (10.7%), and during the morning (28.1%). Odors were more intense in spring (28%) and summer (36.4%) (Table 6). Cases emphasized problems due to the presence of the WTP as follows: odors (50.9%), air suspensions (1.1%), and different health problems (6.3%). It should be mentioned that 72.8% of the residents found the presence of the WTP indispensable, but 17.4% believed that it was dangerous for their health.

3.3. Air Microbiological Study. Forty-seven (47) measurements of temperature (°C) and humidity (%) were carried out during the sampling period (Figure 2). The mean temperature was 13.6°C varying from 7 to 20°C and the mean relative humidity was 57.3%, varying from 38% to 74%. During the evening sampling campaigns, the ambient temperature ranged from 10.8 to 14.9°C and the relative humidity was approximately 67%.

Eighty-three (83) randomly selected isolated bacterial colonies were isolated and identified. Depending on their Gram staining, the microorganisms were initially mainly characterized as cocci (79.5%), as Gram positive bacilli (7.2%), and as Gram negative bacilli (13.3%). Summarized microbiological data are shown in Table 7. Twenty-four strains (29%) were identified as *Staphylococcus aureus*, 30 (36%) as *Streptococcus* spp., 4 (4.9%) as *Enterococcus* spp., and 7 (8.5%) as *Escherichia coli*. Eighteen (21.7%) strains of bacteria could not be typed. The detected loads of airborne microorganisms at the six different sampling stations were, in general, low, but a few higher concentrations were found at the two closest sampling stations, (Locations number 1, number 3). Concentrations of airborne bacteria at each sampling station are shown in Figure 3. Among the sampling locations, Location 1 had the highest concentration of culturable airborne bacteria, with 340.89 CFU/m^3. As the distance increased from the center of the WTP, the concentration of culturable bacteria gradually decreased. Mean concentrations were found lower, while the distance from the center of the WTP was increased more than 800 m. None of the collected air samples was found positive for *Salmonella* spp.

Triplicate samples of bacteria (*Streptococcus* spp., *Enterococcus* spp.) were collected at each sampling time. The airborne microbial concentrations (CFU/m^3) corresponding to the three campaigns in all locations are summarized in Figure 4. The average microbial load per sampling location per day (CFU/m^3) is shown in Figure 5, respectively.

4. Discussion

In the present study, the impact on the quality of life of inhabitants living close to a WTP as well as the evaluation of the air microbiological quality was reported.

Air microbiological analyses have commonly been conducted close to sewage treatment plants [3]. Sawyer et al. [12] measured concentrations of 126–4840 bacterial CFU/m^3 at different heights above the water surface of the aeration tank of wastewater treatment plants. Brenner et al. [10] recorded concentrations of 86–7143 bacterial CFU/m^3 air at a distance of 25 m from the surface of an aeration basin well. Another study showed that the air densities of total aerobic bacteria-containing particles, total coliforms, faecal coliforms, faecal streptococci, total count bacteria, and coliphages increased significantly within the perimeter of the plant during operation of the wastewater treatment plants [11]. Other studies have shown that a percentage of the emitted bacterial contamination can be transported over considerable distances [10]. In our study the highest microbial numbers have been reported in the locations close to the WTP.

In order to evaluate the results of the air microbiological analyses, it should be considered that the recorded microbial loads represent only a "picture" of the sampling time. In connection, with the physicochemical properties of the air, the degree of contamination at a given point can significantly change within a few minutes [16]. An important issue of the study was the season in which the study was performed, which is known to play a significant role in the dispersion of aerosols and odors in the air, as well as microbes, especially during specific seasons of the year. Complaints related to the odors were increased during the summer months and especially during early the morning or evening, when the percentage of humidity was higher at the sampling stations. It is suggested that the seasonal variations of bacterial loads might be related to the contingent meteorological conditions

Table 2: Comparison between cases and controls concerning smoking habits.

Sample characteristics	Cases (235)		Controls (97)		OR	CI	*P* value
	N	%	*N*	%			
Smoker	111	47.2	31	32	1.849	1.120–3.052	**0.015**
Previous smoker	31	13.2	24	24.7	0.707	0.372–1.345	0.290
Years of smoking							**0.001**
<5 years	5	2.1	9	9.3			
5–10 years	29	12.3	13	13.4			
>10 years	97	41.3	23	23.7			
Quantity of cigarettes							0.502
<10 cig.	26	11.1	11	11.3			
10–20 cig.	74	31.5	19	19.3			
>20 cig.	32	13.6	11	11.3			

Table 3: Frequency of feelings from the inhabitants close to the WTP, compared to the controls.

Sample characteristics	Cases (235)		Controls (97)		*P* value
	N	%	*N*	%	
Mood	126	53.6	60	63.8	0.058
Freq. of having bad mood (>2/week)	54	42.9	17	28.4	**<0.05**
Angry	135	57.4	52	58.4	0.873
Freq. of being angry (>2/week)	64	47.4	19	36.6	**0.05**
Tired	154	65.5	67	70.5	0.382
Freq. of being tired (>2/week)	91	59.1	37	57.2	0.904
Sick	36	15.3	19	21.1	0.213
Freq. of being sick (>2/week)	24	68.6	4	22.3	**0.001**

Table 4: Health symptoms associated with the distance living of WTP.

Symptoms/diseases	Cases (235)		Controls (97)		OR	CI	*P* value
	N	%	*N*	%			
Blood	29	12.3	10	10.3	1.37	0.56–3.38	0.601
Neural	102	43.4	18	18.6	4.06	1.82–9.04	**0.001**
Respiratory	39	16.6	21	21.6	0.82	0.34–1.96	0.276
Gastrointestinal	55	23.4	28	28.9	1.07	0.52–2.23	0.296
Skin	29	12.3	13	13.4	0.910	0.45–1.83	0.791
Myoskeletal	66	28.1	16	16.5	1.52	0.69–3.41	**0.026**
Allergies	65	27.8	37	43	0.77	0.38–1.57	**0.009**

Table 5: Frequency of symptoms and medical consultation.

Sample characteristics	Cases (235)		Controls (97)		*P* value
	N	%	*N*	%	
Freq. of gastrointestinal symptoms (>1/6 months)	38	16.2	31	36.1	**0.001**
Medical consultation	21	13.3	13	24.1	0.062
Freq. of respiratory symptoms (>1/6 months)	45	19.2	23	28.4	0.145
Medical consultation	40	25	22	42.3	**0.017**
Freq. of allergy symptoms (>1/6 months)	59	25.6	17	21.3	0.751
Medical consultation	50	31.4	10	25.6	0.480

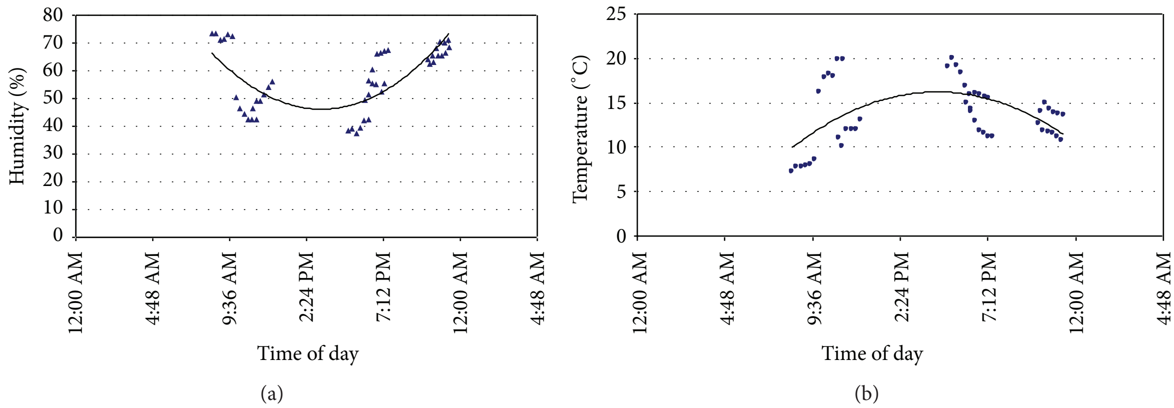

Figure 2: Measurements of humidity (a) and air temperature (b) during the study period.

Table 6: Odors existence and frequency of occurrence (235 cases).

Odors existence	**187**	**79.6%**
Frequency of odors (>3 times/month)	145	61.7%
Odors daily timetable		
Early hours	92	28.1%
Midday hours	35	10.7%
Afternoon hours	68	20.8%
Evening hours	132	40.4%
Odors yearly timetable		
Spring	135	28%
Summer	176	36.4%
Autumn	86	17.8%
Winter	86	17.8%

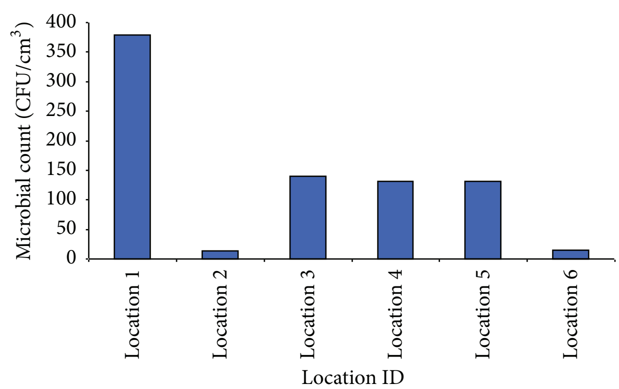

Figure 3: Average microbial count per sampling location (CFU/m^3).

Table 7: Types of identified bacteria.

Microorganisms	Isolated bacteria
Staphylococcus aureus	24 (28.92%)
Streptococcus spp.	30 (36.14%)
Enterococcus spp.	4 (4.82%)
Escherichiacoli	7 (8.43%)

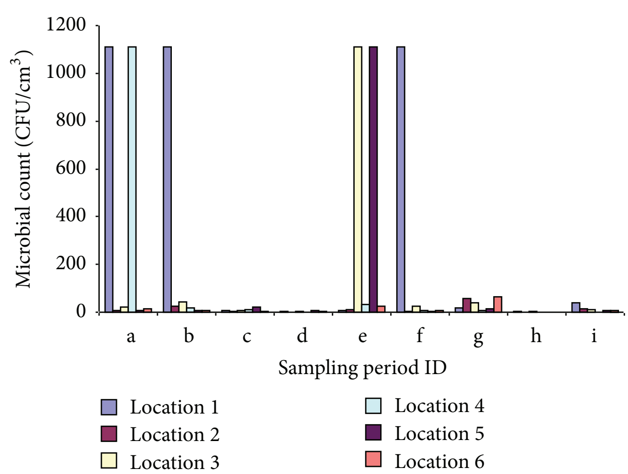

Figure 4: Average microbial count per sampling station (location) and sampling period (CFU/m^3).

(humidity, temperature) and to the intrinsic sensitiveness of different bacteria genera to these factors [17].

Some WTPs produce higher concentrations of bioaerosols compared to others. In previous studies, using personal samplers, it was shown that sewage treatment plant employees that have a higher incidence of headache, tiredness, and nausea were exposed to culturable bacteria. Exposure to rod-shaped bacteria and total number of bacteria was significantly higher in workers reporting headache during work than in workers not reporting headache [11].

A few studies have shown that blood tests of workers who were subjected to aerosol inhalation indicated an increased level of antibodies against Gram negative bacteria and intestinal viruses. The condition has been described as "the sewage worker's syndrome," which has a viral origin and manifests itself with a despondency, overall weakness, catarrh, and fever [11, 18]. Main characteristics of the disease included general malaise, weakness, acute rhinitis, and fever [19], accompanied by gastrointestinal symptoms. In accordance with these studies, we recorded increased odds for the inhabitants who lived near the WTP to develop neurological and myoskeletal

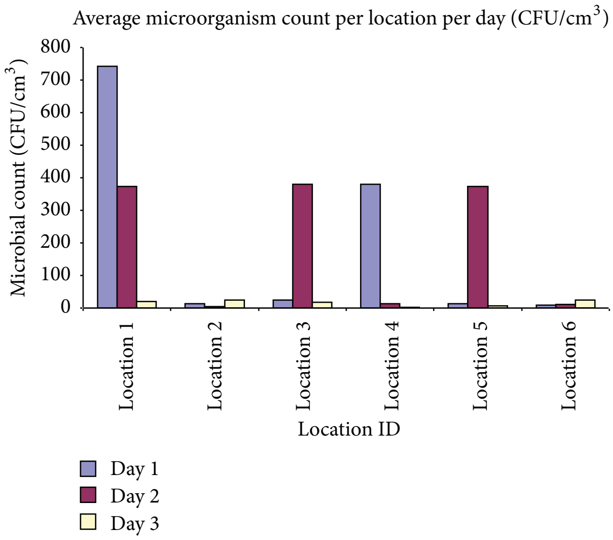

FIGURE 5: Average microbial count per sampling station (location) and sampling period (CFU/m^3).

symptoms at 3.37 and 1.98 times, respectively. Moreover, sewage workers and those who live in the vicinity of a WTP have higher morbidity with intestinal and respiratory system illnesses [11, 20]. In order to ensure public health, health of workers, and good quality of life, it is necessary to determine the composition and concentration of microorganisms in the air. Skin contact, ingestion, and inhalation are the three major routes of exposure to airborne particles [20]. Microorganisms that are associated with intestinal infections such as *Salmonella* spp. and enteric viruses are thought to be transmitted through inhalation [4, 21].

Also, a nationwide survey in Sweden showed that an increased risk for headache, concentration difficulties, unusual tiredness, and head heaviness was reported in workers compared to the controls [18]. Similarly, in our study, feelings like tiredness and sickness were more reported by the cases compared to the controls. Interestingly, our study showed an increased rate in mental disorders to the population living near the WTP. There was no significant correlation of the WTP and the occurrence of gastrointestinal or myoskeletal symptoms to the residents. Also, this study showed no significant correlation concerning gastrointestinal, allergic, and respiratory symptoms although the study sample of the controls was rather small due to the refusal of controls (people in the city) to participate in the study.

In our study, there is a significant presence of possible pathogenic microorganisms in the aerosols close to WTP and this concentration depended on the distance. There is indication of the burden of microorganisms in air according to the distance of the inhabitants. To establish aerosols impact on the human health, more extensive studies are needed including medical examinations in inhabitants. Such studies have not been performed to the area of the WTP.

In order to lower the impact for public health, in areas like this, retaliatory preventive measures should be taken by the authorities in order to protect inhabitant's health. Such measures could be considered the tree growing around the WTP as well as the appropriate function of the WTP with protective equipment for the aerosols.

Competing Interests

The authors declare that they have no competing interests.

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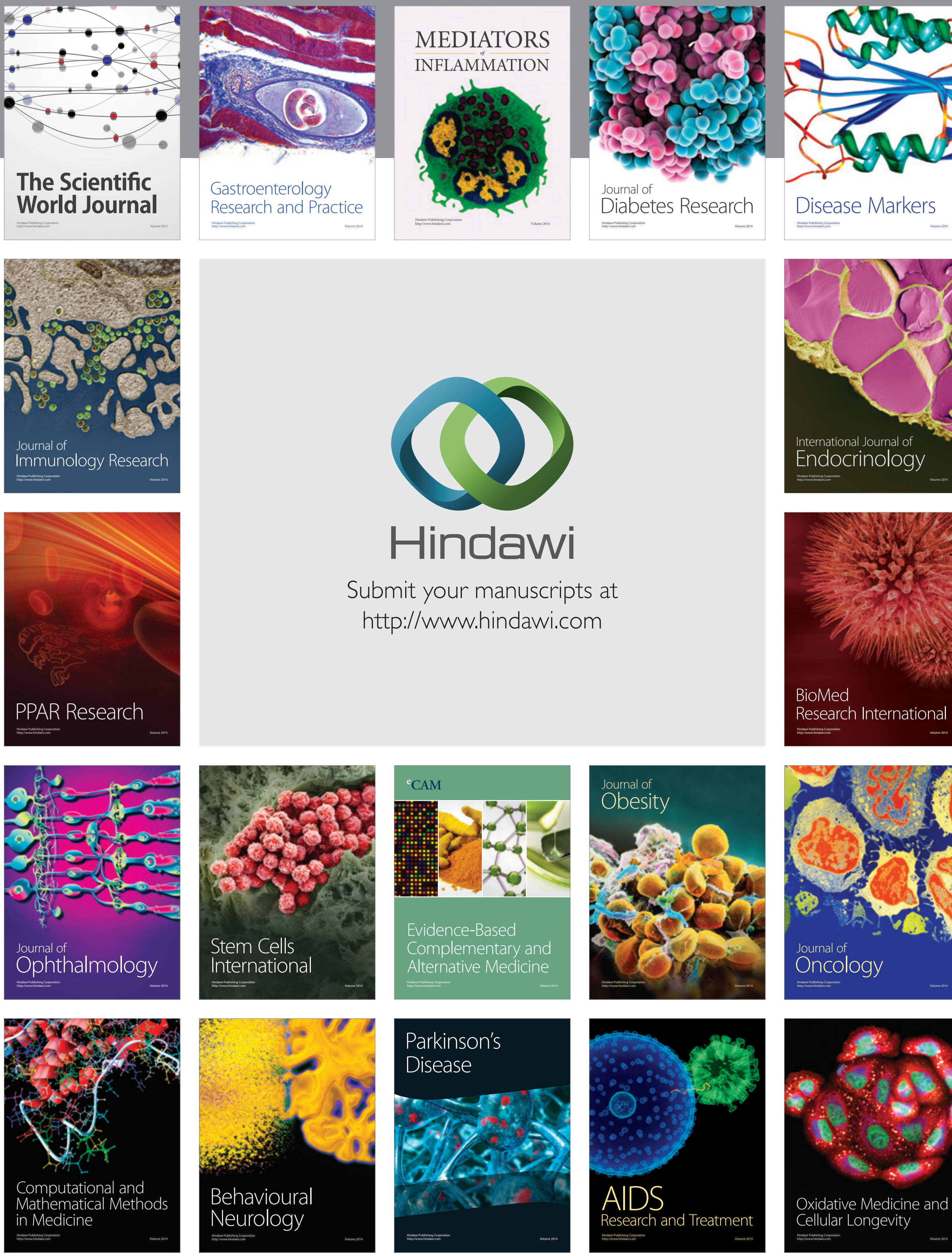
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RECLAIMED WATER TEEMING WITH PARASITES

By Kevin Spear and Sentinel Staff Writer

Orlando Sentinel

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September 16, 2002

More than 100,000 lawns and 400 golf courses in Florida are irrigated with treated sewage, a practice the state endorses as a way to reduce lake pollution and conserve drinking water.

It may also spread potent germs through sprinklers. Kids play in recycled sewage, golfers walk through it and landscapers are doused by it.

For two years, state regulators have required sewer utilities to test for the parasites giardia and cryptosporidium. Both bugs, which can cause illness and death, were found in high levels.

Florida's Department of Environmental Protection hopes that research by a California utility will show that sewage treatment renders the microscopic parasites unable to infect people.

But clean-water advocates are worried by Florida's inaction.

"The state is going blindly forward not accounting for the risk," said Suzi Ruhl, director of the Legal Environmental Assistance Foundation, or LEAF, in Tallahassee. "There will be an outbreak, and it won't be pleasant."

An outbreak did occur in 1996 in the Clay County development of Eagle Harbor, where more than 60 residents were infected by either giardia or cryptospirodium. Health authorities never proved the source, but suspected recycled sewage.

Single cases of infection also are common, though disease specialists don't often determine the cause.

Last year, 88 people were sickened by cryptosporidium and 1,124 by giardia, according to state records.

"You can't do a whole lot with the individual cases," said state epidemiologist Steven Wiersma, who said the germs also show up in such places as diaper-changing areas at day-care centers, and in swimming pools.

There are no limits for cryptosporidium and giardia in treated sewage used to water lawns and landscaping in many of the state's cities and most of Central Florida communities. Instead, utilities must test the reclaimed water for a relatively harmless type of bacteria found in human waste. If the tests show that a sewage plant is removing that bug, then other germs are thought to be stripped away as well.

While state regulators warn against drinking recycled sewage, which is clear and has little or no odor, they say it safe for kids running through sprinklers.

UTILITIES NOT REQUIRED TO ACT

But since the late 1990s, DEP officials have suspected that treatment plants are not getting rid of giardia and cryptosporidium. That was confirmed after the environmental agency began receiving test results from utilities. The agency has been sending warning letters to utilities that have detected giardia at levels of more than five cysts in 100 liters of treated sewage and more than five cryptosporidium oocysts, which are similar to cysts, in 100 liters. State authorities said the letters are meant to increase awareness and don't require any response.

From among utilities in Central Florida, tests detected 2,786 giardia cysts at a Winter Springs plant, 197 oocysts of crytospirodium at a Kissimmee plant and a Palm Bay plant reported 663 giardia cysts.

Researchers say people can become seriously ill after ingesting just one cyst. But DEP's expert for recycling treated sewage said there may be no reason for concern.

"There is simply no documentation of any disease," said DEP's David York in Tallahassee. "So as to where we go, we really don't know at this point."

York also expects research at the County Sanitation Districts of Los Angeles to show that giardia and crytosporidium are reduced to microscopic corpses by sewage treatment plants.

"The little critters that make it through are simply not capable of causing infection," York said.

'THEY ARE MOSTLY DEAD'

Margie Nellor, president of the WateReuse Association and assistant head of technical services at the Los Angeles utility, said ongoing studies by her agency found that the germs are pummeled but not obliterated by sewage treatment.

"The sewer system beats up on them," Nellor said. "You can still see the cysts but they are mostly dead."

For now, Florida officials are waiting to review the California study and other researchers' work.

The state's zeal to promote irrigation with treated sewage has downplayed any sense of risk, said Joan Rose, a critic of the Florida's regulations.

"It gives the people the impression it's just like drinking water," said Rose, a University of South Florida professor who studies waterborne diseases. "I think people should avoid exposure."

Ruhl and Rose also say the state is misguided in claiming that recycled sewage is safe because it has never been blamed for making people sick. Health officials simply don't do a good job of tracking reports of infections by either bug, they said.

While state regulators and clean-water advocates debate the risk of recycled sewage, a retired plumber in South Florida has devoted much of his free time to campaigning for more stringent regulations.

"They are just not telling the truth about this water," said Carl Jacobs, 75, of Boca Raton, who became concerned several years ago after finding that a food vendor at an art festival had accidentally tapped into a pipe containing recycled sewage.

Jacobs has urged local and state health authorities to require utilities to better inform customers about the risks.

"Children should not be allowed to play in this water," he said.

PERCEPTION OF SAFETY

Many people in Central Florida say they know little about recycled sewage but believe that it must be relatively safe because it comes from a public utility.

"I had always heard that it was about two steps away from being drinking water," said Chad Helenthal, 26, a resident of Winter Springs, where 1,600 homes irrigate with recycled sewage.

At various spots in front yards are plastic lids that cover the buried connection between a utility pipeline and home irrigation plumbing.

The lids are often imprinted with "Reclaimed water, do not drink." Some have additional warnings in Spanish: "Do not drink water, contaminated."

Winter Springs resident Bill Maddox, who has four young children and owns a landscaping company, is aware that treated sewage is not for drinking.

But he has never worried about his children setting up sprinklers to spray themselves while they jump on a trampoline. He also said landscapers who fix irrigation sprinklers often get soaked by recycled sewage.

"And they probably don't wash their hands before they eat lunch," Maddox said.

NEWS

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