SUBSURFACE DRIP DISPERSAL OF EFFLUENT ON STEEP SLOPES

by

Mark Kahl, PE

President, All Inclusive Water/Wastewater Solutions, Inc.

Environmental Impact contributed by Kathryn Picoulin, ND, PhD

Background

The treatment and disposal of sewage has evolved considerably since the early 1900's. As populations grew the methods of disposing treated sewage were frequently redesigned. Engineers had to evaluate and adjust to local conditions, climate, rolling steep terrain and the availability of funds.

Municipalities built in the earlier part of the 20th century were designed according to a different set of codes and regulations than the new treatment plants being built today. The trials and errors of yesterday in the wastewater business created new technologies that are being used successfully today.

Unfortunately though, most of the older cities all around the US still use the combined sewer systems that are prone to overflow. Much of the pipe inventory and equipment dates back to before World War II and is well past their expected life span in systems of out dated codes.

During heavy rainfall months combined sewers lack adequate collection capacity forcing the combined output of stormwater and sewage to bypass treatment plants and overflow untreated sewage into our waterways and environment while exposing human heath to contaminants. These overflows are not subject to secondary treatment requirements. (1)

Combined sewer overflows are responsible for an estimated 1.3 trillion gallons of raw sewage being released into our communities every year. In Indianapolis alone more than one billion gallons of untreated sewage is released into the environment every year. A single sewer system in Hamilton County, Ohio releases an estimated 75 million gallons of untreated sewage into Mill Creek every year. (2)

Excess wastewater is released into Muddy Creek, which winds through western Cincinnati, during a rainstorm, exposing the local inhabitants to disease causing microorganisms and toxic contaminants.

Combined sewer systems were effective in the earlier days. But today with growing populations, increased industrial toxic waste and disease causing pathogens, combined sewer systems are totally inadequate to treat sewage enough to protect humans or the environment.

The newer treatment systems being designed include three steps called primary, secondary and tertiary treatment. It is believed that by the time the effluent completes the tertiary stage and is disinfected chemically or physically the final effluent can be discharged into a river, lake, stream, bay, wetland or even used to irrigate a golf course or a park.

In Florida alone 419 golf courses used reclaimed water for irrigation in 2001. Reclaimed water is used in California, Nevada, Arizona, Texas and Hawaii as well as 17 other states. Reclaimed water is also being used in farming, city parks, school playgrounds, sporting fields, fire protection, street cleaning, apartment landscaping, construction projects, etc. In some areas over 4.6 million gallons of reclaimed water is used. (3)

Cities using reclaimed water are beginning to conduct additional tests on their reclaimed water for heavy metals, phosphorous, volatile organics, nitrogen, priority pollutants, pharmaceuticals, pathogens and viruses.

Regulations for reclaimed water require taking samples prior to discharge into the reuse system or holding ponds. However, the re-growth of microorganisms can be predictable since there are no requirements to maintain chlorine residual within the reclaimed water storage and distribution system. Reclaimed water is usually stored in golf course lakes, ponds, lagoons and uncovered tanks allowing potential for post treatment contamination. Chloramines often used as disinfectants are ineffective against contaminants introduced after the treatment process. (5)

According to the American Water Works Association using reclaimed water is becoming a health hazard. Even California is taking a similar stance. (6)

The Whittier Narrows Reclamation plant in Southern California uses a primary, secondary and tertiary treatment method and uses its reclaimed water as groundwater recharge or irrigation for a nearby nursery. The reclaimed water is considered clean enough to drink, yet county officials have detected the residues of prescription drugs.

New technology has been detecting minute doses of chemicals in reclaimed water making its way into California streams and the environment. In spite of rigorous cleansing at certain reclamation tertiary plants, small concentrations of certain pain relieving drugs, antidepressants, estrogens, anti-anxiety and anti-seizure medications were detected along with large levels of some antibiotics and cholesterol lowering drugs. (7)

Water quality officials have been finding that even the most sophisticated wastewater treatment plants are unable to neutralize these chemicals. There are no regulations that require agencies to look or test for them. Many cities using reclaimed water post signs on properties using reclaimed water banning citizens from its use.

However, pharmaceutical residues are not the only concern with wastewater discharges into the environment. If wastewater is to be reused, the design standard must include removal of heavy metals, pharmaceuticals, volatile organic compounds (VOC'S) and volatile toxic organic compounds (VTOC's), pathogenic microorganisms, phosphorus and nitrogen and substances that are carcinogenic, tetragenic and mutagenic that are resistant to typical wastewater treatment processes.

More than half a million synthetic organic compounds have been manufactured since the early 19th century. Every year more than 10,000 new compounds are added.

The release of volatile toxic organic compounds (VTOC) from just California's municipal wastewater treatment plants has been estimated to be as high as 1390 tons per year. And the numbers keep growing. The number of industries that discharge their waste into domestic sewers has increased dramatically in the last several decades. (8)

In 1995 according to the EPA more than 35,000 "significant industrial users" discharged their waste into wastewater treatment plants owned and operated by municipalities and local sewers.

The discharge of VOC and VTOC into the environment with inadequate neutralization of these substances in treatment plants is becoming a great concern to regulatory agencies in meeting the requirements of the clean water act and its amendments.

Further challenges exist. Epidemics of waterborne illnesses develop from being exposed to contaminated water especially among immune-compromised and aging populations. The EPA has estimated that over one million waterborne illnesses occur every year due to drinking water from improperly treated ground water in the United States alone. The annual cost of gastrointestinal illness in the US is estimated at $9500 million.

Studies have shown that every gram of fecal material from an infectious hepatitis patient can contain up to 100,000 infectious doses. Other pathogenic organisms from infected human fecal matter are cholera, typhoid, polio, cryptosporidium, giardia, neospora, e.coli, strep, legionella, salmonella, shigella, vibrio, adenoviruses, Norwalk, rotavirus, amoeba, whipworm, tapeworms, flukes, pinworms, roundworms, klebsiella, clostridium, pseudomonas and mycobacterium tuberculosis. Most of these are never looked for in a routine analysis.

There are more than 150 known pathogens detected in untreated wastewater. Every year new ones are being discovered. Of the 72 enteroviruses many will trigger illnesses that are not gastrointestinal, such as, polio, meningitis, diabetes, muscle diseases and endocarditis (inflammation of the heart muscle that can lead to heart attacks). They can and do produce infectious illnesses in humans that multiply and are re-excreted through fecal material. (9)

Viruses are the smallest of all the infectious agents. Exposure to a low dose of a virus is enough to cause illness. Viruses are difficult to measure using conventional laboratory techniques and the cost is prohibitive. A laboratory would take 14 days to determine the presence of a virus and another 14 days to identify it.

Primary and secondary wastewater treatments are ineffective against viruses. Most tertiary wastewater treatments that involve flocculation, sedimentation, filtration and disinfection can remove most viruses. However, viruses tend to be resistant to standard disinfection.

Most wastewater treatment systems check for fecal coliform once a month as an indicator for fecal contamination. However, viruses and protozoan parasites such as giardia and cryptosporidium are often found even with a negative coliform reading. Other microorganisms have also been detected in effluent samples that have gone through the disinfection process for release as reclaimed water.

When reclaimed water was tested for microorganisms total coliform were found in 63% of reclaimed water samples tested. Fecal coliform and enterococci were found in 27% of the samples, clostridium perfingens in 61% of the samples, F-specific coliphages were found in 40% of the samples, enteric viruses in 31% of the samples, cryptosporidium oocysts in 70% and giardia cysts were detected in 80%, of reclaimed water samples. Not many studies on the variety of microorganisms found in this type of water are done. Many pathogens, including the legionella, are known to be more resistant to chlorine than are coliform bacteria. (10)

Each pathogen is able to exist outside the host for certain periods of time. The more aqueous the environment that it is released into, the longer their survival.

Many viruses can survive in wastewater up to 41 days at 20 degrees centigrade. Once released into the environment they can survive up to 6 or more days in a river and up to 100 days in soil. The protozoa parasite can survive up to 20 days in soil while bacteria can survive up to 120 days. Most worms like the ascaris, tapeworms and trichuris can survive up to twelve months in soil. Their survival in soil depends on moisture, pH, temperature, type of soil and the presence of organic matter. (11)

Aside from actually ingesting reclaimed water, aerosol droplets that are created from spray irrigation while walking or running though newly sprayed lawns or golf courses, playgrounds or sporting fields are inhaled. Some viruses have been detected in ground water 27.5m below an area that was being irrigated with reclaimed water.

As can be seen by research sprayed effluent carries significant liabilities. The liabilities of microorganism exposure by students in ponded wastewater are becoming a real concern by Administrators and School Boards.

The ongoing problem of discharging treated wastewater has triggered important modifications to be tested and implemented. Research is clear that the current disinfection process with combined chlorine is not adequate for viral disinfection.

One solution is soil dispersal using subsurface drip technology.

Subsurface Drip Dispersal

Safer ways to release treated wastewater continue to be developed. One such method is the sub surface dispersal of treated effluent. This would significantly minimize human health risk by eliminating the potential of human contact. In addition to the health benefits the environmental benefits include recharging the aquifer, elimination of phosphate run-off and the reuse of nitrogen. The eutrophication of rivers and waterways due to run-off of phosphates with surface soil during rain events is developing into a serious problem.

Subsurface drip wastewater treatment designs have taken into consideration soil quality, available space, weather, storm runoff, wind, steep slopes, high water tables, flood potential, deep percolation, excessive nitrates, vandalisms, breakdown of equipment, roots and plugged drip lines.

However, wastewater technology using traditional soil dispersal techniques has to deal with the drawback of gravity flow to drain fields, uneven distribution, and the potential of pooling wet spots, especially in rainy weather.

Porous and perforated pipe products are not uniform in their application and eventually suffer reduction in flow, most severe in downstream ends of the line. Extra water must then be applied to compensate the lack of uniformity. Some porous pipe products can recover up to only 75% of its original flow with high pressure flush treatments.

Other problems exist with traditional products. Treated water tends to exit from the earliest holes in the system. This causes a buildup of suspended solids that can precipitate out and cause an accumulation of bacterial overgrowth near the entrance. Bacterial slime also often develops on the lines.

Plus, water quality of the treated effluent being released into the environment would depend greatly on the effectiveness of soil percolation and how the treated effluent is deposited into the soil. The soil is a great ally with the potential to consume a great amount of nitrates and carbon which is useful in the wastewater environment. Even more importantly, soil filtration is effective in binding viruses.

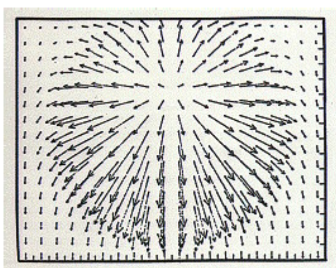
Subsurface drip lines can overcome many limitations of releasing reclaimed water especially in soil with slow permeability. They can also decrease the saturation point in soil preventing deep percolation. They are effective in areas with high water tables and steep slopes.

Steep slopes, historically have been considered environmentally sensitive areas that are easily affected by erosion, stormwater runoff and landslide potential. Erosion develops when steep slopes have been left bare following cultivation. The bare soil is then washed or blown away due to weather.

However, technology developed within the last few decades addresses the negative drawbacks of using drip lines. This has allowed wastewater treatment systems the opportunity to improve the treated effluent that is being released into the environment and prevent the hazards of human contact, while still benefiting from the use of reclaimed water.

Trials performed at the Center for Irrigation Technology on the use of GEOFLOW™ subsurface drip lines, as well as a few others, were documented in the CIT's ***"Research Report".*** Researchers found that subsurface drip lines with emitters impregnated with an herbicide were effective against root intrusion. The inner lining of these drip lines also contained tributyl tin maleate, an antimicrobial with low migratory properties that has been shown to be effective in preventing the buildup off slime even with a BOD as high as 900mg/l. (13)

The use of pressure compensatory emitters ensures that all areas of the drip lines are loaded evenly resulting in uniform distribution. This slow dispersal rate allows for the best absorption time of the soil, avoiding soil saturation with surface contamination and deep percolation into ground water. The water and nutrients are then evenly distributed to the active root zone.



The emitters disperse treated effluent up to 1.5 gallons per hour via capillary action moving vertically and laterally.

Observations

Upon evaluating areas using these subsurface drip lines on steep slopes, this researcher looked at Tenaya Lodge and the Yosemite West Wastewater Treatment Facilities. The Yosemite West Subdivision Wastewater Treatment Plant is owned and operated by Mariposa County. The treatment plant provides wastewater treatment for 110 developed lots. The proposed build-out for the area is 294 lots. The Wastewater Treatment Plant is located in steep terrain with an elevation of approximately 5,000 feet above mean sea level. Up to five feet of snow typically sit on the ground at the Wastewater Treatment Plant during winter months. According to the original Regional Water Quality Control Board approval, the treatment plant was designed to accommodate 100,000gpd of wastewater for all 294 lots.

Winter inspection of the Wastewater Treatment Facility is difficult due to the steep terrain and snow causing inspections to lapse till snow melt in spring. In April of 1997 an inspection of the treatment system revealed leach line failure that resulted in effluent surfacing and flowing down the slope towards Indian Creek, a tributary of the Merced River. Further investigations revealed that staff inspections in late spring have consistently revealed leachline failure resulting in effluent surfacing and flowing down slopes.

The county reported that the inflow and infiltration associated with the snow melt increased flows by 85,000 gpd through the wastewater system indicating that the collection system of the treatment plant was incapable of treating and dispersing the anticipated 100,000 gallons of wastewater per day even for the 110 developed lots. Officials passed ordinances that halted the build-out of the additional projected 184 lots and barred any new sewer hook-ups.

Instead of rebuilding the sewer treatment and effluent disposal system, officials chose to shut down the original leach field except for emergency back up and dispose of effluent via a new system of underground drip emitters. This would prevent any effluent from reaching the surface or Indian Creek.

The Regional Water Quality Control Board mandated the Yosemite West owners to upgrade within four phases. The final phase was to provide seven acres of subsurface drip disposal. Two and a half acres were placed on existing terraces and 4.5 acres were installed on steep slopes ranging from 40 to 60 % gradient. To install sub surface drip lines around large redwoods, forty laborers in three crews hand dug and installed the lines and boxes. Site inspection in October 2006 revealed no surfacing and no overland flows.

Geoflow Installation lines at Yosemite West

Tubing was placed under at least 8 inches of soil. Waste water can then be dispersed underground to root zones. The ground needs to absorb the pathogens that are still viable. This depth allows most pollutants such as nitrates that are not digested by the soil microorganisms to fertilize the surrounding vegetation.

Vacuum breakers are used to prevent dirt from being sucked back into the drip line. Pressure is maintained in the drip lines with pressure compensating emitters. To help equalize pressure in the system, the ends of the drip lines are connected together into a common flushing line. This also helps to keep the system clean.*

Tenaya Lodge is a full service resort at Yosemite, 2 miles from Yosemite National Park south gate and sits on 35 acres that borders the Sierra National Forest. It accommodates 244 guest rooms and suites, three restaurants and a deli. It offers conference facilities, day spa and fitness center.

The Yosemite National Park areas bring in more than four million visitors per year. To accommodate hotel occupancy growth, expansion of effluent disposal fields became necessary. This new field expansion using the GEOFLOW™ subsurface drip lines allowed for the disposal of a total peak day capacity of 103,200 gpd treated wastewater. The disposal area had steep slope gradients of up to 50%. The soils consisted of sands, silts and clay that overlaid granite bedrock at depths of 4.5 feet to greater than 14 feet below ground surface. The average annual precipitation in the area is approximately 32 inches with an average annual evaporation approximately 40 inches.

**Although Geoflow is typically designed for 2 feet of separation, manual digging of trenches around the trees required 3 feet of separation.*

A 250 foot setback is maintained for the sub surface drip line system from on site wells that supply potable water into the lodge. The quality of the two groundwater monitoring wells down gradient of the leach fields were tested and appeared to be stable and unaffected by the leach field operation.

After installing the effluent disposal field the surface area was replanted with native ferns and grasses. Erosion control techniques are required after construction of the dispersal field for a minimum of one winter to allow a natural habitat to develop.

Site inspection in October 2006 revealed no surfacing and no overland flows with an abundance of vegetation proliferating over the drip line area. Under winter snow conditions, the ferns and grasses along with the snow act as insulators to the dispersal area.

According to the Plant Operator the treated effluent disposal system accommodates all flows directed from the wastewater treatment plant.

The planting of vegetation over the sub surface drip lines especially on slopes benefits the effluent disposal system in many ways. Vegetative growth helps to create a stable environment and prevent erosion by helping the capture of sediment and loose soil. It also encourages water holding capacity on the top layer of soil, limiting runoff and decreasing the potential for landslides. It is essential for evapotranspiration of soil moisture.

Increased organic plant matter in the soil from biological activity improves soil conditions for plant growth, provides continual food and moisture for plant life and adds pore space for pathogen destruction. The air in soil is rich in carbon dioxide which is vital for the photosynthesis of plants. Plant roots take up water limiting what can reach groundwater.

Tenaya Lodge with vegetative growth over drip lines

Conclusion

Combined sewers are significantly damaging our lakes, rivers and waterways and exposing humans to disease causing microorganisms. Furthermore, the liabilities of using inadequately tested reclaimed water on our golf courses, sporting fields and playgrounds is a time bomb about to explode.

Answers exist, however, installing new systems or upgrading the existing combined sewers is costly. Implementing additional testing of microorganisms other than coliform is also costly. Many municipalities are faced with financial restraints to even consider these needed improvements. But, lawsuits ready to emerge will be far more costly.

Relying on the effectiveness of each wastewater treatment system to neutralize all microorganisms, pharmaceuticals and toxic organic compounds enough to claim the treated effluent is as clean as water may be premature. More safeguards must be in place.

Subsurface drip dispersal can be a solution to many wastewater challenges. Reclaimed water can continue to be used for landscapes, sporting fields, playgrounds and golf courses without exposing humans to pharmaceuticals, volatile toxic organic compounds or microorganisms. Many are already using subsurface drip treated effluent disposal successfully, such as the landscaping around the Brigham Young University in Hawaii, the rugby field in Laie, Hawaii, the sugar cane and pineapple fields in Hawaii, the Holoholokai Beach Park in Hawaii, Regional Harris Reserve, Scotchman's Run Reserve and City of Ocala Airport to name a few.

Being able to use steep slopes to lay the subsurface drip dispersal system is even more desirable and advantageous for many reasons. Steep slopes have increased runoff during inclement weather preventing any significant amount of stormwater to infiltrate the surface of the soil thus preventing puddles or pools of water to accumulate which would extend microorganism lifespan.

Steep slopes are not in flood hazard pathways and the wastewater release is no where near human recreational or community access areas. Environmental disturbance is limited.

A well designed wastewater treatment system using subsurface drip dispersal as a continuum to the wastewater treatment system provides a valuable solution to the challenges that face many municipalities and reclamation plants today.

REFERENCES

1. Tibbetts, John, *Combined Sewer System: Down, Dirty And Out of Date*, Environmental Health Perspectives, July 2005.
2. NRDC, *Sewage Pollution Threatens Public Health*, Natural Resources Defense Council, 2004.
3. Aertgeerts, R and Angelakis, A, Eds. *State of the Art Report Health Risks in Aquifer Recharge Using Reclaimed Water,* World Health Organization, 2003.
4. State of California Health and Welfare Agency, Department of Health Services, Public Water Supply Branch, *Guidance Manual for Cross Connection Control Programs*, p. V-16, 1988.
5. Snead, M. C., V. P. Olivieri, K. Kawate, and C. W. Kruse, *The effectiveness of chlorine residuals in inactivation of bacteria and viruses introduced by post-treatment contamination*, Water Research 14, 403-408, 1980.
6. Crook, J., (1990, July) *Water reuse in California*, Journal AWWA.
7. Cone, Maria, *Traces of Prescription Drugs Found in Southland Aquifers*, Jan 2006 **REPRINT**: (Source: http://www.latimes.com/news/local/la-me-drugs30jan30,0,5723467.story?page=1&track=tothtml%2C0%2C7964476.story%3Ftrack%3Dtothtml)
8. Metcalf and Eddy, Inc., Wastewater Engineering, Treatment, Disposal and Reuse, Irwin McGraw-Hill, 1991.
9. Mara, Duncan and Horan, Nigel, Water and Wastewater Microbiology, Academic Press, 2003.
10. Gerba, Charles, University of Arizona, Department of Soil, Water and Environmental Science
11. Hunt, C. S., C. P. Gerba, S. C. Lance, and R. C. Rice, *Survival of enteroviruses in rapid-infiltration basins during the land application of wastewater,* Annl. Environ. Microbiol. 40:192-200, 1980.
12. Gerba, C.P., C. Wallis, and J.L. Melnick, *The fate of wastewater bacteria and viruses in soil.* Jr. Irrig. Drain. Div. ASCE 101:157-174, 1975 .
13. Solomon, Kenneth H., Jorgensen, Greg, *Subsurface Drip Irrigation,* Center for Irrigation Technology Research Report, 1994.
14. American Water Works Association. (1990) *Recommended Practice for Backflow Prevention and Cross-Connection Control,* AWWA M14, (2nd ed.), Denver, CO