Options for the Disposal of Wastewater Effluent In Hanalei, Hawaii

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For purposes of this review, wastewater disposal options are limited to secondary- and tertiary-treated effluent because the disposal of primary-treated effluent via ocean outfall systems, which are utilized elsewhere in Hawaii, is not anticipated to be practical. The advantages of a tertiary-treated wastewater effluent over those of a secondary-treated effluent include a reduction in [1] suspended and dissolved solids, [2] soluble nutrients, [3] degradable organic carbon (BOD_5), and [4] some dissolved metals. Currently, both a conventional wastewater treatment facility (perhaps a large packaged plant) and some type of constructed wetland are under consideration. Given that the populated sections of Hanalei have been classified as a natural wetland, it seems unlikely that a "constructed" wetland system could be permitted. In lieu of constructing treatment ponds in native soils, enclosed structures known as *living machines* could be placed into the ground. Living machines reportedly emulate processes that occur within constructed wetlands and are able to utilize local plants and microorganisms to treat wastewater.

The most obvious option for wastewater effluent is direct discharge into one or more of the surface waters running through the Hanalei watershed. This option would be restricted to the Hanalei River due to intermittent flows in the smaller streams; however, the potential problems with this option are many and varied (e.g., restrictions on NPDES permitting for a "Heritage River" and limitations on effluent disinfection because of the toxicity to aquatic organisms). For environmental, political, aesthetic, and countless other reasons, surface water discharge does not appear to be a viable option.

A second option for treated wastewater disposal is groundwater injection, whereby treated effluent is introduced into saline (and presumably unusable) waters underlying the shallower freshwater lens. Although the USEPA is a decade into the process of banning groundwater injection that disposes both hazardous substances and untreated (or slightly treated) sewage, one of the few remaining permissible uses is the discharge of secondary or tertiary treated wastewater. The EPA refers to these permissible injection wells as *Class V Sewage Treatment Effluent (STE) wells*, which are permitted individually in the state of Hawaii for treatment plants that receive **only** sanitary sewage (i.e., no hazardous wastes). This requirement could be met in Hanalei thanks to the absence of industrial facilities connecting to the proposed sewer system. However, the public often associates groundwater injection wells with unanticipated and undesirable consequences, as was exemplified by two STE wells on Maui that were suspected of contributing to increased nitrate levels in nearby surface waters.

The third option for the discharge of wastewater effluent from small treatment works (either conventional or constructed wetland) is direct land application—preferably on a plot located adjacent to the treatment facility. This option usually incurs relatively low construction and maintenance costs, and the infiltration of effluent through shallow soils essentially adds a polishing step to the treatment process (i.e., filters out suspended solids, adsorbs some metals, reduces nutrients via nitrogen and phosphorus uptake by soil microbes). While land application is optimal for some geographic regions, there are a number of papers in the scientific literature that document the degradation of native soils and biota (both macro and micro) on plots used for the land application of wastewater effluent. A further loss of native vegetation to opportunistic species, a gradual change in the chemistry and permeability of soils, a climate characterized by heavy rainfall events, and a shallow groundwater table could render this option a controversial one for Hanalei.

The final option for the disposal of wastewater effluent is reuse, whereby effluent is used to irrigate lawns, golf courses, or (less frequently) food crops. While there are several locations in Hanalei town that could be irrigated using treated effluent, the costs of constructing a delivery network could be high. Perhaps the effluent network could be laid when the sewer laterals are connected to Hanalei households and businesses. The dominant use of irrigation water in Hanalei is for cultivating taro; hence, taro fields represent the most logical destination for reclaimed effluent. Most studies on the use of reclaimed effluent for crop irrigation have focused on conventional growing techniques (i.e., applying water to the ground surface and permitting it to infiltrate). Because the dominant method of taro cultivation in Hanalei includes flooding the crop (i.e., similar to rice cultivation), human contact with irrigation water is extensive. Consequently, there would have to be a major emphasis on disinfecting the water via ozone, UV, or a similar technique before it was delivered to farmers. On a positive note, the requirement for reducing soluble nutrients and dissolved organic matter (constituting the very ingredients of fertilizers that are used on taro) in the effluent might be reduced. Whether the effluent was used to flood taro fields or to irrigate landscaped areas, one could encounter public resistance if people were uncomfortable with the standards and methods of disinfection.

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I. Selected Treatment Option

The options available for the disposal of treated wastewater effluent depend, in large part, on the selected method(s) of treatment. If wastewater is treated to only primary levels, the effluent disposal options are more limited than if wastewater is treated to secondary or tertiary standards. Because primary-treated sewage effluent has so many potentially deleterious effects on both aquatic and terrestrial environments, the only practical means of its disposal in the Hawaiian Islands is via ocean outfalls. These outfall pipes must be designed so that the diffusers are located far offshore and in relatively deep waters, thus minimizing the potential for sewage to contaminate beaches or harbors (e.g., by means of ocean currents, mixing dynamics, surface winds). The cost of building, maintaining, and monitoring these extensive outfall systems is considerable and they are, most probably, not appropriate for a low-volume treatment facility such as that envisioned for Hanalei.

In this short summary, wastewater disposal options will be evaluated in terms of only secondary- and tertiary-treated groundwater. Tertiary-level treatment systems seem to be a rarity in the state of Hawaii (presumably due to their expense), even though the higher costs of influent treatment may be offset by potentially lower costs of effluent disposal — especially in Hanalei where disposal options are anticipated to be limited. At present, it appears that either a conventional wastewater treatment facility (most likely a packaged plant) or some type of constructed wetland will be selected. The most common type of constructed wetland consists of either surface or subsurface ponds that are built into the natural landscape and, following the removal of solids and scum, essentially perform the secondary or biological treatment. The major advantage of these ponds is that they utilize native plants and microorganisms to treat wastewater; however, both diminished treatment efficiencies and reduced or altered species diversity are frequently observed over the lifespan of constructed wetland systems [Gopal 1999].

Considering that much of the Hanalei district is classified as a natural wetland, there appears to be some question as to whether this type of "constructed" wetland system would be permitted. In lieu of constructing the ponds into native soils, so-called *Living Machines* utilize tanks that are emplaced in the ground and reportedly emulate the processes of a constructed wetland. For purposes of evaluating effluent disposal options in this short summary, it is assumed that effluents (either secondary or tertiary) produced by the various wastewater treatment systems are identical.

The basic differences between secondary and tertiary wastewater effluent include a reduction in suspended and dissolved solids (particularly soluble nutrients such as inorganic nitrogen and phosphorus), as well as a reduction in degradable organic carbon (usually measured as a lower biochemical oxygen demand or BOD_5). Tertiary effluent is less likely to create eutrophication problems (e.g., excessive algal blooms) when discharged to surface waters or to produce highly reducing (i.e., anaerobic and often odorous) conditions when discharged to surface or ground waters. Moreover, concentrations of most dissolved metals, if present, are lowered during standard tertiary treatments. Finally, tertiary effluent can be more efficiently disinfected (e.g., via chlorine, ozone, or ultraviolet light) and, consequently, exhibits somewhat lower fecal coliform counts than does similarly treated secondary effluent.

II. Surface Water Discharge

The first option for wastewater effluent is direct discharge into one or more of the surface water streams running through the Hanalei area. This option should be restricted to tertiary effluent because the flow in all of these streams (except the Hanalei River) is extremely variable and would be extremely susceptible to the impacts of secondary-treated effluent. In addition, the effluent (regardless of treatment level) could not be disinfected with chlorine because of the deleterious effects of chlorine residuals and the resulting *trihalomethanes* (*THMs*) on aquatic organisms. During Hanalei's infrequent dry periods, wastewater effluent could account for a significant fraction of the water flow in these small streams—essentially transforming them into effluent conduits leading to Hanalei Bay. It is anticipated that the restrictions on obtaining an NPDES permit for discharging into the small streams could be prohibitive. A permit for discharging effluent into the Hanalei River would likely be impossible due to its "protected" status. From an aesthetic, practical, and ecological perspective, direct discharge into one or more of Hanalei's small surface streams will likely prove to be an unpopular option.

Another option for surface water discharge is via a pipeline into Hanalei Bay. This option would seem to be restricted to tertiary-treated effluent and would entail construction of either a surface or subsurface pipeline leading to the selected point of discharge. This option is quite different from the previously discussed ocean outfall systems, which discharge high-volume wastewater effluents that are normally treated only to primary or advanced primary levels. Selecting an exact location and depth for the diffuser(s) would constitute a formidable task (both technically and socially) given the variable seawater circulation patterns/rates and intense recreational use of the Bay. Furthermore, the primary objective of constructing a wastewater treatment facility in Hanalei is to eliminate raw sewage from entering the Bay and River. While the tertiary-treated effluent will be of substantially higher quality than is the current overflow from individual septic tanks (believed to be entering the Bay via shallow groundwater flow), direct discharge of the effluent into Hanalei Bay will likely prove to be an unpopular option as well.

Results of a water quality study conducted in Mamala Bay suggested that the combination of seawater dilution with offshore ocean water and trapping of stream sediments in harbor and estuaries results in the relatively good water quality despite both point (wastewater effluent) and nonpoint (urban runoff) discharges into the Bay [Laws 1999]. Based on their respective physiographies, flushing rates in Hanalei Bay might be expected to be considerably lower than those in Mamala Bay. Moreover, substantially higher rainfall rates and fewer natural sediment "traps" on the north shore of Kaua'i (compared to the south shore of O'ahu) would likely make Hanalei Bay more susceptible than Mamala Bay to effluent-derived pollution. This is particularly true during extreme rainfall events, when suspended solid loads in both the coastal streams and Hanalei River are extremely high.

III. Groundwater Injection

Although EPA is a decade into the process of banning groundwater injection that dispose both hazardous substances and untreated (or slightly treated) sewage, one of their few remaining permissible uses is the discharge of secondary or tertiary treated wastewater. The EPA refers to these permissible injection wells as *Class V Sewage Treatment Effluent (STE) wells*, which are permitted individually in the state of Hawai'i for treatment plants that receive **only** sanitary sewage (i.e., no hazardous wastes). This requirement is difficult to satisfy for most public and private treatment works; however, it is likely that Hanalei could qualify because of the absence of industrial facilities connecting to the proposed sewer system. In fact, Hawai'i has permitted more operating STE wells than any state in the U.S. except Florida—probably because coastal wells in both these states can be completed into saline (and presumably unusable) groundwater units at moderate depths below ground surface.

The public often associates groundwater injection wells with unanticipated (and undesirable) consequences, e.g., the two STE wells on Maui that were suspected of contributing to increased nitrate levels in nearby surface waters [USEPA 1999]. Given the upslope location of water supply wells in the Hanalei watershed, the issue of effluent migration applies primarily to the Bay and adjacent coastal waters rather than to drinking water sources. Certainly, the chance of surface water contamination by wastewater effluent is much higher for any type of surface water discharge or land application than it is for groundwater discharge. The exact location and depth of an STE well(s) will probably have to be based on a more detailed hydrogeological and hydrochemical study of the groundwater units underlying Hanalei than has been performed to date.

While both secondary and tertiary treated wastewater may be injected into STE wells, the latter reduces any possible and unforeseen environmental consequences. Some of the advantages of groundwater injection include: (1) a reduced risk of adversely impacting surface soils or waters, (2) relatively moderate installation and operating costs, and (3) returning the municipal water (originally supplied by upslope production wells) to the ground, where is mixes with seawater and eventually reaches the ocean via groundwater discharge. Some of the disadvantages include: (1) potential clogging of the well(s) due to microbial fouling (especially secondary-treated effluent that is not disinfected) and (2) possible hydraulic overloading during episodic rainfall events (particularly if the selected treatment option is a constructed wetland).

IV. Land Application

The most popular option for the discharge of wastewater effluents from small treatment works (either conventional or constructed wetland) is direct land application—preferably on a plot located adjacent to the treatment facility. This option not only incurs relatively low construction and maintenance costs, the infiltration of the effluent through shallow soils essentially adds a polishing step to the treatment process. That is to say, soils are effective in filtering out any remaining suspended solids, adsorbing metals and certain organic compounds, and reducing nutrient loads (via inorganic nitrogen and phosphorus uptake by soil microbes). Depending on the efficiency of the shallow soils in removing the aforementioned wastewater constituents, this effluent disposal option has been used to justify the treatment of wastewater to secondary, instead of tertiary, levels. Moreover, research studies conducted in subtropical regions [e.g., Dawes 2003] suggest that most of the effluent "treatment" occurs in the upper meter (~3 feet) of the soil column. In addition to this *infiltration* or *percolation* method of land application, a less-frequently employed method is known as *overland flow*, whereby effluent is allowed to flow freely over the landscape or within wide channels. The latter method (most applicable to arid regions—not to Hanalei) permits effluent to infiltrate and evaporate over an extensive surface area.

While the infiltration method of land application appears, at first glance, to be an obvious choice for most climates and soils, it is not without problems. There are a vast number of papers in the scientific literature that document the degradation of native soils and biota underlying plots that are used for the land application of wastewater effluent [e.g., Pote 1995; Osborne 1994]. Of course, the environmental degradation depends on a number of factors, including: wastewater treatment level, soil type, effluent loading, rainfall, temperature, topography, and characteristics of the native vegetation (e.g., nutrient status, transpiration rates). Despite the substantial differences among land application plots reviewed by researchers, there are three problems that seem to be cited most often.

- ***Loss of vegetation or a substantial decrease in the diversity of existing terrestrial and/or aquatic plants.*** These effects are most often attributed to alterations in natural water level fluctuations and to the proliferation of opportunistic species that can best cope with (or thrive on) radically different nutrient and hydrologic regimes.

- ***Climate patterns that inhibit the efficiency of infiltration and evaporation.*** Unfortunately, the combination of frequent rainfall, high humidity, and coastal environments (precisely describing the conditions in Hanalei) are considered to be among the least favorable for the land application of wastewater effluent.

- ***Changes in soil parameters such as pH, electrical conductivity, cation exchange capacity (CEC), and saturation profile.*** Reduced pH and CEC levels affect the sorption of both transition and alkali earth metals, as well as the viability of soil microflora. In addition, an increase in exchangeable sodium often leads to a reduction in pore size and hydraulic conductivity, which play a major role in limiting infiltration rates. As the soil profile becomes saturated, there is an increased opportunity for shallow soil pore water to migrate laterally and, thus, impact adjacent lands or nearby surface waters.

If the constructed wetland is the selected treatment option in Hanalei, many of the aforementioned factors will have to be addressed. Disposing the effluent on adjacent surface soils may not be feasible due to their already being impacted by the constructed treatment ponds. If so, land application of wastewater effluent will require transport (via pipes or trenches) to areas that are more conducive to infiltration. Even if the effluent is discharged onto relatively porous soils, the combination of (1) frequent heavy rains, (2) a relatively flat topographic surface, and (3) a shallow water table complicates the selection of land application as an option for effluent disposal in Hanalei. Treating the effluent to tertiary, rather than secondary, levels could mitigate some of the chemical complications; however, the hydraulic complications would persist.

V. Irrigation/Reuse

Another approach to the disposal of wastewater effluent is using it to irrigate lawns, golf courses, parks, or (less commonly) food crops. While there are some grassy areas in Hanalei town that could be occasionally irrigated using secondary- or tertiary-treated effluent, the costs of constructing a delivery network would need to be evaluated. Perhaps effluent "supply" piping could be laid when the sewer laterals are connected to individual Hanalei households. The dominant use of irrigation water in Hanalei is for cultivating taro; hence, taro fields would constitute the most logical destination for reclaimed effluent. Most studies on the use of wastewater effluent for crop irrigation have focused on conventional growing techniques (i.e., where water is applied to the ground surface and permitted to infiltrate). Because the preferred method of taro cultivation includes flooding the crop (similar to rice cultivation), human contact with irrigation water is extensive. As a result, there would likely be a major emphasis on disinfecting the water before it was delivered to the taro farmers. By contrast, there might be considerably less emphasis on reducing either the soluble nutrients (i.e., inorganic nitrogen and phosphorus) or the dissolved organic matter―both of which are components of fertilizers. Numerous research studies [e.g., Amiel 1990] have shown that the dissolved organic matter in soil pore water and the underlying water table aquifer increases when wastewater effluent, rather than conventional ground or surface water, is used to irrigate crops.

Whether the effluent is used to flood taro fields or to irrigate landscaped areas, there could be considerable social resistance unless the public was comfortable with both the standards for and the methods of disinfection. Disinfection of wastewaters (particularly secondary-treated effluent) can be rather costly, especially if ozone or ultraviolet light is used as the disinfecting agent. Moreover, the requirements for disinfecting and testing effluent quality will likely be more rigorous for the irrigation/reuse option than for the previously discussed options; however, the disinfection requirement may be offset by less stringent requirements for reducing nutrient and organic carbon concentrations. This is particularly true if the irrigated areas are currently being treated with organic/inorganic fertilizers. One of the difficulties in using secondary-treated wastewater for irrigation is that metals, which are substantially reduced during tertiary treatment processes, can accumulate in the soils or sediments underlying the irrigated areas [Yadav 2002].

VI. Recap

Surface water discharge, groundwater injection, land application, and irrigation/reuse are all possible options for disposing (or using) wastewater effluent in Hanalei. While the climate, topography, ecology, and water use patterns in Hanalei appear to favor some disposal options over others, the final decision regarding the fate of wastewater effluent will probably hinge on three major factors. The first is the selection of a system (tertiary vs. secondary treatment, conventional facility vs. constructed wetland, and method of disinfection), the second is the ability to obtain all requisite environmental and health permits for construction, operation, and disposal/reuse. The third factor is community acceptance, as wastewater effluent disposal is almost always a controversial topic.

VII. References

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