Condition assessment survey of onsite sewage disposal systems (OSDSs) in Hawaii

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ABSTRACT

Onsite sewage disposal systems (OSDSs) are the third leading cause of groundwater contamination in the USA. The existing condition of OSDSs in the State of Hawaii was investigated to determine whether a mandatory management program should be implemented. Based on observed conditions, OSDSs were differentiated into four categories: ‘pass’, ‘sludge scum’, ‘potential failure’ and ‘fail’. Of all OSDSs inspected, approximately 68% appear to be in good working condition while the remaining 32% are failing or are in danger of failing. Homeowner interviews found that 80% of OSDSs were not being serviced in any way. About 70% of effluent samples had values of total-N and total-P greater than typical values and 40% had total suspended solids (TSS) and 5-day biochemical oxygen demand (BOD5) greater than typical values. The performance of aerobic treatment units (ATUs) was no better than septic tanks and cesspools indicating that the State’s approach of requiring but not enforcing maintenance contracts for ATUs is not working. In addition, effluent samples from OSDSs located in drinking water wells estimated 2-year capture zones had higher average concentrations of TSS, BOD5, and total-P than units outside of these zones, indicating the potential for contamination. These findings suggest the need to introduce a proactive, life-cycle OSDS management program in the State of Hawaii.

Key words | capture zone, OSDS management program, public health, sensitive areas

INTRODUCTION

Nationwide, onsite sewage disposal systems (OSDSs) serve approximately 25% of the population and 40% of new developments in the USA (USEPA 2013a). Because most OSDSs provide only partial treatment, they are often considered a temporary solution that will eventually be replaced by a public centralized sewer system (USEPA 2002a) except where it is not economically feasible to extend sewer systems to remote and rural areas. However, adequately managed and maintained decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in low density population areas (Grau 1994; USEPA 1997; Seabloom et al. 2005; Lamichhane 2007). But in many cases, these systems are installed and then largely forgotten until problems arise. In Hawaii, once OSDSs are operational, there is no governmental inspection/management program to monitor on-going performance or system condition except for aerobic treatment units (ATUs) where maintenance contracts are required (DOH 2009) but compliance is based on the honor system. Similar to septic systems, ATUs also use the natural process to treat wastewater but need continued supply of air (oxygen) and produce better quality effluent (USEPA 2000). Failure or poor operation of OSDSs, especially in the vicinity of drinking water supplies, could have serious effects on public health.

A previous study recommended an enhanced version of the Environmental Protection Agency’s (EPA) ‘Operating Permits Model’ as the most applicable method for the implementation of an OSDS management program for the State of Hawaii (Ogata & Babcock 2009). The focus of the recommended model would involve Hawaii’s Department of Health (DOH) issuing renewable permits for OSDSs and requiring inspections every 2 years by licensed professionals for permit renewal in order to protect...
environmental and public health. A successful program would help to ensure a high level of quality for drinking water supplies and recreational waters and protect marine resources like coral reefs that make up the foundation for many marine species and thus are a crucial support system for human life (USEPA 2002b). The US Geological Survey (USGS 2022) recently reported on an outbreak of white coral disease in Kauai’s north shore (one of the eight main Hawaiian islands) believed to be caused by a new strain of Cyanobacteria. Although no direct correlation of this problem to OSDS contamination has been established, sewage spills, in addition to over fishing and other sources of pollution, have been stated as one of the possible causes for the proliferation of Cyanobacteria (USGS 2022). Besides marine wildlife, pollution originating from septic tanks and other OSDSs pose a serious threat to ground water as they act as continuous point sources of pollution including nitrates and pathogens. Properly maintained wastewater treatment and disposal systems are necessary to minimize adverse impacts on public health and sensitive Hawaiian ecosystems.

PERIODIC MAINTENANCE NEED OF OSDS UNITS

An important component of OSDS maintenance is periodic removal of accumulated solids from the tank, and failure to do so may lead to solids carry-over, clogging, and overflow/back-up. In general, household septic tanks need to be pumped every 3 to 5 years (USEPA 2014). The recommended pumping interval is determined by tank size, number of persons in a household, total wastewater generated and the quantity of solids in wastewater (Crites & Tchobanoglous 1998; USEPA 2014). For example, the recommended septic tank pumping interval for a residential dwelling with a 1,000 gallon tank and four occupants is 2.6 years (PSU 2014) (see supporting information, Table S1, available online at http://www.iwaponline.com/wst/070/356.pdf).

STUDY OBJECTIVE

The purpose of this study was to determine the existing condition of OSDSs throughout the state of Hawaii by conducting on-site inspections and to simultaneously educate OSDS owners about their systems. A comprehensive inventory of the sample population included an assessment of each system and a water quality analysis of effluent from all sites where samples could be obtained. Systems were categorized as either residential/domestic or non-residential using the EPA classification definitions (USEPA 2002b). Effluent samples were analyzed for 5-day biochemical oxygen demand (BOD₅), total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) in order to compare water quality with industry assumptions.

The baseline data gathered and described herein will aid regulators, service providers, homeowners, and legislators in first deciding if a new management program is warranted and then, if needed, during the course of program implementation. This investigative study was primarily focused on the potential impacts that OSDS have on environmentally sensitive areas. In particular, the highest priority systems were those near well-heads located within the Source Water Assessment Program (SWAP) capture zone B (CZ-B) and those in close proximity to the ocean and protected marine areas. Capture zones are defined as the surface and subsurface area surrounding a well that supplies a public water system. The CZ-B area is delineated by a theoretical boundary that includes the 2-year time of travel. In addition, the State of Hawaii gives two classifications, Class ‘AA’ and Class ‘A’, to marine areas that are protected (DOH 2012b). No discharge of any pollutants can occur within Class AA waters (DOH 2012c) that are of ‘human-caused source or actions.’ Sewage discharges are also prohibited in Class A waters (DOH 2012a). OSDS units near these areas must achieve a minimum of 50% nitrogen (N) removal according to Section 6217 of Coastal Zone Act Reauthorization Amendments (NOAA 1990) enacted by the EPA and National Oceanic and Atmospheric Administration (NOAA). Potential contamination sources (such as OSDSs) in CZ-Bs and protected waters are of major concern to public health professionals. Denitrification must be incorporated into an OSDS in order to achieve 50% N removal or other modes of sanitation such as a urine source separated sanitation system (Larsen et al. 2009; Lamichhane & Babcock 2012) should be employed in areas with sensitive receiving water bodies.

METHODOLOGY

Correlating potential impacts that OSDSs can have on valuable natural resources raises public awareness and ultimately increases the urgency for preventative action. It is therefore important to locate OSDS facilities that are failing or are on the verge of failure and to make people/homeowners aware of the possible environmental and or regulatory consequences. The most important yet difficult part of the investigation was to find homeowners with...
OSDS facilities willing to cooperate with the research team by giving access to their properties, replying to questions and allowing inspection of their systems. Various communication tools were used to locate willing homeowners. The first approach and most commonly used, was the cold call (phone call with no prior warning). Similar to cold calls, cold visits to properties known to have OSDS were also made. The other approaches utilized were sending out mail packets (containing study purpose, instructions for participation and contact information) to members of the community thought to have OSDSs serving their properties and conducting presentations at community and homeowner association meetings. The activities included: (1) contacting the homeowners with emphasis on those in CZ-B; (2) describing background information regarding OSDSs in Hawaii and possible negative impacts they pose to natural resources like near-shore coastal waters, streams, rivers, lakes, and potable groundwater supplies; (3) providing tips and suggestions for proper care and maintenance of the system; and (4) receiving consent to inspect and assess the OSDS.

At the beginning of each OSDS inspection, the owner or current resident was interviewed for the purpose of gathering critical information including persons served by the unit, system location, tank pumping history, and any other issues that may have occurred during operation of the OSDS. In addition, users were also informed of Best Management Practices (BMPs) for maintaining their OSDS as recommended in two previous studies (DOEDT & DOH 2008; Ogata & Babcock 2009). All OSDS assessments were made based on observations and measurements completed at the time of the visit and water quality results for samples collected during the visit. Flow sensors and a video camera (My Tana, Mini Stand Alone Complete, St Paul, MN, USA) with real time flow monitoring capabilities were also used for investigating OSDS conditions, locations, flows in the lateral pipe and possible bottlenecks/pipe blockages.

**PARTICIPATION**

In total, 443 OSDS properties on five Hawaiian islands were included in the study. The level of participation was divided into three categories: visited, contacted, and inspected. A property for which no form of communication was made was classified as ‘visited’ (no one was at home at the time of a cold visit). Those properties for which contact was established but no OSDS assessment could be made (either refused to allow an inspection and/or OSDS could not be located) were classified as ‘contacted’ and sites for which an assessment was successfully completed were classified as ‘inspected’. Table 1 presents an island-by-island tally of participation by category. The subset of inspected units which were physically ‘accessed’ (opened, sludge level measured, and effluent sampled) is also shown. Out of 443 properties approached, 48% were successfully inspected, of which 85% were accessed (41% of total).

<table>
<thead>
<tr>
<th>Island</th>
<th>Visited</th>
<th>Contacted</th>
<th>Inspected</th>
<th>Island total</th>
<th>Accessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauai</td>
<td>45</td>
<td>31</td>
<td>63</td>
<td>139 (31)</td>
<td>58</td>
</tr>
<tr>
<td>Oahu</td>
<td>21</td>
<td>44</td>
<td>59</td>
<td>124 (28)</td>
<td>56</td>
</tr>
<tr>
<td>Molokai</td>
<td>15</td>
<td>5</td>
<td>7</td>
<td>27 (6)</td>
<td>6</td>
</tr>
<tr>
<td>Maui</td>
<td>34</td>
<td>13</td>
<td>29</td>
<td>76 (17)</td>
<td>17</td>
</tr>
<tr>
<td>Big Island</td>
<td>11</td>
<td>11</td>
<td>55</td>
<td>77 (18)</td>
<td>44</td>
</tr>
<tr>
<td>Category total</td>
<td>126 (28)</td>
<td>104 (24)</td>
<td>213 (48)</td>
<td>443 (100)</td>
<td>181 (41)</td>
</tr>
</tbody>
</table>

*Numbers shown represent the number of sites and numbers in parentheses are per cent of total.

**RESULTS AND DISCUSSION**

This study sought to inventory the general status of OSDSs on all of the main Hawaiian islands. Figure S1 (see supporting information, available online at http://www.iwaponline.com/wst/070/356.pdf) shows the general locations of study sites on each of the five islands. OSDS condition assessment scores with color codes were developed to rate the condition of the OSDS. The OSDSs are categorized into four groups: ‘Pass’, ‘Sludge/Scum’, ‘Potential Failure’, and ‘Fail’. The score and color coding assigned were: Score ‘1’ and blue color for facilities working properly (pass category), score ‘2’ and green color for systems with excessive sludge (system working but problems may arise in future), score ‘3’ and yellow color for system that are liable to fail soon and need immediate remedial actions, and score ‘4’ and red color for failed systems. As indicated in Table 1, out of 443 properties approached, only 213 units were inspected and 181 units were physically accessed (completely inspected and sampled). Scores were only assigned to each of the 181 accessed units and the results are shown in Table 2.

The units that were not scored (262 units or 59% of total) include the units that were accessed but could not be inspected (32 units), homeowners that were ready to let the...
inspection proceed but could not schedule a time (46 units), units that were accessed but homeowner refused to let the team inspect the system (48), units that were accessed but nobody (homeowner or resident) at home during the time of the study (114), and homeowners (units) with whom no contact could be made even after repeated trials (22).

Approximately 68% of all OSDSs thoroughly inspected appear to be in good working order and can be classified as ‘Pass’. Conversely, nearly 16% can be classified as ‘Fail’ and are in need of immediate attention. Also, another 16% are considered borderline condition (score 2 and 3) and need to be maintained in order to prevent future failure. Combining the non-passing OSDS scores, it is apparent that 32% (nearly one-third of all OSDSs in Hawaii) are functioning in a manner which could have adverse impacts on environmental and human health. Because of the small sample size, the study may not perfectly represent the true status but should be indicative of the general status of OSDSs in the State.

Table 2 shows the findings from the study regarding self-reporting of OSDS pumping. As can be seen from the table, twenty-eight per cent of owners/occupants interviewed said they ‘have never had their OSDS pumped’. In addition, 52% of the owners/residents did not know when or even if their OSDS had ever been pumped.

The count denoted as ‘contracted’ were those sites that have a service contract with a septic pumper for periodic inspection and/or pumping. All thirty of the ‘contracted’ sites were public facilities (schools, parks, public housing, etc.). The ‘unknown’ responses are essentially the same as ‘never’ and together represent 80% of the OSDSs statewide in this study. In other words, only about 20% of OSDSs are being maintained at all since pumping is the main form of maintenance for cesspools and septic tanks. This could either mean that most OSDSs are operated such that they do not require pumping (underloaded and/or solids loadings minimized) or that many OSDS can be expected to fail in the future when finally overwhelmed by solids accumulation. The data could also indicate that only about 20% of OSDSs require regular pumping due to overloading or failure of disposal units (attributed to poor soils or clogging with excess suspended solids).

**EFFLUENT QUALITY**

Effluent samples were collected from 72 systems (40%): 58 from septic tanks and 14 from ATUs. Figure 1 presents the average concentrations of TN, TP, BOD$_5$, and TSS for septic tank effluent. For each parameter, a comparison is...
shown between residential sites, public facilities (parks, schools, etc.), Capture Zone B sites, and those sites in close proximity to coastal areas. It is noted that the categories are not mutually exclusive, so some sites are represented more than once in these figures (i.e. some of the residential sites are also Capture Zone B, some of the public facilities are also coastal, etc.). The values in Figure 1 can be used in SWAP modeling efforts and other water quality fate and transport models and risk assessments for Hawaii.

Table 4 compares the measured septic tank effluent concentrations to typical ranges published by EPA (USEPA 2002a) and the Consortium of Institutes for Decentralized Wastewater Treatment (NDWRCDP 2004). The percentage of sample results that fall within the EPA ranges and the percentage that exceed the typical values are indicated. The remaining measured values either were above or below the typical range and/or the typical concentration value.

Percentile distribution curves for septic tank effluent characteristics are also plotted. Figure 2 shows the plot of percentile distribution of septic tank effluent BOD$_5$ and Figures S2–S4 (see supporting information, available online at http://www.iwaponline.com/wst/070/336.pdf) show the septic tank effluent TSS, TN and TP percentile distribution, respectively.

Figure 3 shows a comparison of average effluent water quality for samples collected from septic tanks and ATUs in this study. The comparison shows that the average concentrations were similar for septic tanks and ATUs for all parameters except TSS for which the septic tank value was more than twice as large as the ATU value. In general, ATUs are capable of achieving effluent BOD$_5$ and TSS concentrations of less than 30 mg/L as a running average if operated and maintained properly. These findings suggest that, on average, ATUs in this study were not performing any better than septic tanks (except in terms of TSS) and not performing as well as expected. This probably means that the ATUs are not being maintained adequately (some of the ATUs did not have operating aeration devices). And, even though there were only 14 ATUs sampled, this finding suggests that the existing management program (owners required to have an active maintenance contract with compliance by the honor system) is not working.

**CONCLUSIONS**

In total, 181 OSDS were successfully evaluated in the State of Hawaii, which comprised 0.03% of the estimated 170,000 total cesspools, 2.5% of the 4,500 septic tanks, and 8% of the 250 ATUs. Although the sample size is small, the findings are representative of the current status quo for OSDSs in the State of Hawaii because of the random responses obtained from the spatially well distributed population. Data suggest that 80% of OSDSs are not receiving basic preventative maintenance to remove accumulated solids and scum, which will likely lead to future failures. Two-thirds of the systems were rated as passing while the remaining one-third are in conditions that
places the public health and the environment at unnecessary risk. When compared to residential, public facilities and coastal areas, effluent samples from OSDSs within SWAP capture zone B had higher average concentrations of TSS, BOD$_5$, and TP, which is cause for concern. ATUs evaluated in this study were not performing better than septic tanks and not performing as well as expected to produce effluent with less than 30 mg/L BOD$_5$ and TSS. This means that the ATUs are not being maintained adequately and suggests that the existing management program (owners required to have an active maintenance contract) enforced only via the honor system is not working. About 70% of the effluent samples collected had measured values that exceeded the typical concentrations of TN and TP reported in USEPA literature. About 40% of the effluent samples exceeded the typical concentrations of TSS and BOD$_5$ reported in USEPA literature. A statewide life cycle OSDS management program is needed to address the present OSDS failures and the likely future increase in failures of the many other systems that are being neglected. The previously recommended ‘operating permits’ model with certification of inspectors and maintenance providers would be a major improvement over the current situation and would help to protect public health and the environment.

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