US EPA ARCHIVE DOCUMENT

APPENDIX H

FISH BIOACCUMULATION DATA EVALUATION

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SUMMARY

Samples of fish species of recreational and commercial importance are caught annually at a location near the Sand Island ocean outfall diffuser and at two reference sites in Maunalua Bay to make observations on their health and to collect muscle tissue samples for analysis.

This monitoring is done to collect fish typically caught by hook-and-line fishermen and determine the health of the fish and the body-burden of priority pollutants in muscle tissue. Whole fish were sampled in the field and frozen for shipment to the analytical laboratory for resection and compositing of muscle tissue. Sample sizes ranged from 10 to 36 fish per composite. A contract laboratory analyzed samples. Results to date reveal few samples with detectable concentrations of volatile and base neutral organic compounds. Selected trace metals and a few chlorinated organic compounds [pesticide residues including DDT and breakdown products (DDE), PCB Aroclors and PAHs] along with the ubiquitous phthalates (which are common laboratory contaminants because of their use in plastics) were present in muscle tissue samples at low concentrations when detectable.

In all but a few cases, the concentrations of metals in the tissues of fish from the CCH's study areas are consistent with concentrations from other areas of the Hawaiian Islands, including areas considered to be removed from the immediate influences of contaminant input

Trace metals shown no evidence of bioaccumulation of metals in the fish tissues that would be of environmental or public health concern. There appear to be species-specific differences in the concentrations of contaminants. If there are differences they could be reflective of diet or physiology or residency near known sources of contaminants

The overall concentrations of trace metals found in rig-caught fish caught near the Sand Island outfall are consistent with findings from other outfall bioaccumulation studies done along the Pacific coast (e.g, Young and Moore, 1978, Brown, 1986, Mearns, et. al, 1991, and Spies 1984), which indicate that trace metals, with the possible exception of mercury and arsenic, do not accumulate in the tissues of fish. Most fish have the ability to detoxify and eliminate excess metals from their system (e.g., Brown et al. 1982).

Mean muscle tissue mercury levels have not exceeded the U. S. Food and Drug Administration Action Levels or the Hawaii Department of Health advisory levels for any constituents.

INTRODUCTION

Bioaccumulation is the general term describing a process by which chemicals are taken up by marine organisms from water directly or through consumption of food containing the chemicals (Rand and Petrocelli, 1985). EPA's 301(h) program guidelines define bioaccumulation as the process of biological uptake and retention of chemical contaminants derived from various exposure pathways (Tetra Tech 1985).

METHODS

Annually, since 1999, the CCH laboratory ocean monitoring crew conducts hook-and-line fishing near the outfall diffuser and reference sites in Maunalua Bay to collect fish for analysis to determine body burdens of various contaminants.

Details on the location of the sampling stations and their depths and coordinates are documented annually in the Annual Assessment Reports along with details on the individual fish caught (length and weight) based on field data collected and measurements made on the fish catch. Only the summary information compiled from these records is presented herein. Additional details are presented in the City's Annual Assessment Reports for the present permit period (City and County of Honolulu, 1999, 2000, 2001, 2002, and 2003).

Hook-and-Line Fishing Surveys

Various fish species, which are commonly caught and eaten by local recreational and commercial fishermen, are sampled using baited hooks. Fish are caught in the vicinity of the outfall diffuser and at two sites in Maunalua Bay to the east of Diamond Head outside of Mamala Bay.

Fish are caught by hook and line by CCH staff using long-line rigs consists of 100-meter sections of 1/4 inch twisted nylon line with anchors at either end. The catch is weighed, tagged, and the data recorded on data sheets prior to being wrapped in aluminum foil and put into ziplock plastic bags. It is then put on dry ice for transport to the laboratory freezer. Dissected muscle samples are obtained from the fish in the laboratory after they are shipped and thawed for analysis at the contract laboratory.

Fish Muscle Tissue Analysis Results

Three replicate composite samples are taken from a pool of several individuals of each target species. The composite muscle samples are analyzed for tissue burden levels of priority pollutants, trace metals, chlorinated pesticides and PCBs, and volatile and semi-volatile organic compounds using EPA –approved methods and NOAA Status and

Trends analyte lists. The results obtained from the composite samples each year for each species for detectable priority pollutants (including a few common laboratory contaminants) are summarized in Tables H-1 through H-7 for the three species of fish. Tables H-1 through H-3 are for Ta'ape (Blue-lined snapper) and include the outfall diffuser results (Table H-1) and the two reference sites in Maunalua Bay (Tables H-2 and H-3). Similar tables for the Akule (Big-eyed scad) are presented in Table H-3 (outfall diffuser), H-4 and H-5 (reference sites). Table H-7 is a single table showing the data for Menpachi (Soldierfish) and the reference site for 1998 (the last year this species was caught and used for bioaccumulation analysis). In the past, under older permits and in the case of the Honouliuli outfall monitoring studies, this species has been used for bioaccumulation studies. Note that the values in each of the tables is reported as it was reported in the Annual Assessment Report in terms of the units reported by the laboratory which varied each year (wet or dry weight). For three of the five years, data was presented as dry weight (but unlabelled as such, just ppm except in the summary tables where it was shown as wet weight). Data is presented on the fish used for the composite sampling (average length, weight and the percent dry weight) that supports a conversion to wet weights which are more commonly used in reporting and the fact that quality assessment criteria (health protection guidelines and risk assessment criteria for human health from consumption) are in wet weights. For the key metals of interest to human health, mercury and arsenic (which are know to undergo bioaccumulation in fish), the concentrations have been converted to wet weights and included in separate summary tables to support the discussions of the results.

ASSESSMENT METHODOLOGY

Bioaccumulation can be assessed either by inference and known uptake rates or by evaluating the concentrations of various priority pollutants found in the effluent, marine sediments and the tissues of various organisms. The latter approach is that being used in this application. The staff of the CCH and County of Honolulu's Ocean Monitoring Program collected the fish samples and the analyses were completed by a contract laboratory, Columbia Analytical Laboratories or done in-house

The species caught and subsequently included in the database (after the screening process) are summarized below including the common and scientific names along with the family to which it has been assigned by taxonomists:

Hawaiian/Common Name	Scientific Name	Family
Menpachi (brick soldierfish)	*Myripristis cheryseres*	HOLOCENTRIDAE
Akule (big-eyed scad)	*Trachiurops crumenopthalamus*	CARANGIDAE
Ta'ape (blue-lined snapper)	*Lutjanus kasmira*	LUTJANIDAE

Also, the names are presented on each of the tables.

The bioaccumulation studies were initiated as part of ocean monitoring studies when the present permit became effective. The fish were collected by the CCH monitoring program crew and samples were obtain, packaged, frozen and shipped to a contract analytical firm for most analyses. Certain analyses were done by the CCH laboratory (cyanide). The data was reported back to the CCH and analyzed and summarized in the annual assessment reports.

In the review of the available database, screening was done to eliminate the large number of non-detectable values (most of the organic compounds were non-detectable) and some metals analyses. Compared to past data sets the metals and organics are now routinely detected with the much lower detection levels now achieved.

COMPARATIVE DATA

Finding data for comparison is a challenge in any bioaccumulation studies. EPA provided data for some species in the 1985 compilations developed by Tetra Tech (Tetra Tech, 1985) but none of the Hawaiian species are represented in the data sets. Mearns et. al. 1991, presents a detailed evaluation of contaminants in fish caught in southern California that is very useful in that is also presents information on sediment quality and shellfish. There is also data available from other 301(h) dischargers (San Diego and Orange County). A comprehensive survey of marketed fish was conducted by in 1969 and 1970, which provides an excellent national database of historical interest (see next paragraph for a description).

In 1971, the National Marine Fisheries Service (NMFS) undertook the most comprehensive survey of its type to evaluate the occurrence of 15 elements in 204 marine species representing at least 93% of the volume of the U. S sport fish catch. (Hall et. al. 1978). The Resource Survey provided information on fish and other organisms taken from 198 sites in coastal U. S. waters including Hawaii. The data for 159 species of finfish muscle tissue and 82 species of liver tissue is included in the database. Of these, some important Hawaiian species are included. Among these are Blue marlin (*Makaira nigricans*), Shortbill spearfish (*Tetrapturus angustirostris*), Striped marlin (*Tetrapturus audax*), Dolphin (*Coryphaena hippurus*), Striped mullet (*Mugil cephalus*), Red snapper (Ehu)(*Etelis marchi*), Gray snapper (*Aprion vire*scens), and menpachi (*Myripristis argyromus*). The NMFS historical database provides some very vital data to put locally limited data in perspective of the national markets for fish products and the relative levels of the various trace elements found in a variety of seafoods. Results for mercury and arsenic for these Hawaiian-caught species is summarized in Table H-9. This data set is perhaps the most comprehensive available since it was based on large numbers of samples and provides more of a sense of what average conditions might have been historically.

Menpachi is the only species that has been monitoring by the CCH under its previous permit and in 1998 before the present permit was issued. This species is also monitored at the Barber's Point outfall where both muscle and liver tissues are analyzed. Data for arsenic for the three species for the Honouliuli outfall (based on 1994 NPDES permit application) are presented in Table H-8. Data on the reported concentrations of metals in fish was published annually in review of the literature sponsored by the Water Environment Federation. Data from the last compilation in 1994 is presented in Table H-10.

DISCUSSION OF RESULTS

The primary focus of this review is to summarize priority pollutant bioaccumulation data collected by the CCH monitoring program and analyzed and discuss the results and determine if there is any impact from wastewater discharge practices on levels of contaminants in fish caught and consumed locally.

Each individual chemical is discussed starting with mercury and arsenic, two metallic compounds, which have been shown to be bioaccumulated in fish throughout the world. High levels of these two chemicals have been measured in areas remote from wastewater discharges and other human activities, which might contribute, to degradation of local water quality (Mearns, et al 1991). Thus, the presence of high concentrations in fish does not necessarily indicate that there is an association with wastewater discharge. This is particularly true with mercury where higher level predatory fish such as tuna, marlin and swordfish have been found to have bioaccumulated mercury to high levels > 1 ppm as methyl mercury, the organically bound form that can be concentrated in human nervous tissue leading to chronic toxicity (Table H-9 which presents historic composite data for various Hawaiian fish from a nationwide survey).

MERCURY

Mercury is a potential contaminant that undergoes bioaccumulation and bioconcentration in the marine food web and can result in adverse human health effects (Montague and Montague, 1971). The degree to which mercury poses a potential health threat to humans has been linked with the degree to which it becomes organically bound (methylated) under certain environmental conditions (anaerobic conditions in sediments). Mercury is not found in relatively high concentrations in the Hawaiian environment because there are no geologic formations (cinnabar deposits) such as found in the coastal strata of California that would increase ambient levels.

Sand Island effluent concentrations are so low that only one analysis showed the presence of mercury above detection limits with a concentration of 0.14 ug/l (ppb). Detectable mercury concentrations in sediments are also low and have ranged from 0.02 to 0.06 mg/kg (dry wt basis) (See Appendix G, Attachment G-1 for details on mercury in sediments). The distribution pattern shown through monitoring indicates extremely wide-ranging fluctuations in sediment concentrations both spatially and temporally. There has been no pattern of mercury concentrations that can be related to Sand Island effluent.

Levels of mercury (wet weight) in the muscle tissue of various fish caught at the Sand Island outfall diffuser and reference stations (see summary table H-11 which shows the concentrations as wet weights so they can be compared to health and environmental criteria shown in Table H-13) has ranged from 0.045 to 0.16 ppm or Ta'ape (Tables H-1 through H-3) and 0.048 to 0.162 ppm in Akule muscle tissue composites (Tables H-4 through H-6). For the single menpachi sample (Table H-7) the concentration of mercury was 0.08 at the diffuser site and 0.085 ppm at the reference site. This is lower than other analyses for the same species in Hawaii in the past (Table H-9).

These compare to values from the Honouliuli outfall which historically were found to be to 0.026-0.13 ppm in menpachi, 0.008-0.16 ppm in ta'ape, and 0.034-1.28 ppm in akule (as reported in the 1994 renewal application on file with EPA)

Overall, the ranges of mercury reported are typical of fish caught worldwide (Table H-10) and in Hawaii (Table H-9).

Average edible fish tissues concentrations were well below the 0.500 ppm and 1.0 ppm (as methyl mercury) that the Hawaii Department of Health Services might use for Action Levels (see Table H-13 for listing of Action Levels). When compared to other areas, the Sand Island diffuser-caught soldierfish have typical concentrations of mercury in their muscle tissue (Table H-7).

There is no bioaccumulation of mercury of public health significance now evident near the Sand Island outfall that can be attributed to the wastewater discharge. There has been no increase in sediment concentrations of mercury near the outfall. There does not appear to be any association between sediment concentrations of mercury and tissue burdens in fish.

ARSENIC

Arsenic is a common semi-volatile trace element, well known for its toxic effects on humans when dosed in small amounts in its purest forms. It occurs naturally in seawater in various forms. In organisms, it is detoxified via production of organic forms of arsenic, which are less toxic and more readily excreted.

Arsenic is of interest because it is known to be naturally high in sediments in the marine environment. While high arsenic levels can often be found, it is important to note that only the inorganic fractions of available arsenic are of health concern.

Using total arsenic values can contribute to a high percentage of the risk of cancer when used in a standard human risk assessment model incorporating fish consumption (CCH, 2003). Thus any modeling efforts must be adjusted to account for the organic fraction which requires a different analysis.

Arsenic levels in the muscle tissue of fish caught at the Sand Island outfall appear to be within the range of values previously reported for the Hawaiian Islands (0.4 to 20.8 ppm wet weight or about four times higher for dry weight values). Levels of arsenic in muscle tissue from fish caught off Sand Island (see summary Table H-12) with wet weight values range from 3.3 to 6.9 ppm for ta'ape, 3.0 to 5,7 ppm in big-eyed scad, and 0.09

to 0.24 ppm in menpachi recently (Table H-7) and much higher 5.9-15.5 ppm at the Honouliuli outfall (Table H-8). Given the variability of these values both in time and location, interpretation is challenging. The historical values for arsenic for the ta'ape at Honouliuli (1.1-8.1 ppm) and akule (0.40 to 8.1 ppm) compared to the 5.9-15.5 in golden-finned squirrelfish (Table H-7) show that the data is extremely variable varying significantly over time and do not appear to show any overall pattern. Given the infrequency of sampling and fact that the fish are highly mobile, one would not expect that levels would show any pattern. Furthermore, levels are comparable to other species from Hawaii (Table H-9) and elsewhere in the world (Table H-10). Cubbage (1992) surveyed chemical contaminants in fish and clams from Dyes and Sinclair inlets. The fish samples consisted of pooled fillets from English sole, sand sole, C-O sole, rock sole, and flathead sole. Total arsenic concentrations ranged from 3.3 to 21 ug/g (parts per million, wet weight basis).

The relationships and factors influencing uptake, metabolism, excretion and bioaccumulation of arsenic in fish are not well known. Mearns, et. al. 1991 in a comprehensive evaluation of arsenic in fish tissues in Southern California suggested that there is no correspondence between arsenic in sediments and arsenic levels in the tissues of animals. The large data set for fish tissues collected near the City of San Diego's Point Loma outfall confirm this finding (Tetra Tech, 1995). These large databases have shown that there is a wide fluctuation in arsenic levels in fish over time. These fluctuations occurred while the arsenic contributions from wastewater discharges was decreasing

Evaluation of sediment levels indicated no apparent association between muscle tissue burdens and sediment levels. The same conclusion can be drawn for the Sand Island outfall where sediment arsenic levels range from 0.7 to 16.2 ppm within the ZOM averaging 5 ppm dw, about the same concentration observed in fish (See Attachment G-1 of Appendix G for details on sediment quality). Fish tissue burdens shown no significant increase over sediment levels indicating that bioaccumulation is not occurring. EPA noted in the 1998 TDD that elevated levels of arsenic in sediments of the Wailoa River in Hawaii were found to be caused by arsenic oxide applied as an anti-termite agent between 1932 and 1963. The arsenic was found in the anaerobic zone where the chemical had been undisturbed by biological activity which explained why the biota had low levels of arsenic (Hallacher et al. 1985).

In fish and shellfish tissues, arsenic is primarily in organic form as arsenobetaine (Ballin et al., 1994) with approximately 80-99% of the arsenic in an organic form which is not toxic (Nriagru and Simmons, 1990). The inorganic arsenic content of seafood is generally quite low (Maher, 1983) The toxic species of most concern are inorganic arsenic, monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA), all of which are minor constituents. Information on the relative amounts of these forms in Puget Sound organisms is limited and of uncertain quality. The general picture emerging from local and national studies is that marine shellfish have the highest but also most variable concentrations of inorganic arsenic, followed by marine fish and freshwater fish, in that order (Donahue and Abernathy, 1999). Dietary exposure to arsenic via seafood and other food products is currently an issue of concern and research.

CADMIUM

Cadmium is a common trace element widely used in electroplating, in paints as a pigment, in batteries and as a plastic stabilizer. It has not been found at notable concentrations in the Sand Island influent or effluent and has not been one of targets of source control efforts in the CCH's pretreatment program because of the low levels of the metal. Detectable concentrations in the effluent have only been measured two times at concentrations of 0.03 and 0.6 ppb. Concentrations of cadmium at the core monitoring stations is very low, ranging from ND to 0.15 ppm averaging 0.12 ppm with no increase near the outfall. Levels as high as 0.23 ppm have been measured in the regional monitoring effort. Native or background levels have been estimated to be about 0.06 ppm in deeper offshore waters (See Appendix G).

Most detectable cadmium concentrations have been in the range of 0.03 to 0.12 ppm with one notable exception of ta'ape near the outfall reported in 1998 to have a concentration of 7.4 ppm. This appears to be erroneous data. All other values are below detection limits or very low and there are no differences between species or locations to indicate any bioaccumulation. Levels are comparable to those reported elsewhere (Table H-10).

CHROMIUM

Chromium, like cadmium, is a common trace element widely used in industrial applications and has not been a target of source control efforts because of the low effluent levels (0.4 to 4.4 ppb) Sediment levels have ranged from 3.1 to 25.9 ppm dw. Chromium levels in muscle are limited to a few samples all less or equal to than 1.0 ppm with no differences between species or locations sampled. These values are quite low compared to values measured worldwide (1-6 ppm, Table H-10)

Data show that chromium is not bioaccumulated in fish, even in areas where sediment levels are high, and there is certainly no evidence of bioaccumulation near the Sand Island diffuser.

COPPER

Copper has widespread uses in industrial, commercial and household products and applications. It is present in all types of wastes and materials present in sewage and the fact that it can be leached from copper pipe. Effluent levels now range between 16 and 58 ppb. Sediment levels have ranged from 1-50 ppm across the region

Copper levels measured in the three fish species studied near the Sand Island outfall is presented in Tables H-1 thought H-7. Copper in the muscle tissue of composites of akule ranged from 1.3 to 6 ppm dw, while ta'ape ranged from 1.1 to 1.76 ppm. Menpachi was similarly low in the range of 0.27 to 1.75 ppm. With the exception of the

6-ppm value in akule, the values were very similar in all species and no differences between locations worth noting.

Copper levels in the fish caught at the Sand Island outfall diffuser and Maunalua Bay appear to be similar to the range of values reported elsewhere in the world (Table 10 - 6) which have ranged from 0.8 to 18 ppm. Given that sediment values of copper are up to an order or magnitude higher, there is no evidence of bioaccumulation.

LEAD

Lead has been widely distributed in the environment largely as a result of its prior use a gasoline additive and paints. Both of these uses have been dramatically curtailed and lead levels today are decreasing. Lead in wastewater has its origin in various industrial uses and lead solder in water piping systems. Lead levels in Sand Island effluent have been declining over the years and ranges from 0.8 to 8.4 ppb averaging only 2.3 ppb.

Sediment levels have ranged from 0.6 to 16 ppm, dw with an average of <5 ppm, which appears to be about the background level. These values are comparable to values typical of the California mainland shelf where sediment mean values which range from about 4.1-13 ppm in unpolluted areas along the 60 meter depth contour (Mearns, et. al. 1991)

To date, only akule have shown detectable levels of lead in the fish composite samples of muscle tissue from the Sand Island diffuser or reference area (Tables H-1 through H-7) in the range of 0.02 to 0.08 ppm. No distinguishable difference is noted between the outfall and reference samples.

NICKEL

Nickel has been used in industrial, commercial and household products and applications and thus has a widespread distribution in the environment, including the marine environment. Sand Island effluent levels are very low, ranging from 3.3 to 7.5 ppb and averaging 6 ppb. Sediment levels have ranged from 1-70 ppm averaging about 20 ppm in Mamala Bay with a maximum of 15 ppm in the ZOM (See Appendix G for details).

The CCH's monitoring data show reportable nickel concentration in the muscle of fish caught near the Sand Island outfall and at the reference stations for three years (1999, 2000 and 2001) at consistently low concentrations between 0.2 and 0.6 ppm with no differences between the outfall and reference fish or between the three fish species for which data is available (Tables H-1 through H-7). Levels of nickel were shown to be in the range of 0.77 to 3.25 ppm ww for fish analyzed from Pakistan providing one indicator of the low levels observed in Mamala Bay (Table H-10).

Since ZOM sediment levels of nickel averaged 7 ppm, it is apparent that nickel is not being bioaccumulated. This is consistent with the conclusions of Mearns et.al, 1991 who concluded that nickel and metals other than mercury and arsenic are not being bioconcentrated by fish.

SELENIUM

Selenium has been widely distributed in the environment because is a natural element with a diversity of uses particularly in agriculture and industry. Another use, which contributes to the concentrations found in wastewater, is in dandruff shampoos. Selenium levels in wastewater have only been measured in recent years and generally averages about 2 ug/l with a maximum concentration of 5 ug/l which is typical of primary treated wastewater

Sediment levels have not been at detectable levels which is not surprising since the values reported in more urbanized Southern California were low, ranged from 0.024 to 4.4 ppm (Mearns, et. al. 1992). Selenium levels in the muscle of fish caught near the Sand Island outfall have ranged from BDL to 3.3 ppm dw in ta'ape and 2.1 to 3.88 ppm dw in akule (Tables H-1 through H-6). Menpachi selenium levels, when converted to dry weights, are comparable to the other two species at about 3 ppm (Table H-7). There was no difference between outfall and reference sites. There was an obvious species-specific difference which appeared consistently among the samples over the years with akule having muscle tissue levels two to three times greater than ta'ape. It would not appear based on sediment levels that nickel is bioaccumulating in fish.

SILVER

Silver levels in the muscle of fish caught near the outfall and at the references sites were below detection limits. Past sampling of fish at Honouliuli showed silver at very low levels ranging from 0.034 - 0.05 ppm with similar concentrations averaging about 0.04 ppm for all three species (Tables H-1 through H-7). Such values are typical for the levels from fish caught elsewhere in the world (Table H-10).

ZINC

Zinc levels in the muscle of fish caught near the Sand Island outfall have ranged from 12.5 to 16.5 ppm dw in ta'ape averaging 13.6 ppm at the diffuser and 14.3 ppm at the Maunalua reference sites. Akule muscle tissue was found to have a range from 14.8 to 49 ppm dw averaging 32.2 ppm at the diffuser and 32.4 ppm at the reference location. There was no difference in concentrations noted between outfall and reference sites for either species for the four years of sampling. There are obvious species-specific differences which appeared consistently among the samples over the years with akule having muscle tissue levels two to three times greater than ta'ape. Zinc in sediments has ranged from 0.8 to 42.8 ppm; thus there is no sign of bioaccumulation over ambient levels in sediments.

The concentrations are consistent with findings for the fish caught in southern California, which ranged from 3-65 ppm (City of San Diego, 1995). Zinc in fish from different parts of the world have been reported to be in the range of 2-50 ppm (8-200 ppm dry wt)(Table H-10).

CHLORINATED HYDROCARBONS

There are two chlorinated hydrocarbons, which are generally the focus of most bioaccumulation studies. These are the PCBs (various Aroclor mixtures) and total DDT (DDT and the derivatives and breakdown products DDE and DDD). The pesticide DDT was widely used in urban areas for control of pest insects, and was sometimes broadcast through the neighborhood streets by spray trucks to control mosquitoes. DDT also was used in agricultural insect control before being banned in 1972. It breaks down into products known as DDE and DDD, both of which are toxic and slow to break down

Effluent measurements show that they are consistently found below detection limits.

Chlorinated Hydrocarbons in Sediments and Fish Tissue

Total DDT and PCBs are routinely measured in sediments at very low background concentrations. Levels of these two now-banned chlorinated hydrocarbons are found throughout the world in all media. Levels in sediments are discussed in more detail in Appendix G Attachment G-1. Concentrations are so low that there is no potential for bioconcentration as is evident from the fish muscle analyses (Tables H-1 through H-7).

There is no discernable discharge-related trend associated with chlorinated hydrocarbons in sediments or fish tissues.

However, there are some very high levels of contamination in the watershed areas of Oahu, which have been documented by the U. S. Geological Survey. The findings are discussed below because they relate to two pesticides found in the Sand Island influent and effluent which have caused permit exceedences but are not found in the marine environment (either sediments or fish) near the outfall.

Oahu's Urban Streams Severely Contaminated With Pesticides Chlordane and Dieldrin, Levels the Highest Ever Found in U.S.

Urban streams on the Hawaiian island of Oahu are contaminated with DDT and have the highest levels in the nation of the toxic pesticides chlordane and dieldrin (USGS, 2000). The persistent, man-made chemicals, now banned but once commonly used to control insects such as termites and mosquitoes, are found in the mud at the bottom of streams and also in tissues of aquatic organisms, including fish that live there. The US Geological Survey study of five O'ahu urban streams indicates that any stream flowing through areas developed before 1980 can be expected to contain dangerous pesticides in both streambed sediment and in the fish, crabs and other forms of aquatic biota. The state Department of Health has indicated that people should assume any urban stream aquatic such as crayfish, tilapia, crabs and o'opu are contaminated and potentially hazardous to health if eaten (Table H-14). State officials have posted warnings about contaminated fish and shellfish at Pearl Harbor and the Ala Wai Canal.

Chlordane was Hawaii's termite ground treatment chemical of choice until it was banned for commercial use in 1988. Another termite pesticide used in the Islands, aldrin, breaks down readily into toxic dieldrin.

These compounds, known as organochlorides, bind to the soil and are washed into streams through soil erosion from urban areas. They are associated with a range of health risks to animals and humans, and are considered possible human cancer risks and chemicals that may alter hormone balance.

The USGS studied Kane'ohe, Manoa, Nu'uanu, Poamoho, and Waikele streams and sampled waters of Windward O'ahu's Waihe'e Stream in a forested region without of any houses or agricultural areas as a control site. No pesticides were detected in the Waihe'e Stream samples. Results showed that compared to other surveys done nationwide, as part of the National Water Quality Assessment Program, each of the Hawai'i urban streams had higher levels of chlordane and dieldrin than any Mainland stream tested. DDT levels were comparable to average Mainland levels).

The high levels of the termite chemicals, compared with lower Mainland levels, is understandable given that the Islands, lacking freezing winters that limit termite activity, thus requiring dramatically more treatment to prevent the insects from destroying homes and other structures. These contaminated conditions are impacting the wastewater collection system through infiltration to collector sewers and causing effluent exceedences of limitations placed into the permit (See Appendix C for details).

Other Measurable Priority Pollutants

Interpretation of Results

Interpretation of the analytical results of the levels of contaminants found in the tissues of fish has been done in accordance with applicable methods. Interpretation is generally limited to comparisons and calculations of risk based on local consumption patterns and use of available EPA risk assessment. Given the limited data base, such interpretations are of limited value and are made difficult by a variety of factors including the following:

- Comparisons are limited by species-specific differences, as well as by differences in sex, age, and reproductive maturity within a species.
- The contaminant burdens found may be derived from a variety of sources and may not reflect local sediment levels or water quality conditions. Prey species and the ability of the prey to accumulate contaminants are key factors. Without a consistent pattern, it is difficult to determine the origin of contaminants.

The City of Honolulu's fish bioaccumulation data collection efforts, like that of other dischargers in the 301(h) program is subject to the difficulties of attempting to find suitable reference data for comparative purposes. There are no specific national or state criteria for evaluating fish health, assuming pathological conditions, or contaminant burdens. There are some long-standing criteria for the assessment of consumption quality for humans or for wildlife from a variety of agencies (National Academy of Sciences, 1973; U. S. Food and Drug Administration, 1985; and Office of Environmental Health Hazard Assessment of the California Department of Health Services, 1991). These criteria can be used for general purposes in evaluating the possible health and ecological significance of the measured tissue burdens. A summary of these criteria is shown in Table H-13.

Persistence of Historically Used Chemicals and Their Human Health Effects

The presence of potentially carcinogenic, mutagenic or acutely toxic chemicals in fish and shellfish tissue is commonly accepted as proof of bioaccumulation, which could eventually adversely affect human health. Potential for bioaccumulation is a criterion commonly applied in developing water quality criteria used for establishing and evaluating permit limits for waste discharges to the marine environment. Well-publicized harmful effects such as DDT's effect on eggshells of predatory birds and the effect of mercury on humans (Minamata disease) who have consumed contaminated fish fuel concern about bioaccumulation. Human health criteria have been promulgated and adopted by the Hawaiian Department of Health.

Review of a portion of the growing body of scientific literature, however, suggests that caution is needed in discussing bioaccumulation of contaminants. Although there are clearly effects in nature that are attributable to bioaccumulation of contaminants, there are also many assumptions about harmful effects that do not withstand rigorous analysis. Some of the factors influencing bioaccumulation are elimination, and detoxification.

Elimination

Bioconcentration and bioaccumulation alone are not useful measures for assessing risk to biological communities or human health. Many chemicals undergo some degree of bioconcentration and bioaccumulation; but when organisms are transferred to a clean environment, many of these chemicals are rapidly excreted, thus persistence is a factor that must be considered in species with wide-ranging movements (such as many fish).

Both the toxicity and the bioaccumulation potential of a toxic compound are greatly affected by the rate of elimination from the organism. Common processes by which organisms can cleanse themselves of contaminants include excretion, defecation, diffusion, body secretions (e.g., mucus), and molting (in the case of crustaceans) (Bryan 1979). In most cases, cleansing (depuration) implies that the organism is exposed to reduce external levels of contamination. There is evidence, however, that some marine organisms are capable of regulating tissue levels of certain metals while still in contaminated environments, i.e., concentrations in the tissues are less than what would be expected based on external concentration. Polychaetes, decapod crustaceans, and fish show some evidence of regulation of levels of metals in the tissues, whereas bivalve mollusks do not (Bryan 1979).

Detoxification

Most animals have means of protecting themselves from naturally occurring toxics. One way is through a group of proteins of the metallothione in type, which bind metals, thereby making the metals non-toxic and biologically unavailable (Brown et al. 1985). These proteins normally occur at relatively low levels in tissues and synthesis is induced by exposure to contamination by metals (Bryan 1979). Research on the detoxification process suggests that metallothioneins are effective detoxification mechanisms for metals unless the metal levels in the environment (and therefore the organism) are so high or increase so rapidly as to exceed the body's capacity to manufacture and store these proteins.

One good example is arsenic, a very ubiquitous compound in marine organisms (Bryan 1979). The data compiled suggest that arsenic in marine organisms primarily (as a minimum 80-99 percent) occurs in a less toxic organic state, which is more readily excreted than arsenite and less toxic. Most groups of marine organisms appear to be able to synthesize these organic arsenic compounds. Thus the body burdens normally measured (total arsenic) may not reflect any relative degree of potential effects on physiology or hazard to human health from consumption. Measurement of total arsenic is not reflective of the contaminant level of concern, since it is the elemental arsenic, which poses a toxic threat if humans consume contaminated tissues.

RISK ASSESSMENT

The risks associated with the consumption of fish contaminated with various potentially toxic pollutants is assessed using various methods (EPA, 1986a, 1986b, and 1985c).

Public health risk assessments are presented in the Annual Assessment Reports (CCH, 2003).

Recently, with improved analytical techniques, many more of the priority pollutants have been detected in the Sand Island effluent. Although they are at very low concentrations, human health risk criteria are based on even lower numbers based on extrapolations from health effect studies that sometimes derive theoretical criteria that are below the present limits of detection. The CCH undertakes a health risk assessment using EPA risk assessment methodology each year. The methods and assumptions used are well documented and described in the AARs and will not be repeated here. These assessments indicate that mercury and arsenic along with pesticides have the highest risk for consumers who consume fish with high levels of these contaminants. However, the form of the mercury and arsenic, which is harmful, is not measured (these are the organic forms for mercury and the inorganic forms for arsenic) making the total concentrations presently measured too high for predicting a realistic health risk. Nonetheless, this is the present methodology and data that must be used to perform an assessment in accordance with permit requirements. It is noteworthy that there are no restrictions placed on fish consumption in Oahu for open ocean waters or warnings about consumption of fish other than the general advisory issued by the U. S. Food and Drug Administration on consumption of mercury by pregnant women (Wilbert Kubota, Hawaii Department of Health, Food and Drug Branch, personal communication with Kris Lindstrom, K. P. Lindstrom, Inc.). There are restrictions on shellfish harvesting and warnings posted for Pearl Harbor and the Ala Wai Canal. Generally, all urban streams are areas of concern for the capture and consumption of biota.

Risk assessment analyses are based on evaluation of the dosage to which a person might be exposed and comparing this dosage to the permissible limit which is defined in terms of the average daily intake (ADI). Fish tissue from specimens collected from both the Honouliuli and Sand Island diffuser stations by hook-and-line were analyzed and the results used in the annual risk assessments.

Risk Analysis for Consumption (Screening Value)

As described by the permit, the purpose of the rig fishing is to monitor pollutant body burdens in fish consumed by humans, in order to determine whether or not the effects of waste discharge may constitute a threat to public health by exposure to chemicals that have accumulated in the fish. Exposure is defined as contact between a human and the chemical being evaluated. The chronic or long-term effects are of concern in this analysis due to the very low levels (parts per billion) of contamination. The chemicals found above the detection limits in the effluent have the following categories of health effects (oral intake only):

Chemical	Type of Effect
Arsenic (inorganic)	Chronic carcinogenicity and non-carcinogenicity
Mercury	Chronic non-carcinogenicity
4.4'-DDE	Chronic (probable) carcinogen and non-carcinogenicity
4.4'-DDT	Chronic (probable) carcinogen and non-carcinogenicity
2,4'-DDT	Chronic (probable) carcinogen
PCB 99	Chronic (probable) carcinogen
PCB 138	Chronic (probable) carcinogen
PCB 153	Chronic (probable) carcinogen
PCB 180	Chronic (probable) carcinogen
PCB 187	Chronic (probable) carcinogen
trans-Nonaclor	Chronic non-carcinogenicity

Comparisons to Screening Levels

Based on available data the source(s) of contamination cannot be identified. Sediment from one of ten stations tested, Station E2, tested positive at very low levels for 4,4-DDT, and PCB cogeners 118, 138 and 153. Samples from this site had tested negative for these substances in 1999 and 2000, the only other times the site was sampled. In

2002 the only commonality between sediment and fish tissue testing (non metallic contaminants) were 4.4'-DDT, PCB 138 and PCB 153 found at low levels in one fish species (Ta'ape). None of the contaminants found in fish tissue in 2002 were found in either of the two semi-annual effluent priority pollutant scans. One uncertainty is the spatial or territorial range over which the fish sampled were exposed to the chemicals detected during testing. Another uncertainty is the number and relative magnitude of contaminant sources, other than the SIWWTP outfall, to which the fish may have been exposed within their territory; e.g., outflow from Pearl Harbor or Honolulu Harbors; atmospheric deposition including KONA winds which are known to deposit lead and mercury as well as other contaminants, and the natural sources of metals due to the chemical constituents of volcanic rocks that compose the islands.

More relevant to NPDES compliance, and more quantifiable, is the consideration of whether these pollutant concentrations pose a health concern, regardless of source. Pollutant concentrations in fish tissue were therefore compared to screening values. Screening values are defined by EPA guidance (1993) as "concentrations of target analytes in fish or shellfish tissue that are of potential health concern and that are used as standards against which levels of contamination in similar tissue collected from the ambient environment can be compared." Exceedence of these values in samples is an indication that more site specific monitoring and evaluation may be warranted.

Screening values associated with ingestion of the sampled fish were determined in accordance with US EPA guidelines as presented in two manuals, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Vol. 1 (Fish Sampling and Analysis Second Edition, September 1995)*, (reference 10) and *Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual*, September 1989 (reference 9). The information for analytes listed detected in the effluent is used for the annual risk assessment and compiled from these references and from the IRIS database. When the values appeared in both databases the more conservative was generally used.

Table H-15 shows the calculated screening values for the chemicals found in the fish sampled in 2002 and compares the maximum values found in the fish when those levels exceed the screening values. As shown, arsenic and mercury exceed the screening level limits recommended by EPA. The level of arsenic in fish has previously been discussed with DOH. It was suggested by DOH at that time that the majority of arsenic in fish was probably in the less chemically active pentavalent form so that the more toxic trivalent form of arsenic was less than that found in tests. Neither the arsenic found in the fish nor the arsenic found in all sediment samples has been tested to determine its valence. Mercury is a metal that occurs naturally. Exposure to mercury is possible in some metals refining plants and cement plants where it is released incidental to the processing many ores. Lead and other metals, which were tested for in previous years were not tested for in 2002, as they are not listed as being required in the permit.

It is also noteworthy that the Department of Health prohibits the sale of all locally caught shellfish and relies upon the state fish and game personnel to enforce illegal harvesting and sales.

CONCLUSIONS

Contaminant concentrations with measured in the muscle tissues of fish collected during this program were below the respective FDA action levels (for total PCBs, total DDT+, and mercury). However, FDA action levels have been established only for nine contaminants (seven pesticides, mercury, and PCBs) and with the exceptions of mercury, and were intended to regulate interstate commerce of consumable products and not to protect the health of fish or to govern human consumption of seafood.

From the data collected to date, there is no evidence that the outfall discharge is contributing to the bioaccumulation of contaminants in fish.

The concentrations of most contaminants are very low. For most constituents other than a few trace metals, the levels are routinely below detectable levels. This is the case for DDT and derivatives and PCBs. Chlorinated pesticides, no long in active use and officially banned, are still detectable at very low concentrations causing permit exceedences for the extremely low limitations put into the permit based on theoretical health risks. The CCH will continue to collect data and evaluate the significance of its findings with regard to public health. All evidence to date points to the fact that Mamala Bay fish do not have elevated levels of contaminants an fish are safe to eat.

Table H-1

Detectable Priority Pollutants in Fish Muscle Tissue at the Sand Island Outfall Diffuser

Ta'ape (*Lutjanus kasmira*) Blue-lined snapper	**Year**	**Year**	**Year**	**Year**	**Year**
Metals	**1998**	**1999**	**2000**	**2001**	**2002**
Analyte mg,Kg (units as reported in the AAR)	wet	dry	dry	dry	wet
Aluminum		1.7	1.6	1	
Antimony	0.35 "B"				
Arsenic		26.1	29.5	29	5.70
Cadmium	7.4	BDL	BDL	BDL	
Chromium, total	0.16	BDL	0.5		
Copper	0.33	1.76	1.2	1.1	
Iron		18.2	12	13.2	
Lead		0.03	0.05"B"	0.08	
Mercury	0.07	0.75	0.4	0.35	0.069
Nickel		0.2	0.5	0.4	
Selenium	0.83	1.67	1.4	2	

Table H-1 Detectable Priority Pollutants in Fish Muscle Tissue at the Sand Island Outfall Diffuser (CONTINUE)					
Thallium					
Zinc	3.2	14.1	13.4	14.1	
Other substances, ug/kg weight (ppb)	wet	dry	dry	dry	wet
Endosulphan Sulphate					
Endrin Aldehyde					
Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor		***7***	4.1	15	1.1
Dieldrin					
4,4'-DDT				9.2	1.7
2,4'-DDT		***6***		5.1	
4,4'-DDE				5.5	1
4,4'-DDD					
Methoxychlor					
PBC 99				2.2	
PCB 118			2		0.51
PCB 138				2.9	0.82
PCB 153			5.7	8	1.9
PCB 180			7.2	2.8	0.69
PCB 187	0.011 "P"			2.1	BDL
PCB 1260					
Phenanthrene			78		
Anthracene			15		
Flouranthene			140		
Pyrene			70		
Benza(a)anthracene			18		
Chrysene			25		
Benzo(b)flouranthene			24		
Benzo(k)flouranthene			12		
Benzo(a)pyrene			12		
Indeno(1,2,3-cd)pyrene			15		
Benzo(g,h,i)perylene			13		
Methylene chloride					
Di-n-butyl Phthalate					
Bis (2-Ethylhexyl) Phthalate	0.19				
Composite Information					
No.of Fish composited	27	10	26	36	30
Total solids % Wet		21.8	23	23.8	22.3

Table H-1

Detectable Priority Pollutants in Fish Muscle Tissue at the Sand Island Outfall Diffuser (CONTINUE)

Total lipids % Dry		2.11	1.3	1.3	0.96
Average weight, gm	118.67	235.3	173.79	206.44	249.2
Average length, cm	19.52	25.2	22.46	23.64	25.45

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.
BDL = Below Detection Limit
J = estimated value
B = The reported analyte was detected in the associated method blank as well as the sample
* = Value is average of duplicate samples.

Table H-2

Detectable Prority Pollants in Fish Muscle Tissue from Reference Site #1 in Maunalua Bay

Ta'ape (Lutjanus kasmira) Blue-lined snapper	**Year**	**Year**	**Year**	**Year**	**Year**
Metals	**1998**	**1999**	**2000**	**2001**	**2002**
Analyte Conc. mg/kg (units as reported in AAR)	wet	dry	dry	dry	wet
Aluminum		2.3	3.4	BDL	
Antimony	0.1				
Arsenic	5.8	22.6	16.4	24.2	4.80
Cadmium	0.01	BDL	0.03J	BDL	
Chromium, total	0.1	0.74	0.7		
Copper	0.28	1.73	1.6	1.2	
Iron		18.5	19.4	13.2	
Lead		0.03	0.04"B"	0.05	
Mercury	0.09	0.32	0.5	0.37	0.045
Nickel		0.3	0.6	0.3	
Selenium	0.7	1.86	1	2.4	
Thallium					
Zinc	3.5	15.4	14.6	12.5	
Other substances, ug/kg weight	wet	dry	dry	dry	wet
Endosulphan Sulphate					

Endrin Aldehyde					

Table H-2

Detectable Prority Pollants in Fish Muscle Tissue from

Reference Site #1 in Maunalua Bay

(CONTINUE)

Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor		2		15	
Dieldrin					
4,4'-DDT				9.2	
2,4'-DDT				51	
4,4'-DDE		2		55	
4,4'-DDD					
Methoxychlor					
PBC 99					
PCB 118					
PCB 138					
PCB 153					
PCB 180			3.2	3.2	
PCB 187					
PCB 1260					
Phenanthrene			15		
Anthracene					
Flouranthene			25		
Pyrene			12		
Benza(a)anthracene					
Chrysene					
Benzo(b)flouranthene					
Benzo(k)flouranthene					
Benzo(a)pyrene					
Indeno(1,2,3-cd)pyrene					
Benzo(g,h,i)perylene					
Methylene chloride					
Di-n-butyl Phthalate					
Bis (2-Ethylhexyl) Phthalate					

Table H-2 Ta'ape (continued)					
Composite Information					
No.of Fish composited	20	10	20	35	26
Total solids % Wet	0	22.8	22.6	22.3	22.5
Total lipids % Dry	0	2.41	0.69	0.57	0.55
Average weight, gm	184.38	247.5	229.3	204.89	170.39
Average length, cm	23.63	25.4	24.9	23.94	22.33

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.
BDL = Below Detection Limit
J = estimated value
B = The reported analyte was detected in the associated method blank as well as the sample
* = Value is average of duplicate samples.

Table H-3

Detectable Priority Pollutants in Fish Muscle Tissue at Reference Site No. 2 in Maunalua Bay (Ta'ape)

Ta'ape (Lutjanus kasmira) Blue-lined snapper	**Year**	**Year**	**Year**	**Year**	**Year**
Metals	**1998**	**1999**	**2000**	**2001**	**2002**
Analyte Conc. mg/kg(units as reported in the AAR)	wet	dry	dry	dry	wet
Aluminum		1.7	10	BDL	
Antimony					
Arsenic		20.6	17.4	22	5.20
Cadmium		BDL	BDL	0.07	
Chromium, total		0.72	BDL		
Copper		1.76	1.4	1.1	
Iron		20.9	14.4	13.8	
Lead		BDL	BDL	0.06	
Mercury		0.45	0.3	0.31	0.118
Nickel		0.4	0.5	0.6	
Selenium		1.97	BDL	2.1	
Thallium					
Zinc		13	13.8	16.6	
Other substances, ug/kg weight	wet	dry	dry	dry	wet
Endosulphan Sulphate					
Endrin Aldehyde					
Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor		2			
Dieldrin					
4,4'-DDT					
2,4'-DDT					
4,4'-DDE		2			
4,4'-DDD					
Methoxychlor					

PBC 99					

Table H-3

Detectable Priority Pollutants in Fish Muscle Tissue at Reference Site No. 2 in Maunalua Bay (Ta'ape) (CONTINUE)

PCB 118					
PCB 138					
PCB 153					
PCB 180					
PCB 187					
PCB 1260					
Phenanthrene			36		
Anthracene					
Flouranthene			69		
Pyrene			34		
Benza(a)anthracene					
Chrysene			13		
Benzo(b)flouranthene			12		
Benzo(k)flouranthene					
Benzo(a)pyrene					
Indeno(1,2,3-cd)pyrene					
Benzo(g,h,i)perylene					
Methylene chloride					
Di-n-butyl Phthalate					
Bis (2-Ethylhexyl) Phthalate					

Table H-3 Ta'ape (continued)					
Composite Information					
No.of Fish composited	27	10	26	36	30
Total solids % Wet	0	22.8	23.3	23	22.3
Total lipids % Dry	0	2.5	0.78	0.68	0.6
Average weight, gm	0	192.1	250.3	193.57	245
Average length, cm	0	23.2	25.25	23.34	25.65

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.
BDL = Below Detection Limit
J = estimated value
B = The reported analyte was detected in the associated method blank as well as the sample
* = Value is average of duplicate samples.

Table H-4
Detectable priority pollutants in fish muscle tissue at the Sand Island Outfall Diffuser

Akule -Big-eyed scad fish	Year	Year	Year	Year	Year
Metals	1998	1999	2000	2001	2002
Analyte Conc. mg/Kg (ppm)(as reported in AAR)	wet wt.	dry wt.	dry wt.	dry wt.	wet wt.
Aluminum		3.3	1.5		
Antimony	0.47"B"				
Arsenic	4.1	17.3	11.8	15.8	4.40
Cadmium	0.02	0.03	0.06	0.07	
Chromium, total	0.2		0.6		
Copper	1.5	4.8	4.1	3.2	
Iron		53.3	50.6	46.2	
Lead	0.04"B"		0.05 "B"	0.04	
Mercury	0.08	0.61	0.3	0.45	0.13
Nickel		0.2	0.4		
Selenium	0.91	3.88	2.1	2.7	
Thallium	0.12				
Zinc	8.8	40.4	31	22.1	
Other substances, ug/kg wet weight (ppb)					
Endosulphan Sulphate	0.92 "P"				
Endrin Aldehyde	1.3 "P"				
Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor					
Dieldrin					
4,4'-DDT	1.3				1.5
2,4'-DDT					
4,4'-DDE					
4,4'-DDD					
Methoxychlor					
PBC 99					
PCB 118					
PCB 138					0.76
PCB 153					1.1
PCB 180					0.82
PCB 187					0.57

PCB 1260	36 "P"				

Table H-4

Detectable priority pollutants in fish muscle tissue at the Sand Island Outfall Diffuser (CONTINUE)

Anthracene					
Flouranthene			31		
Pyrene			16		
Benza(a)anthracene					
Chrysene					
Benzo(b)flouranthene					
Benzo(k)flouranthene					
Benzo(a)pyrene					
Indeno(1,2,3-cd)pyrene				30	
Benzo(g,h,i)perylene			22		
Methylene chloride					
Di-n-butyl Phthalate					
Bis (2-Ethylhexyl) Phthalate					

Composite Information					
No. fish composited	20	10	22	30	30
Total solids % Wet		24.2	25.6	25.5	23.4
Total lipids % Dry		2.81	0.94	1.18	1
Average weight, gm	202.3	265.3	220.86	245.3	229.2
Average length, cm	25.35	28.75	26.05	27.4	26.92

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.

BDL = Below Detection Limit

J = estimated value

B = The reported analyte was detected in the associated method blank as well as the sample

* = Value is average of duplicate samples.

Table H-5

Detectable Priority Pollutants in Fish Muscle Tissue Reference Site Reference Site #1 Maunaloa Bay

Detectable priority pollutants in fish muscle tissue	Wet	dry	dry	dry	wet
Akule -Big-eyed scad fish	**Year**	**Year**	**Year**	**Year**	**Year**
Metals	**1998**	**1999**	**2000**	**2001**	**2002**
Analyte Conc. mg/kg (ppm)(as reported in AAR)	Wet	dry	dry	dry	wet
Aluminum		7.4	1.5		
Antimony	0.09				
Arsenic	22.2	13.1	12.1	18.7	5.70
Cadmium	0.03		0.08	0.12	
Chromium, total	0.11	0.68	0.8		
Copper	0.33	4.76	5.1	2.9	
Iron		59.7	60.7	47.9	
Lead			0.02 "B"	0.03	
Mercury	0.07	0.38	0.6	0.33	0.048
Nickel			0.6		
Selenium	0.98	3.79	2.3	2.4	
Thallium					
Zinc	3.7	36	49	23.9	
Other substances, ug/kg weight					
Endosulphan Sulphate					
Endrin Aldehyde					
Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor					
Dieldrin					
4,4'-DDT					
2,4'-DDT					
4,4'-DDE					
4,4'-DDD					
Methoxychlor					
PBC 99					
PCB 118					
PCB 138					
PCB 153					
PCB 180					
PCB 187					
PCB 1260					
Phenanthrene			82		

Anthracene			18		

Table H-5

Detectable Priority Pollutants in Fish Muscle Tissue Reference Site Reference Site #1 Maunaloa Bay (CONTINUE)

Flouranthene			160		
Pyrene			78		
Benza(a)anthracene			20		
Chrysene			28		
Benzo(b)flouranthene			25		
Benzo(k)flouranthene			16		
Benzo(a)pyrene			12		
Indeno(1,2,3-cd)pyrene			14		
Benzo(g,h,i)perylene			14	20	
Methylene chloride					
Di-n-butyl Phthalate	100 "B"				
Bis (2-Ethylhexyl) Phthalate					

Composite Information					
No.of Fish composited	21	10	21	30	26
Total solids % Wet		25.5	26.4	26.5	24.2
Total lipids % Dry		4.43	0.79	1.86	0.59
Average weight, gm	222.89	242.16	282.71	271.6	214.12
Average length, cm	26.62	27.11	28.33	27.97	26.94

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.
BDL = Below Detection Limit
J = estimated value
B = The reported analyte was detected in the associated method blank as well as the sample
* = Value is average of duplicate samples.

Table H-6

Detectable Priority Pollutants in Fish Muscle Tissue Reference Site #2 Maunalua Bay

Akule -Big-eyed scad	**Year**	**Year**	**Year**	**Year**	**Year**
Metals	**1998**	**1999**	**2000**	**2001**	**2002**
Analyte Conc. mg/kg wt (units as reported in AAR)	wet wt.	dry wt.	dry wt.	dry wt.	wet wt.
Aluminum		1.9	1.4	1.1	
Antimony					
Arsenic		13.9	12.3	18.6	3.70
Cadmium		0.04	0.05	0.06	
Chromium, total		0.5	0.7		
Copper		4.67	4.1	4.6	
Iron		53.7	61.2	54	
Lead		0.03		0.04	
Mercury		0.65	0.3	0.29	0.062
Nickel		0.2	0.5	0.2	
Selenium		3.8	2.1	2.6	
Thallium					
Zinc		47.9	39.1	24.7	
Other substances, ug/kg wet weight					
Endosulphan Sulphate					
Endrin Aldehyde					
Heptachlor Epoxcide					
Chlordane, alpha					
Trans-Nonachlor		2			
Dieldrin					
4,4'-DDT					
2,4'-DDT					
4,4'-DDE		2			
4,4'-DDD					
Methoxychlor					
PBC 99					
PCB 118					
PCB 138					
PCB 153			**2.8**	**2.8**	
PCB 180			**3.9**	**3.9**	
PCB 187					
PCB 1260					
Phenanthrene			38		
Anthracene					

Flouranthene			57		

Table H-6

Detectable Priority Pollutants in Fish Muscle Tissue Reference Site #2 Maunalua Bay

(CONTINUE)

Pyrene			31		
Benza(a)anthracene					
Chrysene			10		
Benzo(b)flouranthene					
Benzo(k)flouranthene					
Benzo(a)pyrene					
Indeno(1,2,3-cd)pyrene					
Benzo(g,h,i)perylene					
Methylene chloride					
Di-n-butyl Phthalate					
Bis (2-Ethylhexyl) Phthalate					

Composite Information					
No.of Fish composited	0	10	19	30	30
Total solids % Wet	0	25.1	25.9	26.6	24.8
Total lipids % Dry	0	3.51	1.13	1.43	0.76
Average weight, gm	0	259	255.84	268.03	222.67
Average length, cm	0	28.05	26.47	28	27.05

P = Used for a pesticide/Aroclor target analyte when there is >25% difference for detected concentrations between two analystical columns. The lower of the two values is reported.
BDL = Below Detection Limit
J = estimated value
B = The reported analyte was detected in the associated method blank as well as the sample
* = Value is average of duplicate samples.

Table H-7
Detectable Priority Pollutants in Fish Muscle Tissue at the Sand Island Ouftall and at a Reference Site in Maunalua Bay - Menpachi

Metals	Ave	Ave
Menpachi - Golden-finned squirrel fish	**Sand Island**	**Control**
Analyte Conc. mg/kg wet wt	**1998**	**1998**
Arsenic	0.24 "B"	0.09
Cadmium		0.02
Chromium	0.16	0.11
Copper	0.27	1.75
Lead	0.07	
Mercury	0.08	0.085
Nickel		0.06
Selenium	0.7	0.865
Silver		
Zinc	3.1	5
PCB 1260	0.0099 "P"	
Chlordane, alpha		
Dieldrin		
4,4-DDE		
4,4-DDD		
Cyanide		
Methylene chloride		
Di-n-butyl phthalate	0.096 "B"	
bis (2-Ethylhexyl) phthalate		1.23 "B"
Methoxychlor		
Chloromethane		
Composite Information		
Average weight		
Average length		

BDL = Below Detection Limit
J = estimated value

Table H-8

MuscleTissue Arsenic Levels in Three Species of Fish Caught Near the Honouliuli Ocean Outfall, 1991-95

Arsenic in fish at Honouliuli outfall	Year	Year	Year	Year	Year
Analyte Conc. mg/kg wet wt	**1991**	**1992**	**1993**	**1994**	**1995**
Menpachi - Golden-finned squirrel fish	5.9	11.8	8.1	8.74	15.5
Ta'ape - Blue-lined snapper	3.3	4.49	1.1	5.96	8.1
Akule -Big-eyed scad fish	1.68	5.07	8.1	3.74	0.40

Table H-9

Comparative Table of Levels of Arsenic and Mercury in Market Fish (mg/Kg, wet weight)

Species	**No. of samples**	**Arsenic**			**Mercury**		
		Min.	**Max**	**Mean**	**Min.**	**Max.**	**Mean**
Blue marlin *Makaira nigricans*	18	0.40	7.3	2.25	0.13	9.3	3.2
Shortbill spearfish *Tetrapterus atlanticus*	13	0.89	5.0	2.01	0.02	0.40	0.21
Striped marlin *Tetrapterus audax*	27	0.45	6.1	3.3	0.02	1.52	0.72
Dolphinfish (Mahimahi) *Coryphaena hippurus*	33	1.43	6.9	3.03	0.02	0.38	0.11
Striped mullet *Mugil cephalus*	40	0.50	7.45	2.2	0.02	0.14	0.05
Red snapper (ehu) *Etelis marchi*	40	0.62	20.8	6.72	0.16	0.93	0.50
Gray snapper *Aprion virsescens*	40	0.50	9.45	4.66	0.10	1.0	0.32
Soldierfish (Menpachi) *Myripristis argyromus*	20	2.7	20.0	8.78	0.06	0.16	0.11

Source: Hall, R. A. , E. G. Zook, and G. M. Meaburn, 1978. National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource. NOAA Technical Report NMFS SSRF-721. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. March.

Table H-10
Chemical Residues Reported in Marine Fish Worldwide

Chemical	Concentration ppm, wet wt (unless otherwise indicated).	Location	Reference
Arsenic	0.016-32.3	Saudi Arabia	Atlar et al, 1992
	0.4-2.1	Pakistan	Tariq et al, 1991
Cadmium	0.2-0.27	Denmark	Jorgensen and Pedersen, 1994
	0.23-1.04	Pakistan	Tariq et al, 1991
	0.03 - 0.2	Turkey	Kucuksezgin and Balci,1994
	0.01-0.5 (dry wt)	Spain	Pastor, et. al, 1994
Chromium	1.5-5.1	Turkey	Kucuksezgin and Balci,1994
	3.3-6.2	Pakistan	Tariq et al, 1991
Copper	0.84-4.8 (dry)	Taiwan	Han et al, 1994
	0.8-2.1	Pakistan	Tariq et al, 1991
	2-18	Denmark	Jorgensen and Pedersen, 1994
Lead	0.3-0.8	Denmark	Jorgensen and Pedersen, 1994
	0.9-2.2	Turkey	Kucuksezgin and Balci,1994
	0.05-11.2	Spain	Pastor, et. al, 1994
Mercury	0.03-0.26	Denmark	Jorgensen and Pedersen, 1994
	0.01-0.3	Turkey	Kucuksezgin and Balci,1994
	0.03-1.4	Spain	Pastor, et. al, 1994
	0.08-1.02	Israel	Hornung et al, 1994
	0.003-0.16	Pakistan	Tariq et al, 1991

	0.13-3.2	Italy	Barghigiani and deRamien, 1992.
Nickel	0.77-3.25	Pakistan	Tariq et al, 1991
Silver	0.2-1.76	Pakistan	Tariq et al, 1991
Zinc	20-50	Denmark	Jorgensen and Pedersen, 1994
	2.36-3.8	Turkey	Kucuksezgin and Balci,1994
	1.1-10.7	Pakistan	Tariq et al, 1991

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Hornung,H. et al. 1994. Distribution and Compositon of Fatty Acids in Muscel Lipids of Inshore Fish and Deep Water Sharks from the Eastern Mediterranean. Mar. Poll. Bull. (G. B.) 28,448.

Jorgensen, L. A. and B. Petersen, 1994. Trace Metals in Fish Used for Time Trend Analysis and as Environmental Indicators. Mar. Poll. Bull. (G. B.)., 38,169.

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Table H-11
Muscle Tissue Mercury Levels in Composite Samples of Rig-Caught Fish
1998-2002
Sand Island Outfall Diffuser Region
Analyte concentration in mg/kg (ppm) wet weight

Species	Location	1998	1999	2000	2001	2002
Ta'ape *Lutjanus kasmira* Blue-lined snapper	Outfall diffuser	0.07	0.16	0.09	0.08	0.07
	Reference 1	0.09	0.07	0.11	0.08	0.045
	Reference 2		0.10	0.068	0.07	0.118
Akule *Trachiurpos crumenopthalamus* Big-eyed scad	Outfall diffuser	0.08	0.148	0.078	0.115	0.13
	Reference 1	0.07	0.112	0.158	0.086	0.048
	Reference 2		0.162	0.076	0.076	0.062

Reference samples collected in Maunalua Bay

Table H-12
Muscle Tissue Arsenic Levels in Composite Samples of Rig-Caught Fish

1998-2002

Sand Island Outfall Diffuser Region and Reference Sites

Analyte concentration in mg/kg (ppm) wet weight

Species	Location	1998	1999	2000	2001	2002
Ta'ape *Lutjanus kasmira* Blue-lined snapper	Outfall diffuser		5.67	6.86	6.9	5.7
	Reference 1	5.8	5.1	3.7	5.5	4.8
	Reference 2		4.7	3.3	5	5.2
Akule *Trachiurpos crumenopthalamus* Big-eyed scad	Outfall diffuser	4.1	4.2	3.0	4.0	4.4
	Reference 1	5.2	3.4	3.2	4.9	5.7
	Reference 2		3.5	3.2	4.9	3.7

Reference samples collected in Maunalua Bay

Table H-13

Bioaccumulation Criteria Relevant to Impact Assessment Levels in Marine Organisms (ppm)

Chemical	NAS Recommended Guideline (whole fish) (A)	FDA Action Level or Tolerance (edible portion) (B)	OEHHA Trigger or Health Advisory Level (edible portion) (C)
Total PCB	0.50	2.0*	0.100
Total DDT	0.05	5.0	0.100
aldrin	(D)	0.030*(E)	-
dieldrin	(D)	0.30*(E)	-
heptachlor	(D)	0.30*(E)	-
heptachlor epoxide		0.30*(E)	-
lindane	0.050	-	-
chlordane	0.050	0.30	0.023
endosulfan	0.050	-	-
methoxychlor	0.050	-	-
mirex	0.050	-	-
toxaphene	0.050	5.0	-
hexachlorobenzene	0.050	-	-
any other chlorinated hydrocarbon pesticide	0.050	-	-
mercury	-	1.0* (as methyl mercury)	0.50 (as total mercury)

Footnotes:

A. National Academy of Science. 1973. Water Quality Criteria, 1972 (Blue Book). The recommendation applies to any sample consisting of a homogeneity of 25 or more fish of any species that is consumed by fish-eating birds and mammals, within the same size range as the fish consumed by any bird or mammal. No NAS recommended guidelines exist for marine shellfish.

B. U.S. Food and Drug Administration. 1984. Shellfish Sanitation Interpretation: Action Levels for Chemical and Pisonous Substances. A tolerance, rather than an action level, has been established for PCB.

C. Office of Environmental Health Hazard Assessment. 1991. A Study of Chemical Contamination of Marine Fish from Southern California. II. Comprehensive Study. A health advisory level, rather than a trigger level, has been established for mercury. These values should only be used if they specifically apply to the water bodies for which they were developed.

D. Limit is 5 ppm wet weight. Singly or in combination with other substances noted by footnote .

E. Singly or in combination for shellfish

*Fish and shellfish

Table H-12
Organochlorine Pesticides in Whole Fish, August-October 1998, Oahu, Hawaii

Concentrations in micrograms per kilogram wet weight [µg/kg] unless otherwise specified; <, actual value is less than value shown, which is the minimum reporting level

	Ala Wai Canal at Honolulu	Kaneohe Stream below Kam Hwy		Manoa Stream at Kanewai Field		Nuuanu Stream above Waolani Street at Honolulu	Poamoho Stream near Waialua	Waihee Stream near Kahaluu	Waikele Stream at Waipahu
USGS station no.	211712157494801	16274100		16242500		16235100	213407158065801	16284200	16213000
Land use	urban	urban		urban		urban	agriculture	conservation	mixed
Fish species	*Tilapia sp.*	*Gambusia affinis*	*Poecilia sphenops*	*Gambusia affinis*	*Xiphophorus helleri*	*Poecilia sphenops*	*Hemichromis elongatus*	*Xiphophorus helleri*	*Xiphophorus helleri*
Compound									
Aldrin	<5	<5	<5	<5	<5	<5	<5	<5	<5
cis-Chlordane	17	20	63	64	320	100	<5	<5	<5
trans-Chlordane	9	13	36	31	75	35	<5	<5	<5
Dacthal (DCPA)	<5	<5	<5	<5	<5	<5	<5	<5	<5
o,p'-DDD	<5	<5	<5	<5	<5	<5	<5	<5	<5
p,p'-DDD	15	<5	<5	5.5	12	22	23	<5	<5
o,p'-DDE	<5	<5	<5	<5	<5	<5	<5	<5	<5
p,p'-DDE	57	12	<5	24	38	12	180	<5	43
o,p'-DDT	<5	<5	<5	<5	<5	<5	<5	<5	<5
p,p'-DDT	<5	<5	7.2	<5	20	8.3	11	<5	<5
Dieldrin	50	460	600	1200	870	1200	<5	<5	10
Endrin	<5	<5.4	<5	<5	<5	<5	<5	<5	<5
alpha-HCH	<5	<5	<5	<5	<5	<5	<5	<5	<5
beta-HCH	<5	<5	<5	<5	<5	<5	<5	<5	<5
delta-HCH	<5	<5	<5	<5	<5	<5	<5	<5	<5

Table H-12
Organochlorine Pesticides in Whole Fish, August-October 1998, Oahu, Hawaii
(CONTINUE)

gamma-HCH (Lindane)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Heptachlor	<5	<5	<5	<5	<5	<5	<5	<5	<5
Heptachlor epoxide	<5	66	54	66	55	110	<5	<5	<5
Hexachlorobenzene	<5	<5	23	<5	5.2	16	<5	<5	<5
o,p'-Methoxychlor	<5	<5	<5	<5	<5	<5	<5	<5	<5
p,p'-Methoxychlor	<5	<5	<5	<5	<5	<5	<5	<5	<5
Mirex	<5	<5	<5	<5	<5	<5	<5	<5	<5
cis-Nonachlor	26	47	46	116	130	78	<5	<5	<5
trans-Nonachlor	38	170	180	390	360	210	<5	<5	7.4
Oxychlordane	7.9	<5	110	<5	<5	<5	<5	<5	<5
PCBs total	130	<50	<50	<50	<50	55	<50	<50	<50
Pentachloroanisole	<5	<5	<5	<5	<5	<5	<5	<5	<5
Toxaphene	<200	<200	<200	<200	<200	<200	<200	<200	<200
Sample weight (grams)	10	10	10	10	10	10	10	10	10
Lipids (% by weight)	4.3	4.5	5.3	4.1	3.5	6.4	2.6	4.8	3.3

Table H-15

Screening Values (SVs) for Various Contaminants and Risk Levels Assuming Consumption of Selected Fish Species Caught in Mamala Bay (based on wet weight)

Screening Value Calculation

1	2	3	4	5	6	7	8	9	10	11
Substance	Fish Consump Rate CR kg/day	Body Weight BW kg	Reference Dose RfD mg/kg/day	Cancer Slope Factor, SF 1/(mg/kg/day)	Screening Values For Carcinogens (SVc) @ Indicated Risk Level (RL)				Noncarcinogen Screening Value (SVn) mg/kg;ppm	Maximum Value Found in any Fish Tissue Sample mg/kg;ppm
					1E-04 mg/kg;ppm	1E-05 mg/kg;ppm	1E-06 mg/kg	1E-07 mg/kg;ppm		
Arsenic	0.165	70	3.0E-04	1.8 *	2.4E-02	2.4E-03	2.4E-04	2.4E-05	**0.13**	**5.7**
Mercury	0.165	70	** 3.0E-04	N/A					**0.13**	**0.13**
4,4'-DDE	0.165	70	4.1E-07	.34	1.2E-1	1.2E-2	1.23-3	1.2E-4	0.25	0.0010
4.4'-DDT	0.165	70	3.0E-1	.54	3.0E-3	3.0E-4	3.0E-5	3.0E-6	0.28	0.0017
PCB 118	0.165	70	N/A	1	1.0E-2	1.0E-3	1.0E-4	1.0E-5		0.0005
PCB 138	0.165	70	N/A	1	1.0E-2	1.0E-3	1.0E-4	1.0E-5		0.0008
PCB 153	0.165	70	N/A	1	1.0E-2	1.0E-3	1.0E-4	1.0E-5		0.0019
PCB 180	0.165	70	N/A	1	1.0E-2	1.0E-3	1.0E-4	1.0E-5		0.0008
PCB 187	0.165	70	N/A	1	1.0E-2	1.0E-3	1.0E-4	1.0E-5		0.0006
Trans-Nonachlor	0.165	70	5E-4	N/A						0.011

Notes:
1) Column 2 = Average (U.S. Population) consumption for marine, estuarine, fresh water 0.020 kg/d. Calculations assume a 90. percentile consumption of Fish and Shellfish for marine, estuarine, fresh water of 0.140 kg/day.
2) Column 3 = Assumes 70 kg weight/person and 70 year average lifespan.
3) Columns 6 to 9: SVc=[(RL/SF)*BW]/CR per EPA "Guidance for Assessing Chemical Contaminant Data... Vol. 1" 8/93.
4) Column 10: SVn=(RfD*BW)/CR per EPA "Guidance for Assessing Chemical Contaminant Data... Vol. 1" 8/93.
5) Column 11: Highest level of substance found in any of the three fish species tested.
8) Column 7 is the acceptable risk level generally used in example calculations given in "Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories, Vol. 2 - Risk Assessment and Fish Consumption Limits - EPA, June 1994.
* Values from Ref. 10. All other RfD and SF values from Ref. 9 or the IRIS 2 data base.
a Not listed in Iris data base due to lack of reliable information.
N/A - Not listed in Iris Data base as an oral carcinogen.
** The IRIS database does not provide a reference dose for the metal but does for its soluble salts. The reference dose for the soluble salts are therefore used. For Mercury and lead the soluble salts RfD is higher than the current EPA drinking water standard.
Trans-Nonachlor is a component of Lindane (gama-hexachlorohexane) and RfD is for Lindane.