# WATER QUALITY

# AND ITS RELATION TO USEAGE

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## WATER QUALITY AND USES

The relationship between water quality and its ultimate use has been established over the years. Often the quality of raw water available has governed the site selection for an industrial establishment and, equally important, has determined whether a community grew and prospered or failed to develop.

Molokai has an abundance of water on its eastern coastal mountains and a lack of water on its southern and central plain. The surface water is generally of good quality while the ground water may be of extremely variable quality.

## WATER QUALITY PARAMETERS

Water quality criteria specifically describe the characteristics of water as being desirable for a general or a specific use. The determination of these characteristics can only be determined after a long period of use and observation. On observation of undesirable effects, the quantitative relationship between the water constituent and its effect must be correlated and the limiting water quality standard set. Often the water constituents may inter-relate and may either intensify or nullify the effects of each on the other. The specific parameters of quality are determined from these observations.

### Public Water Supply

The domestic use of water is often more demanding than those for other uses; however, human beings can often tolerate water of a quality unacceptable for certain industries. The high quality of water for the domestic public water supply is necessary for the protection of the human consumer.

For many years the standards set by the U.S. Public Health Service for the protection of travelers on public interstate carriers has served as the guide for water quality in the United States. They have now been adopted by the World Health Organization for international carriers.

The chemical and bacteriological parameters for public water supply are shown in Table 1.

These criteria were established over the years by observation of human physiological reactions to the various waters. Total dissolved solids about 500 mg/l are often objectionable since they produce stomach and other intestinal upsets, and often give a mineral taste to the water. Nitrates in concentrations above 50 mg/l produce methemoglobinenia in infants. Chlorides above 275 mg/l definitely taste salty and cause dehydration in human beings.

On the other hand, waters with a very low level total dissolved solids content, below 40 mg/l, are inclined to be corrosive and be of definite economic effect. The alkalinity and pH must be in sufficient ratio to prevent corrosion, yet the alkalinity must be low enough to avoid incrustation in hot water heaters, hot water pipes, and boilers. Below certain pH and alkalinity levels, water becomes corrosive. This condition can be avoided by proper treatment.

Fluorides in water in concentrations of greater than 0.5 mg/l and less than 1.7 mg/l are recommended for the inhibition of caries in humans; however, concentrations greater than 1.8 mg/l cause mottled enamel in human teeth.

The presence of dissolved oxygen in potable water is always desired to give a fresh pleasant taste. It should also be high enough to indicate freedom from gross pollution, yet in concentrations less than those reported to cause corrosion to pipes.

Concentrations of organic compounds in water may cause undesirable color, taste, odor, or even foaming.

The public will often avoid a safe colored water, showing a preference for a clear colorless water which may or may not be bacteriologically safe. The presence of organic vegetable derivatives of tannin, or decomposing leaves, humic acids, may cause both color and odor. Similarly, the presence of phenol, either from natural or

TABLE 1. WATER QUALITY PARAMETERS
FOR A PUBLIC WATER SUPPLY

| CHARACTERISTIC | LIMITING CONCENTRATIONS IN MG/1 |
|---|---|
| CHEMICAL | |
| TOTAL DISSOLVED SOLIDS | 500 |
| ALKALINITY | > 30 -<500 |
| HARDNESS | 60 - 120 |
| pH (UNITS) | 6.0- 8.5 |
| COLOR (UNITS) | 15 |
| ODOR | 0. |
| TEMPERATURE | < 85°F |
| TURBIDITY | 5 |
| CHLORIDES | 250 |
| FLUORIDE | 0.8- 1.7 |
| NITRATES | 45 |
| SULFATE | 250. |
| PHOSPHATE | <100 MG/1 |
| CYANIDE | 0.20 |
| SILICA | |
| ORGANIC COMPOUNDS | |
| PESTICIDES (SPECIFIC) | |
| HERBICIDES (SPECIFIC) | |
| PHENOLS | 0.001 |
| OILS AND GREASE | ABSENT |
| ALKYL BENZENE SULFONATES | 0.5 |
| CARBON CHLOROFORM EXTRACTS | 0.15 |
| OTHER | |
| AMMONIA | 0.5 AS N |
| DISSOLVED OXYGEN | > 4. |
| RADIOACTIVITY | |
| GROSS BETA | 1000 PC/1 |
| RADIUM 226 | 3 PC/1 |
| STRONTIUM 90 | 10 PC/1 |
| METALS | |
| ARSENIC | 0.05 |
| BARIUM | 1.0 |
| BORON | 1.0 |
| CADMIUM | 0.01 |
| CHROMIUM | 0.05 |
| COPPER | 1.0 |
| IRON | 0.3 |
| LEAD | 0.05 |
| MANGANESE | 0.05 |
| SELENIUM | 0.01 |
| SILVER | 0.05 |
| URANIUM ZINC | 5.0 |
| BACTERIOLOGICAL CONSIDERATIONS | |
| MOST PROBABLE NUMBER | LESS THAN 1 COLIFORM/100 ML |

man-made wastes, will cause objectionable tastes in water both before and after treatment. The treatment of a water containing as little as 1 ppb of phenol with chlorine for bacteriological safety will yield a water with a clearly medicinal taste objectionable to most people.

Water has through the years acquired a reputation as a clear, colorless, odorless, tasteless quencher of thirst. The presence of odor usually indicates organic pollution, which may arise naturally from peat bogs, swamps, fern forests, and even mineral deposits high in organics or it may be caused by the by-products of human activities such as decaying vegetative or organic industrial wastes or sewage. These organic pollutants may be of recent origin in terms of time or water flow, or they may have originated in distant areas or in remote geologic time. Their presence can be detected through carbon chloroform extraction and the quantitative limits were established because of their influence on the taste and odor of water.

The tolerable amount of alkyl benzene sulfonate, a surface-active agent in detergents, has been set because its presence can cause objectionable foaming when the water is agitated.

Because of the use of toxic materials, such as herbicides and pesticides, on watersheds, the presence of such toxic organic materials is completely prohibited from potable domestic water supplies. Similarly, the presence of cyanides, heavy metals and other toxic metals, and radioisotopes is prohibited.

Bacteriological standards for water quality have been established over a period of many years. These standards call for the presence of less than 1 coliform organism in 100 milliliters of water. This is the level at which the safety of human health is considered likely.

## Water Resources of Molokai

The quality of the surface waters of Molokai have been presented and discussed in some depth in the section of this report titled, "Water Quality of Molokai."

*SURFACE WATER.* The surface water of Molokai is often used as a public water supply; however, it has been noted that much of each year the color of this water and its peaty taste exceed the levels of the standards and iron stained bathroom fixtures are common. In periods of high runoff, the turbidity of the water reaches unacceptable levels. Frequently the bacteriological standards for potable water are exceeded despite the inaccessibility of the watershed areas and the rigid policing which is practiced to keep intruders from the watershed reserve. In addition few of the surface-water sources of Molokai are aesthetically acceptable without treatment. Although certain community water supplies dispense such surface water, it is not acceptable according to the U.S. Public Health Service and the consumers use it because it is the only water available. Examples of such water supplies are those of Mauna Loa, Kualapuu and the Hawaiian Home surface supply.

With conventional water-treatment procedures and equipment, the surface waters of Molokai can be treated to a level both aesthetically and bacteriologically acceptable for use as a domestic potable supply.

*GROUND WATER.* Molokai's ground-water is obtained from diked, perched, or basal sources. The quality of the water varies with the location of the source and the method used to obtain it.

In general the best quality of water comes from dikes, especially those at the rift zones of the East Molokai volcano. The overflow from the confined barriers surface as high-level springs which yield high quality water.

Many of the perched-water sources in the upper and lower volcanic series of East Molokai have been tunneled to obtain a high quality water for the county water system.

The basal ground-water lens of the island of Molokai floats on the surrounding sea water. In areas of high rainfall and high recharge of the lens, the water is of good quality; however, in areas of low rainfall and low recharge, particularly the shoreward areas of the west and southern edge of the island of Molokai, the basal lens is brackish even at the center of the island mass. Springs in East Molokai and West Molokai reflect the amount of recharge and also their proximity to and level above the sea. In the East Molokai area they are only slightly brackish and in West Molokai they are very brackish.

The shallow wells of the southern area of Molokai produce water of variable quality, deeper wells reflect penetration to the basal lens and there is a progressive deterioration of water quality with depth.

The Maui-type shafts developed at higher elevations inland from the coast, skim the fresh water from the top of the lens and are a good source of water.

All of these sources serve as water supplies for some of the major communities on the island of Molokai. In general, they are fine sources of quality water for domestic potable purposes. However in one case, the well of the Hawaiian Home Commission we may observe a water supply which approaches the extreme limits of the U.S. Public Health Service Standards in two particular categories, that of total dissolved solids and iron content.

With care in the selection of site and with proper development, ground-water sources of water on Molokai can produce safe and acceptable water for domestic community supplies. The matter of safe yield and protection of the supply over an extended life period are matters of engineering consideration.

The use of water on Molokai for domestic potable consumption is shown in Table 2.

The projected demand for future domestic potable water is shown in Table 3.

## INDUSTRIAL USES

The industrial uses of water are numerous and varied and may range from a simple one of heat transfer as in cooling or heating

TABLE 2

DOMESTIC POTABLE WATER USE
PRESENT

| COMMUNITY OR SYSTEM | | CONSUMPTION MGD |
|---|---|---|
| MOLOKAI IRRIGATION DISTRICT | | 0.330 |
| HAWAIIAN HOME LANDS | 2 | 0.285 |
| KALAUPAPA | 3 | 0.216 |
| KAUNAKAKAI | 5 | 0.278 |
| UALAPUE | 6 | 0.064 |
| KALAE | 9 | 0.010 |
| HALAWA | 8 | 0.0005 |
| MOLOKAI RANCH, LTD. | 10 | 0.285 |
| LIBBY, MCNEILL AND LIBBY | 4 | 0.230 |
| CALIFORNIA PACKING CORP. | 7 | 0.165 |
| TOTAL | | 1.8635 |

NUMBERS INDICATE CORRESPONDING ITEM IN TABLE 2.

2, 3, 4, 8, 10 -- SURFACE STREAM FLOW

6 -- MAUI TYPE WELL SUPPLIES

7 -- DEEP WELL SUPPLY

9 -- PERCHED, TUNNEL SYSTEMS

5 -- SURFACE AND MAUI TYPE WELL SUPPLY

TABLE 3

ESTIMATED POTABLE WATER DEMANDS
1985

| COMMUNITY | | FUTURE WATER DEMANDS MGD |
|---|---|---|
| KAUNAKAKAI | 5 | 1.840 |
| KAMILOLOA-KAWELA | 6 | 0.750 |
| MAKOLELAU-KAMALO | 6 | 0.860 |
| KEAWANUI | | 2.240 |
| PUKOO | 6 | 0.480 |
| HOOLEHUA | 2 | 0.373 |
| KALAUPAPA | 3 | 0.200 |
| KALAE | 9 | 0.390 |
| MAUNA LOA | 4 | 0.250 |
| TOTAL | | 7.413 |

(BASED ON MOLOKAI LAND USE AND MASTER PLAN, COUNTY OF MAUI, 1961 UPDATED TO 1966) (steam generation) or it may be complete incorporation of the water into the product as in the production of carbonated beverages.

Water-quality requirements vary also according to the use. Water incorporated into a food product must meet all the quality requirements of the U.S. Public Health Service Standard but water used for cooling need only be non-corrosive.

The criteria of water quality which must be evaluated for industrial use vary considerably in magnitude, but a selected list of these criteria are given in Table 4 with some of the extremes of limits for these materials.

TABLE 4

WATER QUALITY PARAMETERS FOR INDUSTRIAL USE

| CHARACTERISTIC | EXTREME VALUES OF LIMITING CONCENTRATIONS IN MG/1 | |
|---|---|---|
| TOTAL DISSOLVED SOLIDS | 0 | 34,000 |
| ALKALINITY | 4 | 15,000 |
| ACIDITY | 0 | 78,000 |
| HARDNESS | 0 | 12,000 |
| pH | 4.5 | 12. |
| TOTAL SUSPENDED SOLIDS | 0 | 10,000 |
| TEMPERATURE $^{\circ}$F | 33$^{\circ}$ | 95$^{\circ}$ |
| SILICA | 0.00 | 150 |
| BICARBONATE | 0. | 30. |
| CHLORIDES | 0 | 38,000 |
| FLUORIDE | 0 | 4 |
| NITRATE | 0 | 10 |
| PHOSPHATE | 0 | 70 |
| SULFATE | 0 | 500 |
| DISSOLVED OXYGEN | 0 | SATURATION |
| TOTAL ORGANICS | | |
| CARBON CARBON-TETRACHLORIDE EXTRACTABLES | | <100 |
| CHEMICAL OXYGEN DEMAND | | <100 |
| HYDROGEN SULFIDE | | < 4. |

ALSO ALL ADDITIONAL PARAMETERS LISTED IN TABLE 5.

It is interesting to note that many of the suggested water quality parameters for industrial use have grown out of chemical constituents which have given industry the greatest problems.

The most demanding use for water is in the manufacture of color television viewing tubes. The water-quality demands amount to that of quadruple distilled water or completely ion-free water.

Other requirements are somewhat more prosaic. In the case of fluorides, this low value was set by the brewing industry since water with fluorides caused a haze to appear in the beer and whiskey upon extended shelf storage. Similarly, requirements for low hardness in water resulted from the excessive use of soap in the laundry industry. Color in water was found to be extremely objectionable in the perfume-formulating industry.

The greatest ultimate use of water in industry is in the generation of steam.

Over the years, steam has come to be the preferred heat-transfer media and an efficient and relatively inexpensive source of power. The generation of steam from water is a relatively simple phase conversion, however, the solids deposited and gases evolved from the water in the phase transfer from liquid to steam vapor has given rise to boiler and heat transfer problems which increased in nearly direct proportion to the increase in steam pressure. As a result certain suggested limits for tolerance for boiler-feed waters have evolved. These are shown in Table 5.

The inclusion of a limit to the amount of organic compounds in industrial water quality standards is of extreme interest because the National Technical Advisory Committee on Water Quality Standards included organics which are extracted by the carbon-carbon tetrachloride method. In potable water standards the organics described are those extracted by carbon-chloroform extraction. The extraction method utilizing activated carbon followed by carbon tetrachloride extraction does not extract many of the organics which are extracted by chloroform. It is interpreted that while industry is vitally concerned with organics

TABLE 5 - SUGGESTED LIMITS OF TOLERANCE FOR BOILER FEED WATER

(FROM "PROGRESS REPORT OF THE COMMITTEE ON QUALITY TOLERANCES OF WATER FOR INDUSTRIAL USES".)
(PARTS PER MILLION, EXCEPT FOR DISSOLVED OXYGEN AND pH)

| PRESSURE (LB. PER SQ. IN.) | 0-150 | 150-250 | 250-400 | OVER 400 |
|---|---|---|---|---|
| TURBIDITY | 20 | 10 | 5 | 1 |
| COLOR | 80 | 40 | 5 | 2 |
| OXYGEN CONSUMED | 15 | 10 | 4 | 3 |
| DISSOLVED OXYGEN A/ | 2.0 B/ | 0.2 B/ | 0.0 B/ | 0.0 B/ |
| HYDROGEN SULPHIDE ($H_2S$) C/ | 5 | 3 | 0 | 0 |
| TOTAL HARDNESS ($CaCO_3$) | 80 | 40 | 10 | 2 |
| SULPHATE-CARBONATE RATIO (A.S.M.E.) ($Na_2SO_4:Na_2CO_3$) | 1:1 | 2:1 | 3:1 | 3:1 |
| ALUMINUM OXIDE ($Al_2O_3$) | 5 | 0.5 | 0.05 | 0.01 |
| SILICA ($SiO_2$) | 40 | 20 | 5 | 1 |
| BICARBONATE ($HCO_3$) A/ | 50 | 30 | 5 | 0 |
| CARBONATE ($CO_3$) | 200 | 100 | 40 | 20 |
| HYDROXIDE (OH) | 50 | 40 | 30 | 15 |
| TOTAL SOLIDS D/ | 3000-500 | 2500-500 | 1500-100 | 50 |
| pH VALUE (MINIMUM) | 8.0 | 8.4 | 9.0 | 9.6 |

A/ LIMITS APPLICABLE ONLY TO FEED WATER ENTERING BOILER, NOT TO ORIGINAL WATER SUPPLY.

B/ GIVEN AS ML. PER LITER. MULTIPLY BY 0.70 FOR PPM.

C/ EXCEPT WHEN ODOR IN LIVE STEAM WOULD BE OBJECTIONABLE.

D/ DEPENDS ON DESIGN OF BOILER.

in water, they are concerned primarily with those that cause fouling of ion-exchange resins and condenser tubes or similar metal heat-transfer surfaces which are more closely represented by the carbon-carbon tetrachloride extract.

The inclusion of chemical oxygen demand, a direct chemical measurement of chemically oxidized carbon compounds, serves merely to give an index to the relative level of organic matter present. This gross test is primarily for the protection of industrial process equipment. Water exhibiting a chemical oxygen demand of any magnitude would be looked at askance if suggested for potable water. Similarly, the inclusion of suspended matter serves merely to indicate potential danger to process equipment, the suspended matter may be bacteria, sewage solids, turbidity from soil particles, even suspended sand; all these are injurious to industrial process equipment but completely unacceptable in a domestic potable water supply.

The inclusion of pH, alkalinity, acidity, bicarbonate, silica, sulfates, phosphates, and dissolved oxygen all have a bearing upon the corrosivity of the water. Without proper balance even a natural water may be corrosive to piping and process equipment. Water with a proper balance of these constituents means less treatment of the water prior to industrial use.

It is interesting to note the absence of bacteriological requirements for general industrial use. Specific uses in the food industry however are as demanding as potable water, but general use in the generation of steam or as a heat transfer media do not demand such standards.

Temperature requirements are included merely to assure thermal acceptability of water for industrial use.

## Molokai Industrial Uses

Industrial water use on Molokai is very small. A certain amount of the water from the public supply is used as cooling water at the electric power generating plant in Kaunakakai. Aside from this there is no other industrial use.

It should be pointed out here however that the water available from several sources on Molokai would pose certain problems to industry.

*SURFACE SUPPLIES.* The surface-water sources of Molokai provide a soft, colored, slightly acid water which contains bacteria, iron, and silica. The water is corrosive and requires extensive treatment and conditioning before it would be considered prime industrial water.

The presence of iron limits its use in end products in which water is the main constituent and, without treatment, silica in the water limits its use to boilers of less than 250 psi.

*GROUND WATER SUPPLIES.* Water from ground sources except those from high-level dikes poses an entirely different picture.

Again the quality of water definitely reflects the source and the method of securing the water. Ground water from the elevated portions of the Ghyben-Herzberg lens is uniformly of better quality, approaching that of confined dikes. Ground water from the lower springs and wells is of less acceptable quality as the source nears the ocean.

In contrast to the corrosive unstable surface waters of Molokai, the ground waters approach a level of stability that is less likely to cause corrosion.

As might be expected in any ground water, the total dissolved solids of these waters is much higher than for surface waters. The water is moderately soft and is relatively low in iron and other metals.

As the sources are located nearer the sea, the chloride content becomes progressively higher until some springs at or below sea level reflect the salinity of the sea water in the immediate area.

In every case, ground-water sources on Molokai contain a considerable amount of silica. The quantity of silica is such that the maximum allowable pressure of steam which can be generated without undue difficulty is 250 psi.

The ground waters of Molokai will pose some problems in treatment for an industrial supply. The use of sodium-cycle cation exchange is complicated by the relatively high sodium content of the water and the use of a strong base anion exchange media is hampered somewhat by the high chloride and bicarbonate ion values. Some of these waters can be economically treated by using ion exclusion methods. In many locations ground water has a chloride content exceeding 700 mg/1. This concentration can certainly cause an unusual saline taste, but, furthermore, it makes the water extremely corrosive.

Approximately 50% of the total dissolved solids in the ground water is organic. The high organic content may be due to decaying organic matter of recent or past origin. At higher elevations, it is believed to be caused by decaying vegetable matter but at the lower levels of the island it may indicate pollution from sewage. This material, a refractory organic matter, will not only impart an unusual taste to the water but it will also foul ion exchange resins, heat exchanger surfaces, and generally degrade the water quality. Although organic matter has usually been oxidized to an advanced state, about 20% of the total dissolved solids in the better quality water supplies to as high as 50% of the total dissolved solids in water supplies from sources near the extreme discharge edges of the lens is organic matter.

The presence of organic matter is further confirmed in the finding of phenol or phenol-like organics in the waters. The phenol content exactly equals the maximum standard permissible. This indicates that when the ground water is chlorinated for bacteriological control it will have a heavy medicinal taste.

If industry of any type locates on Molokai, it must look carefully into the sources of water for many of the sources of water on Molokai can never meet the standards required for industry's use.

The projected master plan for 1980 for Molokai envision approximately 250,000 gallons per day for use in Kaunakakai town and approximately 275,000 gallons per day in the southshore areas. No water quality standards are set.

A summary of Suggested Water Quality Tolerances for use in Industry are included as Table 6. The requirements are, for the most part, self-explanatory.

## AGRICULTURAL AND OTHER USES

The use of water for agriculture in Hawaii is largely to irrigate growing plants, specifically sugar cane. However, other agricultural uses such as for farms and livestock are significant in their demands. Livestock presents needs which are somewhat similar to but less stringent than the quality standards for domestic human consumption. Irrigation water standards are far less rigid.

The parameters for agricultural water are shown in Table 7.

The prime consideration for setting standards and parameters for water quality in agricultural use is to ensure a suitable quality of food products for human beings and livestock.

There are two unique parameters in this classification of water uses. These are (1) the concentration of dissolved organic compounds in water (whether pharmaceuticals, herbicides, pesticides, industrial wastes) is determined by two factors, the toxic limit of the material and its biological accumulation in the animal body and therefore its concentration in the product intended for human consumption, and (2) the Sodium Adsorption Ratio (SAR) in irrigation waters which is a measurement of the rate at which sodium in the water is adsorbed on soil particles. A high SAR value indicates high sodium adsorption and a high sodium level in the plant product making it a less desirable product for human consumption. Further a high sodium adsorption ratio often causes the soil grains to break down and makes the soil less permeable, seriously affecting aeration and the ability of

TABLE 6 - TABLE OF SUGGESTED WATER QUALITY TOLERANCES

(FROM "PROGRESS REPORT OF THE COMMITTEE ON QUALITY TOLERANCES OF WATER FOR INDUSTRIAL USES".)

| | ALLOWABLE LIMITS IN PPM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| INDUSTRY OR USE | TURBIDITY | COLOR | HARDNESS AS $CaCO_3$ | IRON AS FE | MANGANESE AS MN | TOTAL SOLIDS | ALKALINITY AS $CaCO_3$ | ODOR TASTE | HYDROGEN SULPHIDE | OTHER REQUIREMENT |
| AIR CONDITIONING | --- | --- | --- | 0.5 B/ | 0.5 | --- | --- | LOW | 1 | NO CORROSIVENESS, SLIME FORMATION. |
| BAKING | 10 | 10 | --- | 0.2 B/ | 0.2 | --- | --- | LOW | 0.2P. | A/ |
| BOILER FEED | --- | --- | --- | --- | --- | --- | --- | --- | --- | SEE TABLE 1. |
| BREWING, LIGHT BEER | 10 | --- | --- | 0.1 B/ | 0.1 | 500 | 75 | LOW | 0.2P. | NaCl LESS THAN 275 PPM (pH 6.5-7.0) |
| DARK BEER | 10 | --- | --- | 0.1 B/ | 0.1 | 1000 | 150 | LOW | 0.2P. | NaCl LESS THAN 275 PPM (pH 7.0 OR MORE) |
| CANNING, LEGUMES | 10 | --- | 25-75 | 0.2 B/ | 0.2 | --- | --- | LOW | 1 P. | |
| GENERAL | 10 | --- | --- | 0.2 B/ | 0.2 | --- | --- | LOW | 1 P. | |
| CARBONATED BEVERAGES | 2 | 10 | 250 | 0.2 (0.3 B/) | 0.2 | 850 | 50-100 | LOW | 0.2P. | ORGANIC COLOR PLUS $O_2$ CONSUMED LESS THAN 10 PPM |
| CONFECTIONERY | --- | --- | --- | 0.2 B/ | 0.2 | 100 | --- | LOW | 0.2P. | |
| COOLING | 50 | --- | 50 | 0.5 B/ | 0.5 | --- | --- | --- | 5 | NO CORROSIVENESS, OR SCALE FORMATION. |
| DISTILLING | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| FOOD, GENERAL | 10 | --- | --- | 0.2 B/ | 0.2 | --- | --- | LOW | ---P. | |
| ICE | 5 | 5 | --- | 0.2 B/ | 0.2 | | --- | LOW | ---P. | $SiO_2$ LESS THAN 10 PPM |
| LAUNDERING | --- | --- | 50 | 0.2 B/ | 0.2 | --- | --- | --- | --- | |
| PLASTICS, CLEAR, UNCOLORED | 2 | 2 | --- | 0.2 B/ | 0.02 | 200 | --- | --- | --- | |
| PAPER AND PULP, GROUNDWOOD | 50 | 20 | 180 | 1.0 B/ | 0.5 | --- | --- | --- | --- | NO GRIT, CORROSIVENESS. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| KRAFT PULP | 25 | 15 | 100 | 0.2 B/ | 0.1 | 300 | --- | --- | --- | |
| SODA AND SULPHITE | 15 | 10 | 100 | 0.1 B/ | 0.05 | 200 | --- | --- | --- | |
| HIGH-GRADE LIGHT PAPERS | 5 | 5 | 50 | 0.1 B/ | 0.05 | 200 | --- | --- | --- | |
| RAYON (VISCOSE), PULP PRODUCTION | 5 | 5 | 8 | 0.05 B/ | 0.03 | 100 | TOTAL 50 HYDROXIDE 8 | --- | --- | $Al_2O_3$ LESS THAN 8 PPM. $SiO_2$ LESS THAN 25 PPM Cu LESS THAN 5 PPM. |
| MANUFACTURE | 0.3 | --- | 55 | 0.0 | 0.0 | --- | --- | --- | --- | pH 7.8 TO 8.3. |
| TANNING | 20 | 10-100 | 50-135 | 0.2 B/ | 0.2 | --- | TOTAL 135 HYDROXIDE 8 | --- | --- | |
| TEXTILES, GENERAL | 5 | 20 | --- | 0.25 | 0.25 | --- | --- | --- | --- | |
| DYEING | 5 | 5- 20 | --- | 0.25 B/ | 0.25 | 200 | --- | --- | --- | CONSTANT COMPOSITION. RESIDUAL ALUMINA LESS THAN 0.5 PPM |
| WOOL SCOURING | --- | 70 | --- | 1.0 B/ | 1.0 | --- | --- | --- | --- | |
| COTTON BANDAGE | 5 | 5 | --- | 0.2 B/ | 0.2 | --- | --- | --- | --- | |

A/ P INDICATES THAT POTABLE WATER, CONFORMING TO U. S. P. H. S. STANDARDS, IS NECESSARY.

B/ LIMIT GIVEN APPLIES TO BOTH IRON ALONE, AND THE SUM OF IRON AND MANGANESE.

TABLE 7

PARAMETERS FOR AGRICULTURAL WATERS

| CHARACTERISTIC | CONCENTRATION PERMITTED IN MG/1 |
|---|---|
| FOR LIVESTOCK | |
| TOTAL DISSOLVED MATERIAL | <10,000 |
| RADIONUCLIDES | |
| (GROSS BETA, | < 1,000 PC/1 |
| RADIUM 226 | < 3 PC/1 |
| STRONTIUM 90) | < 10 PC/1 |
| ARSENIC | < 0.05 |
| BORON | < 0.01 |
| CADMIUM | < 0.05 |
| CHROMIUM | < 2.40 |
| FLUORIDE | < 0.05 |
| LEAD | < 0.01 |
| SELENIUM | |
| FOR IRRIGATION | |
| TOTAL DISSOLVED MATERIAL | < 750. |
| SODIUM ADSORPTION RATIO | < 4 |
| CHLORIDES | < 750 |
| pH | |
| RADIONUCLIDES | AS ABOVE |
| METALS | |
| ALL METALS FROM ALUMINUM TO ZINC. | INDIVIDUAL CROP VARIETY TOLERANCES |

the soil to drain with ease.

In an island community, the chloride content of raw water for agricultural use is of intense interest. Above certain limits, chlorides in water and their associated sodium frequently lead to adverse effect on plants. This has been experienced many times when highly saline waters have been used to irrigate golf courses.

## Agricultural, Livestock, and Associated Uses on Molokai

*Irrigation uses.* Irrigation in central and west Molokai is essential for it is here that the arable land is located. Over the years the crops that have entered into Molokai's agricultural economy have been those which require a minimum of water. Pineapple has therefore developed as the crop of choice. Presently, there are 16,200 acres of pineapple which require from 5 to 6.5 million gallons of water a day when the fields are irrigated. If every bit of arable land potentially suitable for pineapple (32,500 acres) were to be converted to pineapple production 8.6 to 12.3 million gallons of water a day would be needed.

The apparent intention to diversify crops in the Molokai area, as initiated in the 1,000-acre state land south of the Molokai Airport, will mean that the irrigation demands for water will increase in direct proportion to crop needs. Twenty eight thousand acres of land are available for this purpose if such a plan is instituted, if so, the demands for irrigation water would best be doubled.

Irrigation offers the least monetary return on water of any consumptive use. The quantity of water required to produce a pound of vegetable is more than 10,000 times the amount required to produce a pound of animal tissue. On the basis of return on the money invested domestic water is the most remunerative on a quantitative basis.

*Livestock uses.* Livestock operations in south Molokai have been initiated some years ago. The estimated needs for such an enterprise have been set at 3.5 million gallons of water a day. Certain agricultural interests have proposed a poultry raising operation, the development of a dairy enterprise, and game ranching as a tourist attraction in south Central Molokai. The estimated consumptive use of water in these enterprises is 1.16 MGD. A hunting club presently operates on Molokai. This attraction is considered to be growing and is expected to use at least 100,000 gallons a day.

*Associated uses.* Tourism and the estimated uses for ancillary attractions to compliment tourist hotels, golf courses and parks (considered a basic agricultural use, needing irrigation to grow grass cover and green plant areas) are estimated to demand 1.2 million gallons of water a day. The hotels to be located on Molokai will exert a demand for themselves and their employees of 900,000 gallons per day. This water was previously included in the estimates for domestic potable water.

The total projected water needs of Molokai vary according to the estimator from 24 to 31 million gallons of water per day.

## Sources of Irrigation Water

Water for irrigation on Molokai comes from both surface and groundwater sources. The largest single source is the water provided through the Molokai Tunnel Project of the Division of Water and Land Development of the state's Department of Land and Natural Resources.

Surface sources are the stream flow of the Waokolu Valley, largely surface runoff supplemented by overflow from perched and diked-water supplies. Ground water is obtained by well development in the central plains area and along the southern coast.

The standards of quality for irrigation water have been listed earlier in this report. The surface waters have proven to be satisfactory thus far. Color, turbidity, and bacteriological quality conform to the standards and the total dissolved solids are uniformly low. In addition, the loss on ignition indicative of the total organics present runs from 6 to 40 percent, being from 6 to 15 percent in most surface sources. Chlorides are at levels from 10 to 15 mg/1. The sodium absorption ratio is on the order of 0.4 to 0.5, considered to be very low. Such a characteristic is indeed widely sought after since it directly affects the vegetables produced (a low sodium content) as well as the permeability of the soil and its ability to drain.

Ground water secured from wells for irrigation purposes varies in quality with its source and site. Many coastal wells are so brackish that it makes them completely unsuitable as sources of irrigation water.

Studies have been made on the suitability of coastal waters for crop production. Unfortunately, every well water varies in composition and no correlation has been made of physical and chemical properties of the water and the resulting crop production. It has been established that vegetable crops can be grown successfully in the Kamalo-Pukoo region since the water is only slightly contaminated by sea-water intrusion. Alfalfa has been grown in Kawela and Kaunakakai with brackish water; however, water with chloride levels of as much as 4700 mg/l of chloride ion has caused destruction of grass on golf courses.

While the development of agricultural products on Molokai are predominant in the immediate plans, it appears that tourism has the most important part in future of this island, according to the master plan for the island. In every plan golf courses, recreation areas, parks, and grassy areas have a definite role. For this, the quality of the water for surface crop irrigation is most important, and the standards are well defined.

## FISH AND WILDLIFE

One of the greatest, but often unrecognized, use of natural waters is in the protection and preservation of fish and wildlife. Naturalists look upon the production of fish and wildlife as a reproducible resource, thus the parameters set upon water quality for such use is designed to insure the conditions of the environment essential for the survival, growth, reproduction, and general health of such a crop.

## Water Quality Standards for Fish and Wildlife

Over the years it has been the custom for naturalists to define the acceptable water quality for such use. These are listed in Table 8.

TABLE 8

PARAMETERS FOR THE SURVIVAL AND INCREASE IN FISH AND WILDLIFE

| CHARACTERISTICS | |
|---|---|
| TOTAL DISSOLVED SOLIDS | |
| SALINITY | |
| TEMPERATURE | |
| TURBIDITY | 1 M BY SECCHI DISC<br>WAVE LENGTH 400-700 MU |
| COLOR | |
| HARDNESS | |
| ALKALINITY | |
| pH | |
| DISSOLVED OXYGEN | |
| CARBON DIOXIDE | |
| OBJECTIONABLE CONTAMINANTS | |
| OIL | |
| ALKYL BENZENE SULFONATE | |
| METALS (HEAVY AND TOXIC) | |
| CYANIDE | |
| RADIONUCLIDES | |
| TOXIC SUBSTANCES | 1/100 OF THE 96 HR TLM LEVEL |
| PESTICIDES | |

It is of interest to note that a maximum concentration of 0.050 g/l has been set for the following pesticide groups:

(1) chlorinated hydrocarbon base pesticides, Aldrin, Benzene hexachloride, Chlordane, Endrin, Heptachlor, Lindane, DDT, Dieldrin, Endosulfan, Methoxychlor, Perthane, D.D.D, 2.4.5.T, Toxaphene and

(2) organophosphorous base pesticides, Coumaphos, Dursban, Fenthion, Naled, Parathion, Ronnel.

The Sub-committee on Fish, Aquatic Life, and Wildlife of the National Technical Advisory Committee on Water Quality Criteria has set general guides for wide application. These guides have much to be said for them for instead of setting exact quality criteria for the waste discharge or the water into which they flow, they rely upon baseline observations of water quality and standards which relate to deviations from the baseline. This is indeed a refreshing approach.

Examples of this approach is the criterion which relates to dissolved solids. It states that dissolved materials should not be increased by more than one-third of the concentration that is characteristic of the natural condition of the water into which discharge is made. Another example is in connection with the salt water environment. Salinity changes have an acceptable range of ten percent of the naturally occurring variation. The temperature of waste waters discharged into a receiving body should not exceed more than $5^{\circ}F$ above the monthly average of the maximum daily prevailing water temperature. This is an exceptional approach for it accommodates temperature requirements of both warm and cold water species.

Requirements on the discharge of wastes containing oil are well defined:

(1) oil will produce a visible color film on the surface, or

(2) impart an oily odor to the receiving water, or

(3) coat or taint the banks or the bottom of the receiving body of water.

Bioassays are recommended to determine the tolerance levels for metals and cyanides of fish and wildlife to provide positive protection in any given area. The material to be tested is the waste discharge in the receiving water, although a somewhat unique approach, it is however an accurate measurement of the area and water.

In every case an evaluation of a waste load must include chemical and bacteriological identification of the waste constituents in addition to the level of desirable water quality characteristics.

## RECOMMENDATIONS

While water quality data for Molokai is sketchy, the development of new wells and the use of their water is not well recorded. This is essential if orderly development of the island is to take place with a minimum of economic loss.

Further, a study should be made of the observation of plant crop reaction to increasing quantities of salinity. This should serve as a baseline against which land use and available water supply may be matched.