APPENDIX D
SEWAGE TREATMENT IN HOT CLIMATES

D-1. General considerations.

Although this manual is intended to serve U. S-based activities, the U.S. Army and Air Force often must establish bases in areas which may be hotter; drier or wetter than conditions faced in the U.S. Certain factors generally found in hot climates bear special consideration.

D-2. Establishment of flow rates.

Calculation of wastewater flow may be based, as in temperate climates, upon fresh water use. However; sewage flow may be either much larger or much smaller than water use. In areas of high rainfall and water abundance, personnel will bathe more often, use water for cooling and will tend to be less water conscious. Wastewater flow may be greater than expected for a given population. Although brackish water may be used for washing, cooling or cleaning, if it is allowed to enter the wastestream, the increased salinity will lower biological process efficiencies. High dissolved solids concentrations have an impact on the treatment process efficiency. This condition should be considered in designing these systems. On the other hand, greywater may be separated from the wastestream and recycled for purification, or used directly onsite for lawns, plants, washing or cooling. Under these circumstances, wastewater flow will be low and much more concentrated. Loss of water by evapora-tion and from pipelines into the ground may further decrease flow to the treatment plant.

a. Typical low flow regimes where desert posts utilize a standpipe, practice water conservation and recycle water may require only 5-20 gallons per day per person of stored fresh water and only 2-10 gallons per day per person may arrive at the treatment plant.

b. Typical high flow regimes in the humid tropics are subject to considerable infiltration, use of warm rooftop or cistern stored water and high shower utilization require 100-125 gallons per day per person of fresh water and 130-150 gallons per day per person may appear at the treatment facility.

c. The engineer must, therefore, assess the water use, storage and transport patterns of the site in order to assign reasonable sewage flows.

D-3. High temperature parameters.

A major design parameter will be water temperature. Use of rooftop rain storage, cistern water; brackish water; and the ambient conditions will result in very warm sewage. The engineer shall expect high salt content, including sulfate, chloride, phosphate, borate and nitrate anions, and both alkali and alkaline earth cations. Oxygen levels will be very low and chalcogenides as well as dissolved hydrogen sulfide should be anticipated. The most dramatic effect of high temperature will be upon biochemical reaction rates. The general formula relating temperature to rate constants is as follows:

$K_t = K_{20}\,1.047^{(T-20)}$ where,

K_t = the rate constant for the sewage treatment reactions involved;

K_{20} = the rate constant for that same reaction at 20 degrees Celsius.

Using this equation, the rate constants can be calculated at 10 degrees Celsius and 35 degrees Celsius. The result indicates a 3-fold increase in the rate coefficient. It is this high rate of biological reaction which results in unexpectedly high sulfide levels, very low dissolved oxygen concentrations and large biomass accumulation. All chemical moieties found in the sewage will arrive in the reduced state in a much more microbiologically rich liquor.

D-4. Unit operations in the tropics.

Although activated sludge, trickling filter or rotating biological filter processes may be used in hot climates, strong sunlight and adequate space will often dictate the use of oxidation ponds. Temperature and sunlight intensity will control algal growth, which will be intense. The most useful type of pond will be the facultative pond, which is aerobic at the surface and anaerobic at the bottom. Pond retention time may be over 30 days; depth is usually between 5 and 10 feet.

a. Not only are photosynthetic and microbiological processes accelerated, but gas formation is also increased as temperature rises. Sludge rising is often a problem since sludge accumulates at a rapid rate and much gas is evolved in the material. Daily desludging is normally required rather than the usual weekly desludging. Settlement rate is controlled by viscosity so that the temperature increase does not dramatically change reten-tion time in primaries, which is usually 1-2 hours in a correctly designed tank.

b. The effect of increased temperature reduces the saturation concentration of oxygen in any process, such as a trickling filter or packaged activated sludge plant, but, fortunately, the mass transport coefficient is increased. In any system involving plug flow, initial oxygen demands will be very high. Flow to the plant will usually be anaerobic. The engineer should, therefore, anticipate 5-15 percent larger blower or bubbler air demands than required in the U.S. At high altitudes, the oxygen saturation value will again be reduced, requiring further increased air capacity at about 5 percent per 1,000 feet. Dissolved oxygen electrodes should be mandatory in hot climate wastewater treatment plant processes because both under and over-aeration will result in process distrubance. In package treatment plants where gravity return of settled activated sludge is common, the sludge will usually turn anaerobic, making positive sludge return usually advisable. Aerobic stabilization of activated sludge is most applicable in hot climates.

c. Trickling filters and rotating biological disc filters show great promise in hot climates. Since filter media volume requirements are proportional to $T^{o.15}$ as temperature increases, the volume decreases.

d. Sludges dry much more rapidly in hot climates; but in the humid tropics, covers will be required. Odor problems have been common in the sludges produced in hot climates, indicating that aerobic digestion or aerobic composting are potentially useful. Anaerobic digestion and gas produciton should be investigated since a hot climate encourages microbiological fermentation reactions.

e. The engineer should examine each unit operation in a proposed system for potential problems caused by high temperature, torrential tropical rain, and local sewage characteristics variations.