- Moving the chlorination point to the end of the treatment process so that most precursors are removed prior to disinfection (70–75% TTHM reduction)
- Optimizing coagulation and settling processes to improve precursor removal

Within the second category are the following options:

- Using ozone, chlorine dioxide, or potassium permanganate to disinfect without THM formation (60–90% TTHM reduction)
- Dechlorination using *sodium metabisulfate* or other methods after chlorination to prevent the reaction of chlorine with precursors
- Adding ammonia to water prior to discharge to induce chloramine formation, since chloramines suppress the formation of THM's

25–60% TTHM's can also be removed after formation by contacting with granular activated carbon.

Caution is required when changing to alternate disinfectants. The disinfectant and its byproducts should be evaluated to determine disinfecting power, residual power, toxicity, and other health effects.[7]

Costs of operation will increase when alternate disinfectants are used. Moving the point of application may not result in any significant operating costs after a modest capital expenditure is made. Cost of using ozone as an alternative disinfectant is often less than using chlorine dioxide, but it is more than using chloramines or changing the points of chlorine application.

[7] Ozone does not form any potentially dangerous byproducts.

## 6 COMPARISON OF ALKALINITY AND HARDNESS

Hardness measures the presence of $Mg^{++}$, $Ca^{++}$, $Fe^{++}$, and other multi-valent ions. Alkalinity measures the presence of $HCO_3^-$, $SO_4^{--}$, $Cl^-$, $NO_3^-$, and $OH^-$ ions. Both positive and negative ions can exist side by side, so an alkaline water can also be hard.

If certain assumptions are made, then it is possible to draw conclusions about the water composition. For example, $Fe^{++}$ is an unlikely ion in most water supplies, and it is often neglected in comparing alkalinity and hardness.

Figure 7.1 gives an easy method of comparing hardness and alkalinity, and using the comparison to deduce other compounds in the water.

If hardness (as $CaCO_3$) and alkalinity (also as $CaCO_3$) are the same, then there are no $SO_4^{--}$, $Cl^-$, or $NO_3^-$ ions present. (That is, there is no non-carbonate, permanent hardness.) If hardness is greater than alkalinity, however, then non-carbonate, permanent hardness is present, and the temporary carbonate hardness is equal to the alkalinity. If hardness is less than alkalinity, then all hardness is carbonate, temporary hardness, and the extra $HCO_3^-$ comes from other sources (such as $NaHCO_3$).

M = alkalinity
H = total hardness
Ca = calcium
O = hydroxides
S = sulfate hardness
L = free lime

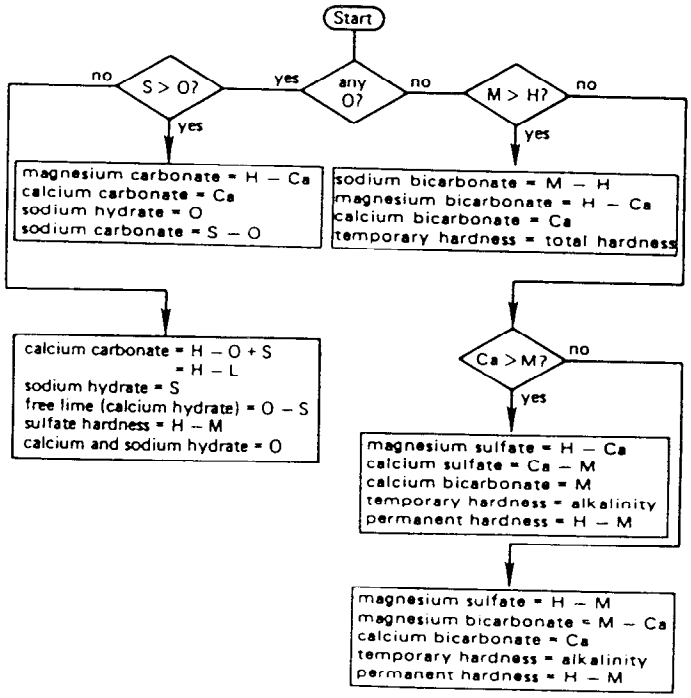


Figure 7.1 Hardness and Alkalinity
(All results expressed as $CaCO_3$)