Pool and Tap Water Survey: Chemical & Microbiological Perspective

A multi-element Study of Tap and Pool Water in Pima County, Arizona

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This survey is a continuation of last years study and has been extended to provide a larger and more detailed examination of actual pool water and tap water samples from private pool owners in Pima County, Arizona. The analytes tested include calcium, magnesium, iron, manganese, copper, zinc, silica, fluoride, chloride, chlorine, chlorate, chlorite, nitrate, nitrite, phosphate, sulfate, bromide, bromate, pH, alkalinity and cyanuric acid. Microbiological analysis of the pool water samples is also presented. The data is illustrated to provide comparisons of pool and tap waters, as well as those relationships that exist with such factors as NSPI standards, TDS, water balance, pool water age, sanitation types and environmental issues.

History

There are few published surveys that describe extensive details about the components of swimming pool waters. One study by Beech, Diaz, Ordaz & Palomeque (1980) focused only on nitrates, chlorates & trihalomethanes. In another study by The Pinellas County Public Health Unit and Occidental Chemical Corporation (1994) pools were tested for pH, chlorine, cyanuric acid and bacteria. In each case the study was limited to a select few components.

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Objective

This survey of water provides a comprehensive picture for twenty-three components from a large sampling of pool and tap waters. This study illustrates the hypothesis that pool water quality is a function of tap water quality, added chemicals, evaporation rate, and environmental factors such as bather waste, lechates from pool system, by-products of disinfection, and precipitation.

Furthermore, this survey will illustrate the effects of chlorine on total bacteria.

Analytical Methods

Component	Method
Anions	Ion Chromatography
Metals	ICP-OES
Total Dissolved Solids	Conductivity Meter
Total Chlorine	Iodometric titration
Cyanuric Acid	Turbidity
pH	pH meter
Total Alkalinity	Base titration
Hardness	EDTA titration and ICP-OES
Total Bacteria	Heterotrophic Plate Count

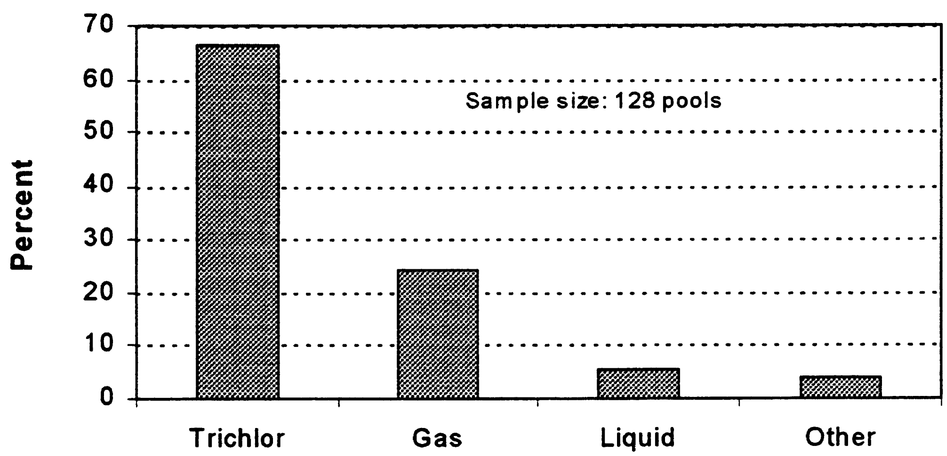
Water Components Analyzed and Method Detection Level (MDL).

Component	MDL	Component	MDL	Component	MDL
pH	NA	Bromide	0.05 ppm	Calcium	0.02 ppm
Total Alkalinity	2.0 ppm	Bromate	0.06 ppm	Magnesium	0.01 ppm
Chlorine	0.1 ppm	Phosphate	0.07 ppm	Iron	2 ppb
Cyanuric Acid	10.0 ppm	Sulfate	0.2 ppm	Manganese	1 ppb
Total Dissolved Solids	1.0 ppm	Fluoride	0.04 ppm	Copper	3 ppb
Hardness	0.1 ppm	Chloride	1.0 ppm	Silica	.10 ppm
Nitrite	0.04 ppm	Chlorite	0.04 ppm	Zinc	3 ppb
Nitrate	0.10 ppm	Chlorate	0.05 ppm		

The MDL is based on routine laboratory analysis of these components in a pool water matrix and would be considered the practical quantitation limit. Extraction and concentration procedures were not used.

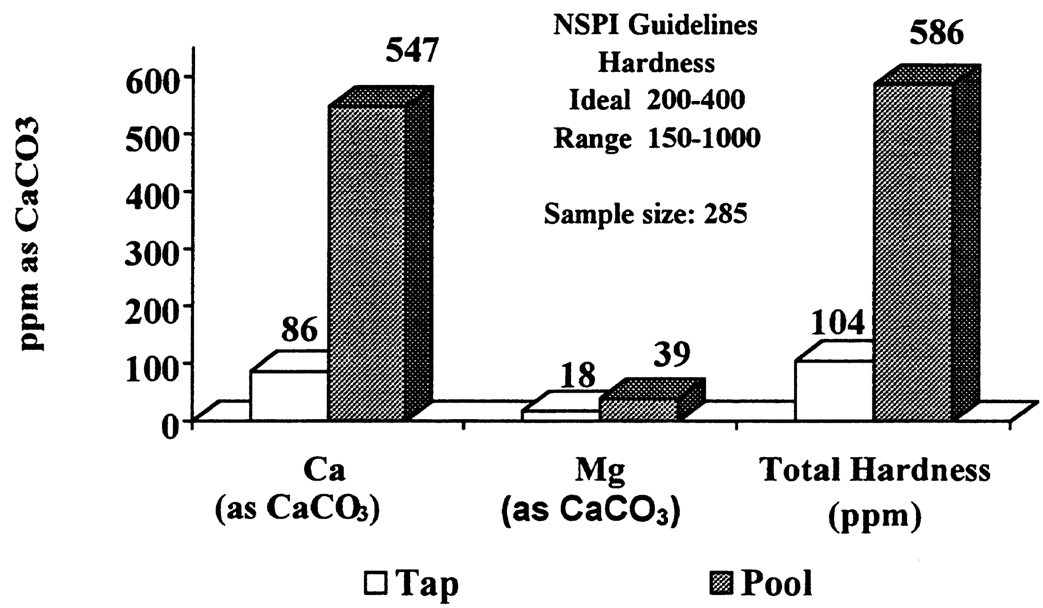
Results and Discussion

1.0 Pool Sanitizer Survey



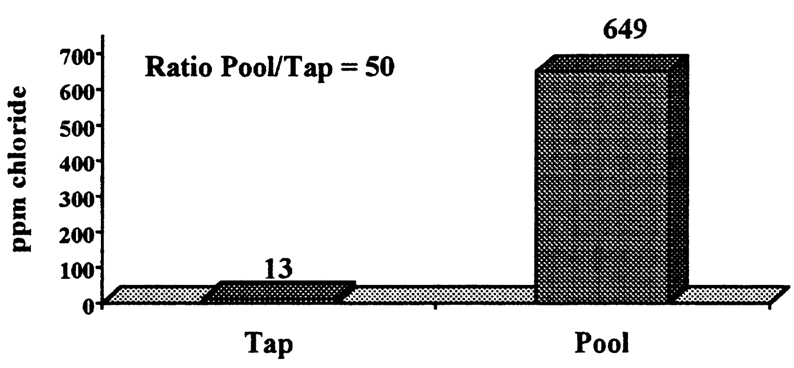
Most of the surveyed owners used trichlor as their sanitizer. Other forms of sanitation include chlorine & ozone generators, calcium hypochlorite and ionizers.

2.0 Hardness



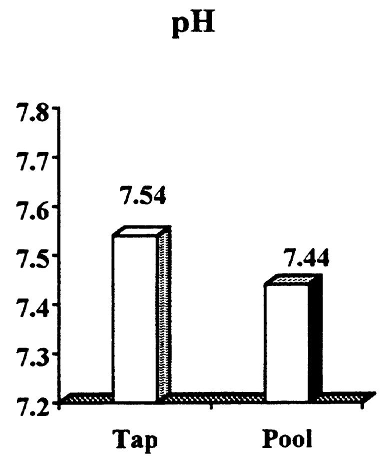
Calcium is the primary component for water hardness in pool water. Magnesium has a greater contribution in tap water and is concentrated in pool water through evaporation. Sometimes calcium chloride is added to increase hardness. Use of calcium hypochlorite as the primary sanitizer can also increased the hardness. The average pool water hardness is well above the NSPI ideal concentration, but within the accepted range. The average age of the pool water fill is 5 years.

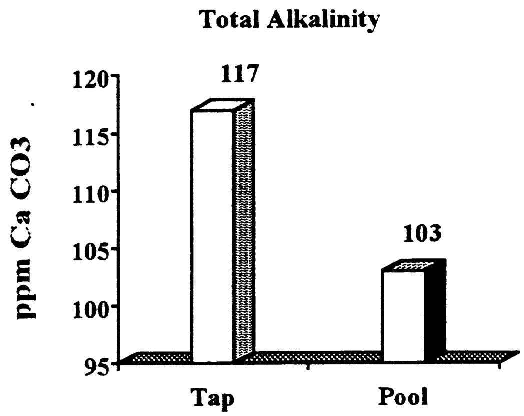
3.0 Chloride



Some of the chloride content is due to the addition of calcium chloride (hardness increaser). However, a significant amount of the chloride build up is most likely due to the use of chlorine with the formation of chloride as a by-product.

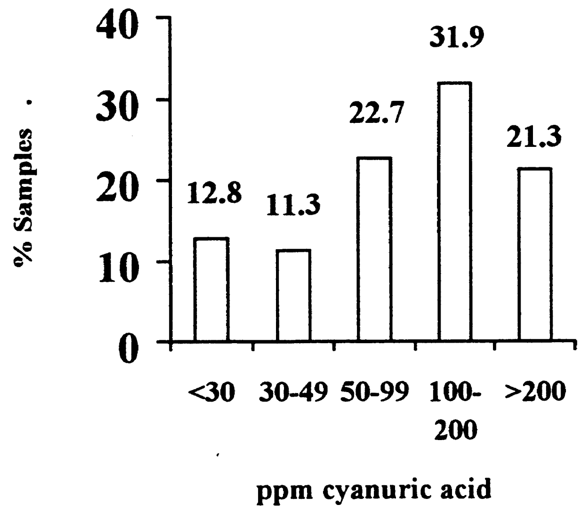
4.0 pH and Total Alkalinity





The average pH and total alkalinity values are acceptable. Data from 285 samples (pool + tap) were used to make these charts.

5.0 Cyanuric Acid

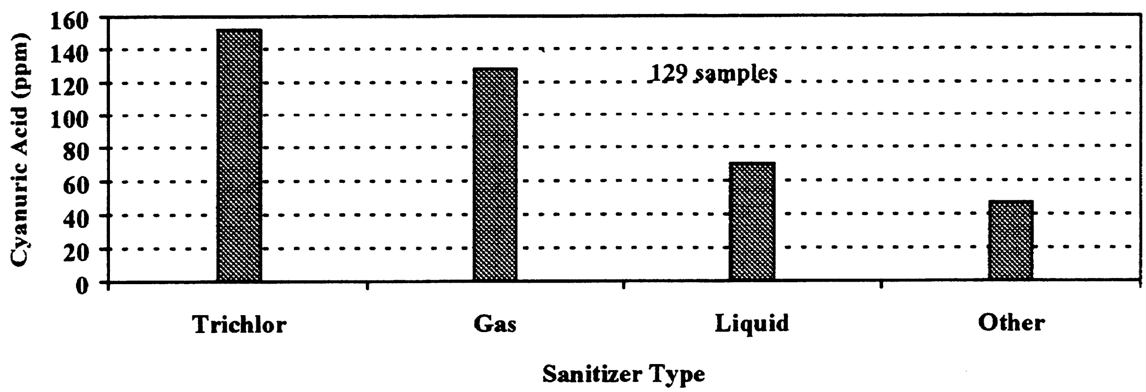


Cyanuric Acid

Average	133 ppm
Low	0
High	*629 ppm*
NSPI range	*30-50 ppm*
Target for gas pools	*100 ppm*

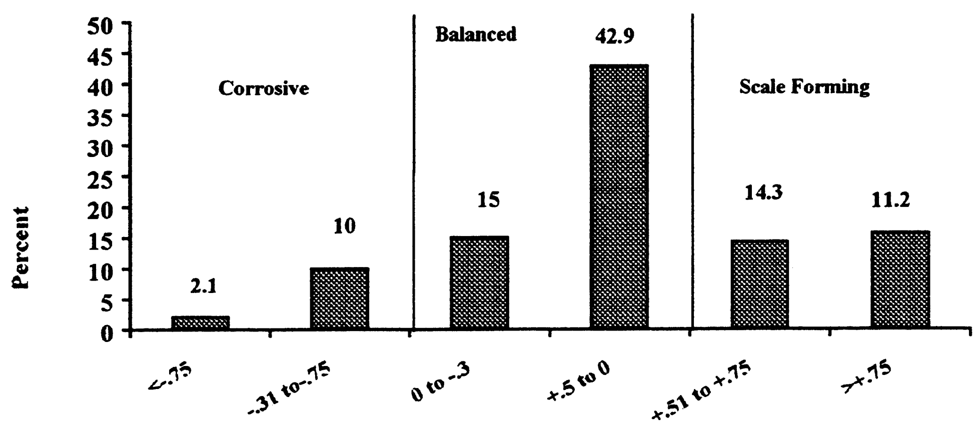
The average cyanuric acid concentration is extremely high. In fact more than 53% of the pools have concentrations significantly higher than the suggested NSPI range. One factor is that gas chlorinated pools are maintained with higher concentrations of cyanuric acid. About 13% of the surveyed pools have insufficient cyanuric acid. This would suggest inadequate pool water maintenance.

Other causes for high cyanuric acid levels may be from the exclusive use of trichlor. Almost 65% of the pools routinely use trichlor. The following chart illustrates the cyanuric acid concentration compared with sanitizer use.

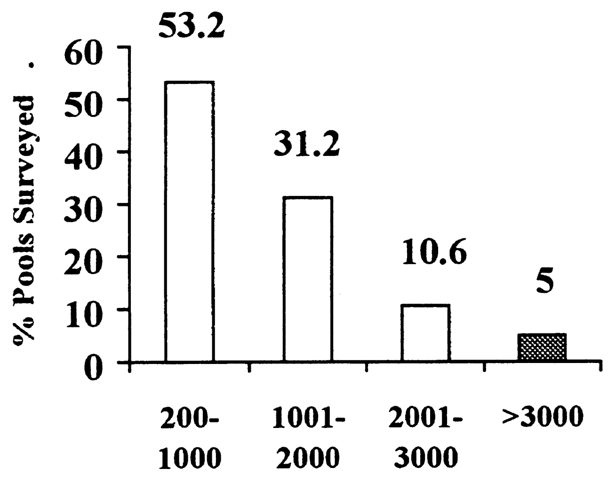


6.0 Langelier Saturation Index for Pool Water

Almost 60% of the surveyed pools (140 pool samples) had an acceptable Langelier Saturation Index, where the water was neither corrosive nor scale forming. The majority of the remaining water samples tended to be slightly scale forming.



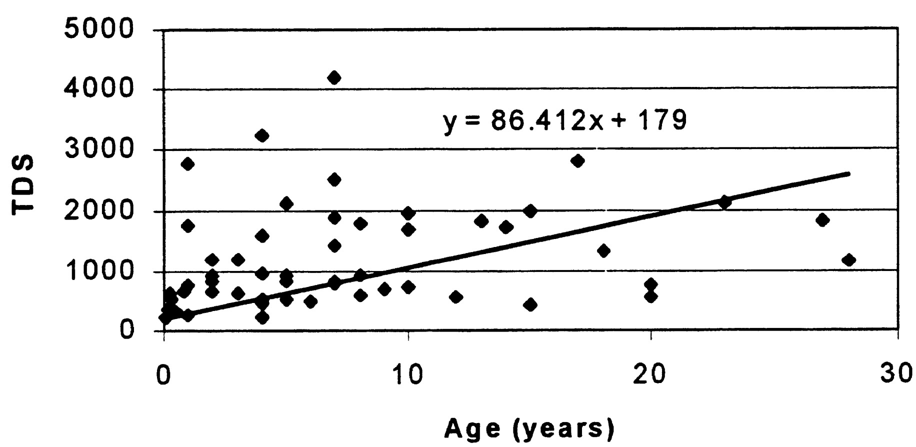
7.0 Total Dissolved Solids



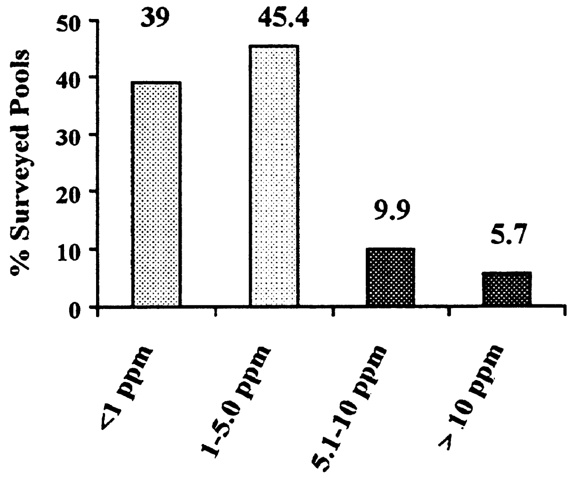
TDS (ppm)	
Average	1273
Low	207
High	*4500*
Tap Average	179
NSPI, max	1500 above tap

The TDS described in this study was measured using a conductivity probe that was calibrated with various sodium chloride solutions. Therefore, the TDS can best be described as the ionic species of dissolved solids. The average TDS for the surveyed tap water was 179 ppm. This would suggest that an acceptable maximum TDS should be about 1679 ppm. Almost 25% of the surveyed pools have a TDS greater than this value. Since increasing TDS is a factor of pool water age we examined the data for a correlation.

There was limited information regarding pool water age. Only 38% of the surveyed owners provided an answer to the question of pool water age.



8.0 Total Chlorine & Bacteriological Correlation



Total Chlorine Range .

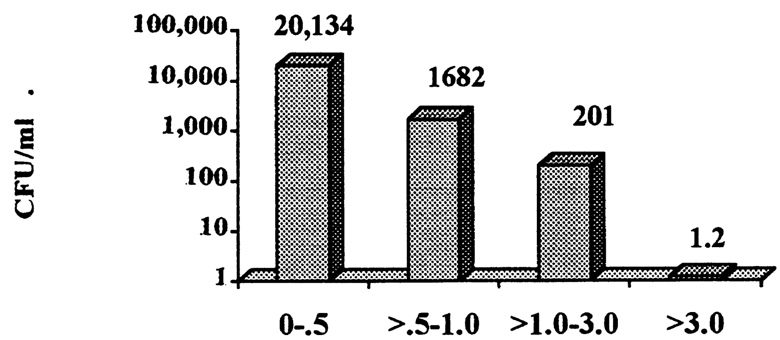
<u>Total Chlorine (ppm)</u>

Average 2.87
Low 0
High 16.5

 # Pools sampled: 141

Almost 25% of the surveyed pools had no detectable total chlorine. Bacteriological (HPC) data and total chlorine analysis for 66 of the 141 pools were available to provide evidence of the effectiveness of chlorine as a sanitizer.

Average Total Bacteria Count vs. Total Chlorine



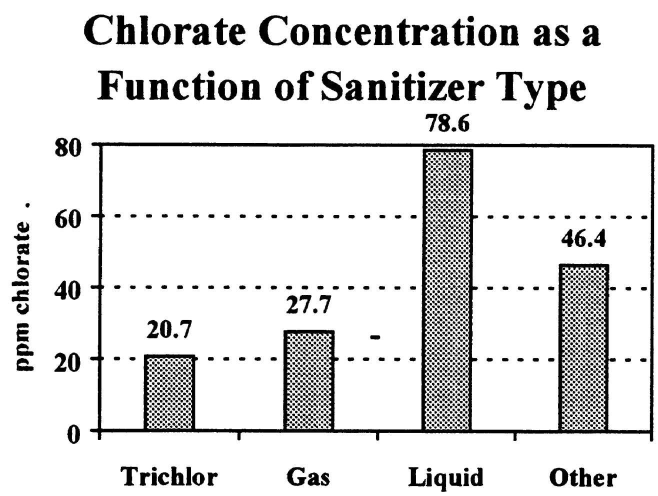
Total Chlorine Range (ppm) .

Another way to look at the effectiveness of chlorine is to examine a pass/fail analysis of the data with the average total bacterial and average chlorine values. A pool water sample with >200 CFU/ml would fail to pass the AOAC guidelines for safe water. The table below clearly shows that close to 40% of the surveyed pools had a total bacteria count of >-200 CFU/ml with an average of 1.7 X 10^4 CFU/ml and an average total chlorine concentration of 0.7 ppm. 28.6% of the "failed" pools had no detectable total chlorine and 10% of the "passed" pools had no detectable chlorine.

In general, a pool with £1.0 ppm total chlorine carries about a 70% risk of being microbiologically active, while a pool with about 3 ppm chlorine carries about a 6.0% risk. (Only 2 samples out of 33 with acceptable total chlorine contained > 200 CFU/ml total bacteria.)

	Fail (>200 CFU/ml)	**Passed (£200 CFU/ml)**
% Pools	39.4%	60.6%
Average Chlorine	0.70 ppm	3.30 ppm
Average Total Bacteria	1.7 X 10^4 CFU/ml	10 CFU/ml

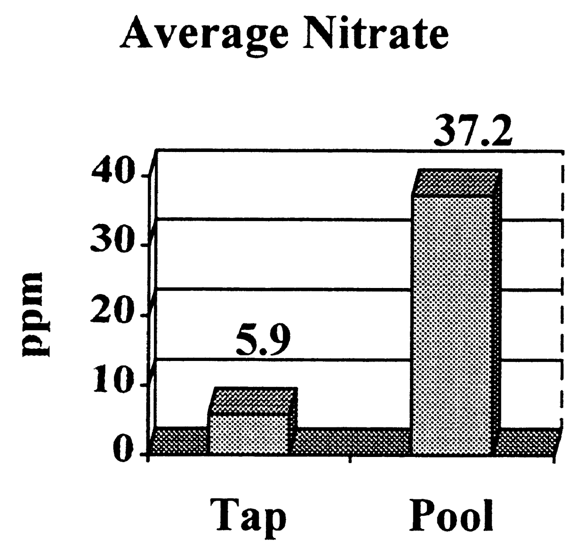
9.0 Chlorate



Chlorate (ppm)
Average 25.6 ppm
Low 0.2 ppm
High 218 ppm

Chlorate is a typical by-product of chlorine sanitation and was found in all pool water samples. There appears to be a correlation between chlorate concentration and sanitizer type. Pools treated with liquid chlorine have the highest chlorate concentration.

10.0 Nitrate



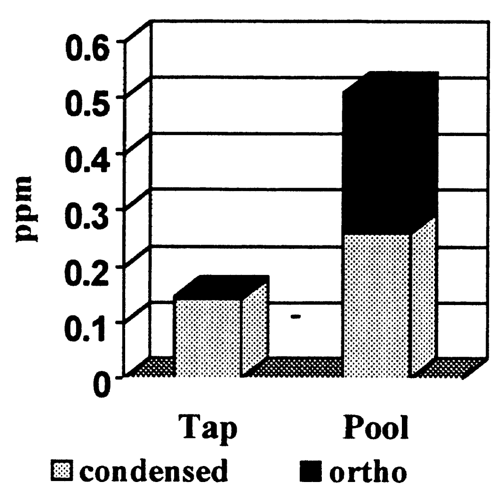
Tap water from Pima County has slightly higher nitrate concentrations, possibly due to excessive agricultural run-off. Nitrite concentration is insignificant.

Nitrate will build up in pools due to the following:
- Oxidation of bather waste.
- Concentration due to evaporation.

The process by which nitrites are converted to nitrates in pool water is described by the following equation. This reaction is a rapid oxidation of nitrite to nitrate by *free chlorine.*

$$\underset{nitrite}{NO_2^- + HOCl} \rightarrow \underset{nitrate}{NO_3^- + Cl^-}$$

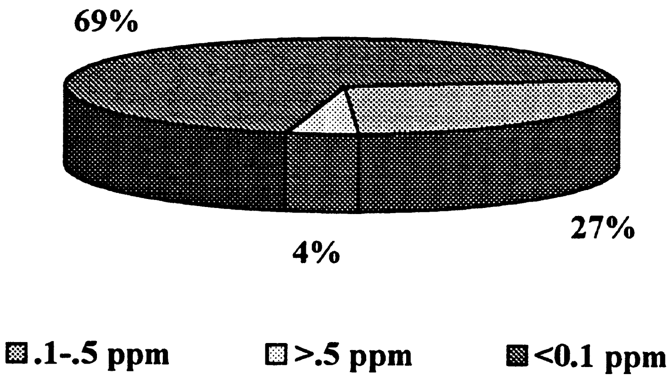
11.0 Phosphates



Phosphates are a problem in pool water because they promote algae growth. 44% of the sampled pool water population contained o-phosphate at an average concentration of 0.25 ppm. Almost all the pool water samples contained condensed phosphate, at 0.26 ppm (expressed as o-phosphate). Condensed phosphate can decompose into o-phosphate.

Phosphates are found in the tap due to minerals from the ground water and agricultural run-off. Pool water will build up phosphates from tap water and run-off from lawn fertilizer. Another surprising source of phosphates are pool chemicals, such as sequestrants and hardness reducers

O-Phosphate Concentrations in Pool Water



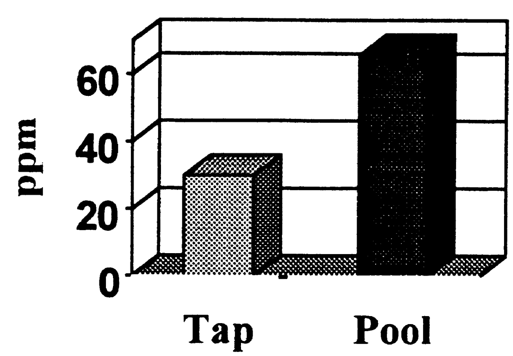
O-Phosphate in Pool Water

- 44% samples contain o-phosphate
- Highest value 2.0 ppm.

On average the typical US pool contains about 0.4 ppm o-phosphate. This is high enough to promote algae growth. In general, the o-phosphate concentration in pools tested in this study were slightly below average at 0.25 ppm. The presence of condensed phosphates adds an additional potential of 0.26 ppm.

12.0 Silica

Average Silica Concentration



The silica concentration is significant in the Pima County tap water. This may be due to excessive groundwater minerals, or silicate may be added by the municipalities as a corrosion inhibitor.

In some pool water samples the silica concentration approaches the maximum solubility of approximately 120 ppm.

13.0 Metals and Oxidation of Metals with Chlorine.

The following table describes the prevalence of common metals found in the pool and tap water samples. The average value was calculated by including only those data points greater than zero.

	Tap		Pool	
Component	**Occurrence**	**Average**	**Occurrence**	**Average**
Iron	27%	72 ppb	2%	30 ppb
Manganese	13%	70 ppb	8%	5 ppb
Zinc	73%	85 ppb	61%	30 ppb
Copper	92%	30 ppb	92%	38 ppb

There was little detectable iron or manganese in the pool water samples. This is due to the oxidation of metals by chlorine. The following equation provides the mechanism by which the metals were removed.

$$Mn^{+2} + HOCl \xrightarrow{\text{pH 7-8, bicarbonate}} MnO_2^{-} + Cl^{-}$$

$$Fe^{+2} + HOCl \xrightarrow{\text{pH 7, excess bicarbonate}} Fe(OH)_3^{-} + Cl^{-}$$

14.0 Prevalence of Common Anions

Some water components were not discussed in detail in this report. The following table provides frequency that each component was found (occurrence) and the average concentration of those components calculated by including only those data points greater than zero.

	Tap		Pool	
Component	**Occurrence**	**Average**	**Occurrence**	**Average**
Fluoride	100%	.26ppm	100%	.55 ppm
Sulfate	100%	33 ppm	100%	134 ppm
Chlorite	15%	.05 ppm	63%	.21 ppm
Nitrite	24%	.02 ppm	39%	2.1 ppm
Bromide	39%	.06 ppm	5%	24 ppm
Bromate	<1%	<.01 ppm	44%	2.6 ppm

Bromide was found in 39% of the tap water samples but only 5% of the pool water samples. Bromate (the oxidation product of bromide) was found at much higher frequency (44%) in the pool water samples. Few of the tap water samples contained bromate. Therefore, it is not unreasonable to suggest that bromide from tap water is being oxidized by chlorine to bromate in the pool water.

15.0 Summary

In summary, the final table provides a list of some of the tested components. For each of these components a ratio of the average ratio of pool water/average tap water concentration is calculated and listed in descending order of build-up. Chlorate had the highest increase in concentration. Although evaporation of tap water is a major contributor to higher concentrations of components in the pool water, the following table provides a list of potential causes of build-up.

Contaminant	Ratio [Pool/Tap]	Causes
Chlorate	287	– Decomposition of hypochlorite – Contaminant in liquid chlorine source
Chloride	50	– Calcium hardness adjustment – Chlorine decomposition
o-Phosphate	37	– Sequesterants – Agricultural run-off
Calcium	6.7	– Hardness adjustment – Calcium hypochlorite – Gunite plaster leachates
Nitrate	6.3	– Oxidation of bather waste

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