The Total Dissolved Solids Contributions of Various Swimming Pool and Spa Balancing Compounds

Kim Skinner
onBalance

The amount of total dissolved solids (TDS) contributed by certain swimming pool and spa balancing chemicals has been misreported in various publications of trade literature. The correct contributions, as well as the calculations used to arrive at these figures, and the rationale which explains the errors, are delineated.

Just how much do swimming pool chemicals add to the total dissolved solids (TDS) content of the water? Do all chemicals of equal amounts (by weight) add identical amounts of TDS to swimming pools? This paper is written to clarify the chemistry and to eliminate some of the confusion as to the contribution to TDS by certain swimming pool chemicals.

It has been published in the industry trade press (for example, see Dickman 1992, Lowry 1996a and 1996b) that if one pound of any chemical is added to 15,000 gallons of water, an increase of 8 parts per million of TDS is always realized in the pool. While this is true with some chemicals, it is not always true with all chemicals. Perhaps what is not understood is that after being added, some chemical elements and compounds can literally escape from the water and not contribute to TDS. Another possibly misunderstood fact is that portions of these chemicals will transform themselves into water and thus will no longer be part of TDS.

Journal of the Swimming Pool and Spa Industry
Volume 5, Number 1, pages 57–59

The TDS Contribution of Gas Chlorine

We will first look at adding a pure chemical that provides the full increase of its weight to the total dissolved solids content of the water. Chlorine gas is a good example. At levels of 1000 parts per million or below, chlorine is virtually 100 percent soluble at a pH of 4.5 or above (White 1972). Therefore, if one pound of pure chlorine is dissolved into water, the result will be 8 ppm of TDS per 15,000 gallons.

One way of calculating this reaction is as follows: 15,000 gallons of water weighs about 125,000 pounds, which is one-eighth of a million. We multiply the one pound of chlorine by eight and get the 8 ppm of TDS.

The TDS Contribution of Common Pool and Spa Bases

As with all acidic sanitizers, after adding gas chlorine it is usually necessary to add an alkaline chemical to adjust pH and alkalinity upward. These chemicals would normally be either soda ash, sodium sesquicarbonate, or sodium bicarbonate. Unlike chlorine gas however, adding these alkaline chemicals does not ultimately add 8 ppm of TDS per pound of powder added in 15,000 gallons.

When these products are added to pools in order to neutralize acidic sanitizers, these chemicals form carbon dioxide, which over a period of time will release into the atmosphere. Only the sodium element from these chemicals remains in the water and adds to the TDS. The following equations will help illustrate:

Soda Ash:

$$Na_2CO_3 + 2HCl = 2NaCl + H_2CO_3$$
$$H_2CO_3 \rightarrow CO_2 + H_2O$$

Sodium Bicarbonate:

$$NaHCO_3 + HCl = NaCl + H_2CO_3$$
$$H_2CO_3 \rightarrow CO_2 + H_2O$$

Sodium Sesquicarbonate:

$$Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O + 3HCl = 3NaCl + 2(H_2CO_3) + 2H_2O$$
$$2(H_2CO_3) \rightarrow 2CO_2 + 2H_2O$$

In the first reaction, soda ash reacts with acid (in this example, from acidic sanitizers) to produce two ionic compounds. The first compound is sodium chloride and the second is carbonic acid. Sodium chloride remains in the water as salt, which contributes to TDS, while carbonic acid will dissociate into carbon dioxide and water. Obviously, the pure water formed does not contribute to TDS, and carbon dioxide will eventually escape into the atmosphere – thereby also not contributing to the TDS content of the water. The second reaction, reacting sodium bicarbonate with acid, forms the same compounds – salt and carbonic acid. The third reaction, for sodium sesquicarbonate, is a combination of the first two (with an added water component) since sodium sesquicarbonate is a blend of the two former chemicals.

To calculate the actual amount of TDS contributed by one pound of each of these three compounds, it is necessary to determine the molecular weight of the total compound. Sodium (Na) has a weight of 22.99, carbon (C) is 12.011, oxygen (O) is 15.9994, and hydrogen (H) is 1.008. For our purposes, the rounded off figures which illustrate the point add up as follows:

Soda Ash: Na_2CO_3

Na =	23	•	2	=	46
C				=	12
O =	16	•	3	=	48
			Total	=	106

Sodium Bicarbonate: $NaHCO_3$

Na				=	23
H				=	1
C				=	12
O =	16	•	3	=	48
			Total	=	84

Sodium Sesquicarbonate: $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$

Na =	23	•	2	=	46
C				=	12
O =	16	•	3	=	48
Na				=	23
H				=	1
C				=	12
O =	16	•	3	=	48
H =	1	•	4	=	2
O =	16	•	2	=	32
			Total	=	226

The (rounded off) molecular weight of soda ash is therefore 106, sodium bicarbonate is 84, and sodium sesquicarbonate is 226. Sodium by itself has a molecular weight of 23, and there are two sodium molecules in soda ash, only one in sodium bicarbonate, and three in sodium sesquicarbonate. The sodium element comprises about 43.4 percent of the soda ash, about 27.4 percent of the sodium bicarbonate, and about 30.5 percent of the sodium sesquicarbonate. Therefore, when adding one pound of soda ash, 43.4 percent would contribute to TDS, with sodium bicarbonate, 27.4 percent contributes to TDS, and with sodium sesquicarbonate, 30.5 percent contributes to TDS.

The final calculations are as follows: if one full pound of a material in 15,000 gallons of water would normally equate to 8 ppm of TDS, then soda ash, with only 43.4 percent of its total which remains as TDS only contributes about 3.47 ppm of TDS. Likewise, one pound of sodium bicarbonate (with 27.4 percent remaining) adds about 2.2 ppm, and one pound of sodium sesquicarbonate (with 33 percent remaining) adds about 2.5 ppm.

Obviously, until these chemicals actually react with an acid, the entire contents of the various compounds would be present as TDS.

The TDS Contribution of Hydroxide–contributing Compounds

Another class of chemicals which are added to pools and spas, but which does not introduce the full TDS of its weight is that class of compounds which adds hydroxide or which forms hydroxide when added to water. Hydroxide (OH) will likely end up combining with an hydrogen ion to form pure water (H_2O). After hydroxide reacts to form water, the OH portion is no longer part of the TDS of the solution.

Sodium hypochlorite (referred to in the industry variously as liquid chlorine or bleach) is an example of a this type of compound.

Sodium Hypochlorite:

$$NaOCl + H_2O = HOCl + NaOH$$

$$HOCl \rightleftharpoons HOCl + HCl$$

$$HCl + NaOH = NaCl + H_2O$$

In the first reaction, sodium hypochlorite reacts with water to form hypochlorous acid and sodium hydroxide. In the second reaction, hypochlorous acid decomposes to hydrochloric acid. Then, hydrochloric acid reacts with sodium hydroxide to form sodium chloride, which increases the TDS content, and water, which does not.

In every gallon of sodium hypochlorite (in this example, 15% trade or 12.5% weight), there is about 1.25 pounds of chlorine and about 1.6 pounds of sodium hydroxide, for a total of 2.85 pounds of potential TDS. This would normally equate to about 23 ppm of TDS for every gallon added to a 15,000 gallon swimming pool. However, since hydroxide accounts for about 42.5 percent by weight of sodium hydroxide (and since that hydroxide will eventually convert to water), this component is subtracted from the compound, so that, together with the chlorine, about 2.2 pounds in a gallon of sodium hypochlorite adds to the TDS content of a solution. Thus one gallon of sodium hypochlorite adds about 17.5 ppm of TDS (rather than 23 ppm) in 15,000 gallons of water.

A Few Notes on the TDS Contribution of Other Pool Compounds

Muriatic acid (hydrochloric acid) is another common product that, when added to pool water, will contribute significantly to the TDS content. This 20 degree baume acid at 31.45 percent strength adds about 3 pounds of TDS per gallon. Although the hydrogen from this acid can react with hydroxide to form water, it is such a small percentage of the total weight of the acid that it will not change significantly the overall contribution of this acid to TDS. Therefore, one gallon of muriatic acid will increase the TDS content about 24 ppm per 15,000 gallons of water.

There are other chemicals do not always provide their entire contents in increasing TDS. Chemicals that add oxygen or nitrogen will also likely gas off a portion of their weight, thus decreasing the overall TDS contribution. Calcium hypochlorite is an example of a compound that adds oxygen. The percentage of the calcium hypochlorite contribution that ends up as oxygen is about 22 percent. Therefore, its contribution to TDS is only 78 percent of its total weight. Also, products that contain ammonia are examples of chemicals that form nitrogen to pool water, which would likely gas off, reducing their effect on TDS.

It should be noted that adding trichlor, sodium dichlor, and cyanuric acid to swimming pool water will result in the full increase of their weight to TDS.

References

Dickman, David "TDS: What to check when chemistry looks right but things go wrong." Service Industry News July 24, 1992, p. 4.

Lowry, Robert W. "Chlorine, Put To Spa Use." Pool & Spa News July 17, 1996a p. 44

Lowry, Robert W. (Response to a letter to the editor) Pool & Spa News August 21, 1996b p. 16.

White, George Clifford. Handbook of Chlorination. (New York, Van Nostrand Reinhold Company) 1972.

About the Author

Kim Skinner is the president of Pool Chlor in Livermore, California. A former general manager of Skinner Swim Pool Plastering in the Los Angeles area, he has been with Pool Chlor for the past 30 years. He is also a partner in onBalance, a pool chemistry and pool plaster surface consulting firm. He may be reached at kim@poolchlor.com.