The Relative Effect of Sodium Carbonate and Sodium Bicarbonate on Increasing Alkalinity and pH in Pool Water

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onBalance

The correct alkalinity and pH results from the addition of sodium carbonate and sodium bicarbonate are given, along with an explanation of the chemistry. This information refutes incorrect material that is being presented in some industry literature and in trade show classes.

For many years, there have been some misconceptions within the swimming pool service industry regarding the effects and quantitative results when comparing sodium carbonate (soda ash) and sodium bicarbonate (baking soda) when these two chemicals are added to swimming pools.

The misinformation being promulgated in seminars throughout the industry varies. Some instructors claim that, pound for pound, sodium carbonate and sodium bicarbonate add equal amounts of alkalinity to pool water, while others claim that sodium bicarbonate actually increases the alkalinity more than sodium carbonate. Another inaccurate claim is that sodium bicarbonate will always increase the pH.

This paper will address the above misinformation and clarify the actual differences between these two chemicals when added to water.

Sodium Bicarbonate

To begin, a 1% solution of sodium bicarbonate in distilled water has a pH of approximately 8.3. Understanding this, when sodium bicarbonate is added to water having a pH lower than 8.3, it will cause the pH to rise towards 8.3. Conversely, and what is not understood by some, is that if the water's starting pH is greater or higher than 8.3, (which does occur occasionally in swimming pools, and especially upon the filling of new plaster pools) adding sodium bicarbonate to this water will decrease or lower the pH down and towards 8.3. In general, adding sodium bicarbonate will affect the pH more significantly when the beginning pH of the water is further away from 8.3. However, the amount or content of the total alkalinity present in the water will also determine the degree or the amount of the pH change when sodium bicarbonate is added to water. The rule here is that when the content of carbonate alkalinity is low, a greater effect on the pH from the addition of sodium bicarbonate occurs. For example, if sodium bicarbonate is added to one pool that has a pH of 7.0 and an alkalinity of 20 ppm and also added to another pool that has a pH of 7.0 and an alkalinity of 100 ppm, then the greater pH increase will result with the pool that has alkalinity of 20 ppm. This is due to the greater pH buffering of water with higher amounts of alkalinity.

Sodium Carbonate

A 1% solution of sodium carbonate in distilled water has a pH of approximately 11.4. Because of this high pH condition, sodium carbonate will raise the pH in water more significantly than will sodium bicarbonate. And just as with sodium bicarbonate, sodium carbonate will also

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more significantly increase the pH when a lower alkalinity level exists.

Alkalinity Contribution

The alkalinity of water is a measurement of its capacity to neutralize acids, and the measurement of alkalinity in water is generally expressed as its calcium carbonate equivalent. There are several ways to calculate the amount of contribution to alkalinity by sodium bicarbonate and sodium carbonate. The following is one example.

Sodium Bicarbonate — In order to calculate the amount of alkalinity increase by the addition of sodium bicarbonate, we must know its calcium carbonate equivalent. We know that the equivalent weight (mass) of calcium carbonate has been assigned as one hundred (100) and the equivalent weight of sodium bicarbonate is one hundred sixty-eight (168). By dividing calcium carbonate's equivalent weight (100) by sodium bicarbonate's equivalent weight (168), we know that sodium bicarbonate is only 59.5% of the equivalent strength of calcium carbonate. By determining the amount of alkalinity contributed by pure calcium carbonate, we will then be able to determine how much alkalinity is contributed by sodium bicarbonate.

If twelve (12) pounds of calcium carbonate was added to a million pounds of water, we would have twelve (12) parts (pounds) per million (pounds) of water (also known as "ppm") of alkalinity as calcium carbonate. Since water has an approximate weight of 8.34 pounds per gallon and 10,000 gallons of water weighs about 83,400 pounds, this is one-twelfth of a million pounds and one pound of calcium carbonate added to 10,000 gallons of water would make 12 ppm. Knowing this we then multiply 12 ppm by the percentage strength of sodium bicarbonate (which is 59.5%) and learn that one pound of sodium bicarbonate would add 7.14 ppm of alkalinity in 10,000 gallons of water.

Another way of arriving at this result is to calculate that one part per million alkalinity, divided by the atomic weight of calcium carbonate multiplied by 1000, and then multiplied by twice the atomic weight of sodium bicarbonate equals the amount per liter, in grams, of sodium bicarbonate to add per ppm increase desired:

$$\frac{1}{(100.09)(1000)} \times 2(84.0077) = 0.001678643$$

This amount multiplied by the conversion factor to convert from grams to pounds

$$0.001678643 \times 0.00220462 = 0.0000037$$

and then multiplied by the number of liters in a 10,000 gallon pool

$$0.0000037 \times 37853 = 0.1400561 \text{ pounds}$$

and then multiplied to increase the 0.14 pounds to 1 full pound

$$\frac{0.14 \text{ pounds}}{1 \text{ pound}} = \frac{1 \text{ ppm}}{7.14 \text{ ppm}}$$

shows that 1 pound of sodium bicarbonate is gives a 7.14 ppm alkalinity lift in a 10,000 gallon pool.

Sodium Carbonate — With sodium carbonate, the equivalent weight (as compared with calcium carbonate) is one hundred six (106). Dividing calcium carbonate's equivalent (100) by sodium carbonate's equivalent weight (106) we learn that sodium carbonate is approximately 94.3% strength of calcium carbonate. Therefore, using the above example, adding one pound of sodium carbonate to 10,000 gallons of water will result in 11.32 ppm of alkalinity.

Using the other method, one part per million alkalinity, divided by the atomic weight of calcium carbonate multiplied by 1000, multiplied by the atomic weight of sodium carbonate equals the amount per liter, in grams, of sodium carbonate to add per ppm increase desired:

$$\frac{1}{(100.09)(1000)} \times 105.9794 = 0.001058841$$

This amount multiplied by the conversion factor to convert from grams to pounds

$$0.001058841 \times 0.00220462 = 0.000002334$$

and then multiplied by the number of liters in a 10,000 gallon pool

$$0.000002334 \times 37853 = 0.088349 \text{ pounds}$$

and then multiplied to increase 0.088349 pounds to 1 full pound

$$\frac{0.088349 \text{ pounds}}{1 \text{ pound}} = \frac{1 \text{ ppm}}{11.32 \text{ ppm}}$$

shows that 1 pound of sodium bicarbonate is gives an 11.32 ppm alkalinity lift in a 10,000 gallon pool.

As we can see from the above information, sodium carbonate increases the alkalinity of water approximately 58.5% more than sodium bicarbonate, or a better way of comparison is that in terms of alkalinity, sodium bicarbonate is only about 63% as strong as sodium carbonate.

Part of the confusion regarding these two chemicals is the misunderstanding of how acid neutralizes alkalinity. A false assumption is that is takes the same amount of acid to neutralize one pound of sodium bicarbonate as it does one pound of sodium carbonate. This can better be understood if we look at the chemical formulas of sodium bicarbonate and sodium carbonate and their reaction with acid.

(1) $NaHCO_3 + HCl = H_2C0_3 + NaCl$

(2) $Na_2CO_3 + HCl = NaHCO_3 + NaCl$

(3) $NaHCO_3 + HCl = H_2CO_3 + NaCl$

In Equation (1) sodium bicarbonate ($NaHCO_3$) is reacted with a single hydrochloric acid molecule and results in the formation of carbonic acid (H_2CO_3) and sodium chloride (NaCl). Carbonic acid is not alkalinity, nor is sodium chloride. We see that it only took one molecule of acid (HCl) to convert sodium bicarbonate (alkalinity) into an acid.

In Equation (2), we see that sodium carbonate (Na_2CO_3) is reacted with a molecule of acid (HCl) which then forms sodium bicarbonate and sodium chloride (NaCl). We can see that we have converted one form of alkalinity (sodium carbonate) into another form of alkalinity (sodium bicarbonate). This reaction hasn't eliminated all of the total alkalinity, but has reduced the alkalinity by half. Now in Equation (3), the sodium bicarbonate (created in reaction 2) is now reacted with another acid molecule to produce carbonic acid and sodium chloride. As we can see, it took two molecules of acid (hydrochloric) reacting with sodium carbonate to form carbonic acid and two sodium chlorides. The following reaction will also help illustrate.

(4) $Na_2CO_3 + 2HCl = H_2CO_3 + 2NaCl$

Again, this equation illustrates how it requires two molecules of acid to neutralize sodium carbonate (alkalinity) as compared to one molecule of acid for sodium bicarbonate and create carbonic acid and a non-alkaline component.

Since we see that sodium carbonate has twice the content of alkalinity as compared to sodium bicarbonate, it has been asked why sodium carbonate doesn't contribute exactly double the alkalinity increase as does sodium bicarbonate. The answer lies in the molecular weight differences between these two chemicals. As mentioned earlier, the molecular weight of sodium bicarbonate is 84 and sodium carbonate is 106. Because of this fact, sodium bicarbonate has approximately twenty percent (20%) more molecules in one pound of $NaHCO_3$ than there is in one pound of sodium carbonate. The equations in Illustration 1 will better illustrate.

As we can see in Illustration 1, there are five molecules of sodium bicarbonate ($NaHCO_3$) in the left column, with a molecular weight of 420. There are only four molecules of sodium carbonate (Na_2CO_3) in the right column, with an almost equal molecular weight of 424. This represents the 20% higher amount of sodium bicarbonate molecules as compared to sodium carbonate. Then, we see that

Illustration 1 – Relative Contributions to Total Alkalinity from Sodium Carbonate vs. Sodium Bicarbonate

Bicarbonate reduction with acid	Carbonate reduction with acid
$NaHCO_3 + HCl = H_2CO_3 + NaCl$	$Na_2CO_3 + 2HCl = H_2CO_3 + 2NaCl$
$NaHCO_3 + HCl = H_2CO_3 + NaCl$	$Na_2CO_3 + 2HCl = H_2CO_3 + 2NaCl$
$NaHCO_3 + HCl = H_2CO_3 + NaCl$	$Na_2CO_3 + 2HCl = H_2CO_3 + 2NaCl$
$NaHCO_3 + HCl = H_2CO_3 + NaCl$	$Na_2CO_3 + 2HCl = H_2CO_3 + 2NaCl$
$NaHCO_3 + HCl = H_2CO_3 + NaCl$	
Molecular weight ca. 420	Molecular weight ca. 424

there are a total of five (5) HCl acid molecules in the left column with sodium bicarbonate, and we see that there are a total of eight (8) molecules of HCl in the right column with sodium carbonate. Thus we see that sodium carbonate requires 60% more acid to neutralize its alkalinity content by weight as compared to sodium bicarbonate's alkalinity content.

This accounts for why the different quantitative results between these two compounds is not double the amount.

Due to the high pH of soda ash, adding a lot of it may precipitate calcium carbonate and thus lower the calcium level of pool water. And when that occurs, the pH and the alkalinity may not increase at all, due to the offset of sodium carbonate "in" vs. calcium carbonate "out."

About the Author

Kim Skinner began work in the pool industry at family-owned Skinner Swim Pool Plastering, Inc. of Sun Valley, California, and later became president of Pool Chlor, a chemical service firm with offices throughout the Southwest. He has worked in the swimming pool industry for over 50 years.

Mr. Skinner has performed both laboratory and field research on pool water chemistry and on the relationships between water chemistry and pool plaster surfaces. He has developed novel processes for swimming pool chemical treatment, including the bicarbonate start-up method for new plaster pools.

He is the co-author of several technical reports on swimming pool water chemistry and plaster phenomena, which have been featured in the trade press. He has also authored material published in previous issues of the Journal of the Swimming Pool and Spa Industry. He has been a voting member of many industry committees, including the APSP Technical Committee and Recreational Water Quality Committee.