A Review of pH Rise in Distributed Drinking Water from GAC Filter upon Commissioning

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The Town of Hudson as asked about the potential pH rise that commonly occurs with the start-up of a GAC filter.

First a primer on GAC and the potential pH rise in water -

The pH rise is due to ash (mineral salts) contained in the coal or plant-based raw materials that are charred and then activated. Ash remains in the lattice structure of the GAC when initially charred. Coal derived activated carbon may contain up to 9% ash. Plant-derived activated carbon is about half the ash content of coal. Every coal seam has a different chemistry and ash content. There are differences between lignite, sub-bituminous, bituminous, and anthracite. Plant-based carbon will also have variances of ash content when derived from coconuts grown in different soils.

Now a primer on the water –

Water is known as the universal solvent. Most minerals, specifically ash, are in some degree soluble in water. Some minerals, like glauberite, a double-sodium salt, are essentially insoluble. Carbon is considered insoluble. Common salt, NaCl, is very soluble. When mineral salts dissolve in water they are driven to an equilibrium point where the water is saturated with those mineral salts. Gases also are soluble in water and achieve an equilibrium, oxygen and carbon dioxide particularly, but also include H_2S and VOCs.

The internal chemistry of the water includes the interaction of dissolved minerals and gases all moving toward equilibrium. Exposure to a different mix of mineral surfaces or ambient atmosphere will create a shift in the equilibrium of the soluble salts. Some may precipitate while others dissolve.

External conditions can change that affect the equilibrium point of solubility of minerals. Temperature, pressure, and flow/movement will shift the equilibrium of the salts in the water. Many salts like sodium are more soluble as the temperature elevates, but calcium and magnesium are the opposite. Pressure will significantly influence the solubility of dissolved gases.

Groundwater is at equilibrium with its environment as it is pumped out of the ground. When GAC is first exposed to water, the environment is immediately changed. Water will dissolve or leach some of the ash content of the GAC. How much ash is dissolved is a function of the buffering or existing mineral content of the water and the nature of the ash in the GAC. It is reported that the typical GAC will become depleted and have its ash reach an equilibrium with the water within the first 100 to 1000 bed volumes of water processed. This will vary due to the ash content of the GAC. The other factor is the carbonate and bicarbonate equilibrium or buffering, of the groundwater.

Based on the 2017 Annual Drinking Water Quality Report the average water chemistry is reported to have a pH of 7.0. and a TDS of 146.5 mg/l. Extrapolating the ionic balance with chlorides reported at ~60 and Sulfate at ~15, leave the bicarbonate alkalinity at about 40 – 80 mg/l, as $CaCO_3$. This indicates there is relatively low buffering of the water and the pH rise of the leaching GAC ash may push the pH up as high as 8.2. This is speculative. Estimating the worst case, a rise of the bicarbonate/carbonate equilibrium point will produce about 240 mg/l alkalinity, as $CaCO_3$.

Consider also that the total flow of distributed water is 2000 GPM and the GAC filter is serving a flow of 700 GPM. The average alkalinity of the total distributed water, if projected linearly is 65%(80 mg/l) + 35%(240 mg/l)/2 = 136 mg/l. For alkalinity of 136 mg/l, the pH generally falls in a range of 7.6 to 7.8.

The Annual Report indicates that the water is corrosive (below the equilibrium point of metal solubility) and requires the addition of potassium hydroxide for corrosion control. Essentially this is adding buffering to the water, converting bicarbonate ions to carbonate, and it elevates the pH.

For the Hudson, MA project the GAC filters contain 80,000 pounds or 2,900 cubic feet of GAC. A bed volume is 21,700 gallons. At 700 GPM or 1MGPD that is 46.5 bed volumes per day. At worst the pH rise will diminish after 21 days or 1000 bed volumes. It is more likely the duration will be on the low side, 100 bed volumes, due to the Hudson water being corrosive and leaching the ash content of the GAC much quicker. The pH rise could diminish within two days or one week.

The Town should be prepared to trim the potassium hydroxide additions during the start-up of the GAC filter. The combination of the increased alkalinity from the GAC and the decrease of KOH can offset each other and maintain the desired pH and alkalinity of the distributed water.

There are commonly employed methods of reducing or minimizing the pH rise experienced as GAC filters are brought online. These methods increase the cost of GAC which must be offset by the avoidance of regulatory penalties, or a significant upset in distributed water quality. These include:

1. Treating the carbon in bulk loads while in transit to the job site with CO_2. The CO_2 will dissolve into the wet carbon and form carbonic acid, H_2CO_3. The carbonic acid will leach some of the ash from the carbon in transit.
2. Treating the carbon once loaded into the on-site vessels with CO_2. The vessel can be pressurized and left to soak indefinitely to leach more of the ash. The carbon bed is rinsed and backwashed before placed into service.

3. The GAC is acid-washed and rinsed before it is transported to the job site and loaded into the vessels.

TIGG did not offer any of these options in our proposal. We recognized the water quality provided as we reviewed this project did not warrant any special consideration to the normal quality of GAC that we provide. The implementation of any of these methods will require additional funds for the project.