CARBON FILTER CAPACITY: Is my filter half full, or half empty?

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Introduction

Activated and Impregnated Carbon materials can be effective at filtering contaminants out of liquid or air streams. This process is called adsorption. Like any filter in today's laboratory, significant energy is spent replacing used carbon filters. Is it then critical to understand how long your filters should last?

Of course it is.

Expressing Capacity

Carbon filter capacity is expressed in a several different ways, but two methods are most typical.

1. Filter manufacturers typically have dedicated catalog numbers for filters, and those filters have standard sizes. A filter's capacity is often expressed as a volume for a specific chemical that filter has the capacity to hold. (For example, a filter is rated to hold 250mLs of xylene, then the theoretical volume capacity of that filter for xylene is 250mLs.)
2. Carbon and Filter manufacturers often choose to express a filter's capacity for any given chemical by providing a percentage. This is a "capacity by weight" ratio that can be used to calculate volume based on filter size. (For example, a carbon filter has a filter weight capacity for xylene of 27.6%. If you had 100 grams of carbon, you could theoretically trap 27.6 grams of xylene.)

Capacity Factors

Theoretical Values

Any time spent in a chemistry lab will teach you that the theoretical values obtained through stoichiometry and other calculations don't pan out in the real world – I blame significant digits. Typically, realistic estimates for capacity are around 1/3 of calculated theoretical values. Make sure you ask for clarification, are the capacities provided theoretical or realistic values.

Chemical Concentration

Another major factor in filtration capacity revolves around concentration. No, not how hard the bench chemist is focusing on his titrations, but the evaporative concentration of the given chemicals; the higher the concentration, the better the adsorption capacity, typically (Labconco Corporation 4-6).

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Calculate This!

To Calculate Expected Filter Life (in hours) have this information ready:

- Specific Gravity of Chemical – in grams/mL.
- % Filter Capacity – The percent by weight in grams that a filter can hold of a given chemical.
- Filter weight – in grams.
- Evaporation Rate of chemical – in mL/min

Here is the simplified calculation:

Theoretical Filter Life (min) =[(total Filter weight (g) x % Filter Capacity) / Specific Gravity (g/mL)]
Evaporation rate (mL/min)

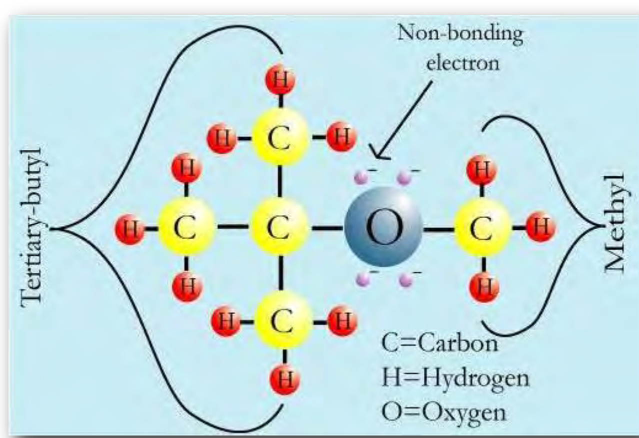
Divide the solution by 60 minutes to convert Theoretical Filter life into Hours.

There is a catch, the higher the concentration, the higher the volume of chemical going into your filter. An increase in efficiency and capacity does not always mean your filters will last longer (in terms of time).

Mixtures

Here's another fun fact: working with mixtures causes a reduction in capacity by nearly 25-40%. Think of your filters as batteries. If Battery A is used to operate Device 1 (a television remote) until it is exhausted then it will last X minutes. If Battery A is used to operate Device 2 (a remote controlled car) until it is exhausted then it will last Y minutes. Assuming that the car will drain Battery A faster than the tv remote, if Battery A is used to operate both devices at the same time until it is exhausted, the battery will last a shorter duration than it did when operating the device with the shorter battery life. For filters this is 25-40% shorter.

Of course, there are exceptions to this rule. Some chemicals experience "displacement" during carbon adsorption. This happens when a chemical has a very weak affinity for activated carbon (such as Methyl alcohol) and is paired in application with a chemical that has a higher affinity, like xylene. Xylene, with greater 'desire' to be trapped will actually 'bump' the methyl alcohol off of the carbon, releasing it into the exhaust. If your displaced chemical has a low exposure limit, toxicity threshold, or is dangerous to downstream apparatus, take extreme care and monitor downstream concentrations. You may need to employ a polishing system.



Conclusion

In all, there is a laundry list of variables that factor into “filter life”, here are a few:

- Specific Chemical characteristics (molecular weight, volatility, size, etc…)
- Chemical concentration
- Evaporation rate
- Volume of chemical used/released into the stream
- Humidity (adverse)
- Temperature
- Presence of other chemicals
- Filter make-up
- Chemical mixtures

With the appropriate information and chemical data, carbon filter life can be calculated through a simple set of formulas (Garrett).

As a general rule for good practice and per SEFA 9, laboratories should inquire with the equipment manufacturers to the suitability of carbon filtration for their independent and specific application. Should there be changes in laboratory practice or the purpose of a carbon filtered device, the laboratory should assess how the changes may effect this equipment (Scientific Equipment & Furniture Association).

References

Garrett, Brian. "Cabron Filter Capacity: Calculate This!" *Labconco General Chemistry eNewsletter* August 2012.

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