Guar as a Carbon Source

Guar is used during fracturing and drilling operations as an aqueous viscosifier. Increased viscosity of water is useful for suspending and transporting particulate solids, such as fracturing proppants or drill cuttings. Guar is an organic material, so contains carbon. Organic carbon, on one hand, can interfere in remediation actions that rely upon in situ oxidation and, on the other hand, support anaerobic remediation processes by acting as an electron donor. In either case, quantitative understanding of this role for guar can be advantageous if not desirable. This memorandum describes how to determine the carbon content of guar and provides an estimate of its potential impact on remediation processes.

In the extreme, guar can yield no more carbon than it contains. In reality, the quantity of available carbon that can be realized may be less because stable products might form that suppress additional reactivity. Identifying such reactions is an ad hoc exercise. Rather, we will compute the maximum amount of carbon available in guar. Whether this is a conservative or approximate answer may depend upon your point of view. For example: in the case of oxidative remediation process, this calculation provides a conservative limit that suggests the maximum degree of interference guar will exert. In contrast, for anaerobic systems, the calculation provides an estimate of that amount of carbon that might augment remedial efforts – prudent designs would not rely on this value.

Our calculation amounts to a simple exercise in molecular stiochiometry. Guar is a polysaccharide composed of the two simple sugars, galactose and mannose. Galactose and mannose have the same chemical formula, $C_6H_{12}O_6$, and differ only in the arrangement of the hydroxyl groups within their structure. The simple sugars join to form chain – like structures, which can have short side chains, by the simple condensation, or dehydration, reaction

$$\text{simpleSugar} + \text{simpleSugar} \dashrightarrow \text{disaccharide} + H_2O$$

If the number of simple sugars in the polymer chain is n, then the number of water molecules released is n-1. Accordingly, the chemical formula for guar is $C_{6n}H_{12n-2(n-1)}O_{6n-(n-1)}$ or $C_{6n}H_{10n-2}O_{5n-1}$ The value for n is not well documented. Regardless, the weight fraction of carbon in guar can be calculated straightforwardly because of the identical chemical formula of the two simple sugars. The exercise outlined in Table 1 shows that molecule size has little impact on the weight fraction.

Evaluation of Column (e) for n = 1 and infinity teaches that the carbon weight fractions in guar ranges from 0.4022 and 0.4444. The weight fraction for finite values of n is within 1% of the limiting value of 0.4444 when n exceeds 10. A similar exercise for hydrogen shows that the weight fraction of hydrogen ranges from 0.0670 to 0.0617 with similar dependence of n. Substantially larger values of n are viable; while the molecular weight of the simple sugars is 180, useful macromolecules can have weights in the hundreds of thousands, which implies n of hundreds.

The above calculation shows the weight fraction of carbon in guar to be about 45%. If the carbon is completely oxidized, a stiochiometric quantity of oxygen will be needed. From the molecular formula of CO_2 and atomic weights of 12 for carbon and 16 for oxygen, the weight ratio of oxygen to carbon is 2x16/12 = 2.667 lb Oxygen per lb of Carbon. Multiplying this ratio by the weight fraction of carbon in guar generates the oxygen demand of guar itself.

2.667 lb oxygen per lb carbon X 0.45 lb carbon per lb guar = 1.2 lb oxygen per lb guar.

Repeating this calculation for hydrogen, which uses the stiochiometric ratio of water (8 lb oxygen / lb hydrogen,) shows that each lb of gaur also exerts a demand of ½ lb of oxygen to oxidize the hydrogen.

8 lb oxygen per lb hydrogen X 0.062 lb hydrogen per lb gaur = 0.496 lb oxygen per lb guar

The total of the contributions of carbon and hydrogen amounts to an oxygen demand of ~1.75 lb per lb of guar.

Constituent	Simple Sugar Formula (a)	Guar Formula (b)	Atomic Wght (c)	Col (b) X Col (c) (d)	Wgt Fraction (e)
Carbon	6	6n	12	72n	$\frac{72n}{162n+17}$
Hydrogen	12	10n-2	1	10n + 1	$\frac{10n+1}{162n+17}$
Oxygen	6	5n-1	16	80n + 16	$\frac{80n+16}{162n+17}$
Totals				162n+17	1.000

Table 1. Calculation of the weight fraction of constituents in guar.