ENV 6519: Physical & Chemical Processes in Environmental Engineering

Spring 2008 — University of South Florida
Handout — Civil & Environmental Eng.
Costs of GAC Systems for Water Treatment — J. A. Cunningham

I. Main cost elements of GAC systems
   A. Capital costs
      1. Steel pressure vessels
      2. Backwash pumps
      3. Indirect costs
      4. Initial load of GAC
   B. Operating & Maintenance costs
      1. Process electricity (incl. backwash)
      2. Building electricity
      3. Electricity for pumping water through GAC bed
      4. Maintenance
      5. Labor
      6. Carbon replacement
   C. Spent GAC management
      1. Replace with virgin GAC? (O&M only)
      2. On-site regeneration? (Capital and O&M)
      3. Off-site regeneration? (O&M only)
   D. Total cost
      1. Expressed as net present value
      2. Expressed as annual cost and as $ per 1000 gallons treated

II. Equations for capital costs
   A. Steel pressure vessels (1983 dollars)
      1. Cost includes plumbing, instrumentation, etc. – all direct costs
      2. Cost does not include indirect costs
      3. V = volume of GAC in ft^3
      4. Cost $= 16,125 + 7,632(V)^{0.523}$ if $V < 400$ ft^3
      5. Cost $= 16,125 + 8,410(V)^{0.523}$ if $400\ \text{ft}^3 < V < 1000\ \text{ft}^3$
      6. Cost $= 100,100 + 149.1(V)^{0.997}$ if $1000\ \text{ft}^3 < V < 3000\ \text{ft}^3$
      7. Cost $= 100,100 + 155.6(V)^{0.997}$ if $V > 3000$ ft^3
   B. Initial load of GAC (1988 dollars)
      1. M = mass of GAC, in kg or in lb, as needed
      2. Cost $= 0$ if $V < 1000$ ft^3 – included in "package plant"
      3. Cost $= M *$ (unit price) if $V > 1000$ ft^3
      4. Unit price $= (\$2.00/\text{lb}) * (M/5000\ \text{lb})^{-0.27}$ – unit price decreases if you buy more

II. continued

C. Backwash pumps (1983 dollars)

1. Cost includes plumbing, instrumentation, etc. – all direct costs
2. Cost does not include indirect costs
3. Q_B = capacity of backwash pumps, in gallons per minute
4. A_X = cross-sectional area of GAC beds, in ft^2
5. Estimate $Q_B = (10 \text{ gpm/ft}^2)A_X$
6. Cost = 0 if $V < 1000$ ft^3 – included in "package plant"
7. Cost $= 47,200 + 21.8(Q_B)^{0.933}$ if $V > 1000$ ft^3

D. Indirect cost = 35% of direct cost

III. Equations for O&M costs

A. Electricity for backwash pumping and building energy – use \$0.10 per kWh in 2008

1. Energy (kWh/year) $= 2,983(A_X)^{0.4289}$ if $V < 1000$ ft^3 and $A_X < 50$ ft^2
2. Energy (kWh/year) $= 203.2(A_X)^{1.12}$ if $V < 1000$ ft^3 and 50 ft^2 $< A_X <$ 200 ft^2
3. Energy (kWh/year) $= 12(A_X) + 1,000(A_X)^{0.813}$ if $V > 1000$ ft^3

B. Labor – use \$15/hr in 1988

1. Labor (hrs/year) $= 256 + 248.6(A_X)^{0.2104}$ if $V < 1000$ ft^3 and $A_X < 50$ ft^2
2. Labor (hrs/year) $= 766.6 + 0.00224(A_X)^{2.491}$ if $V < 1000$ ft^3 and 50 ft^2 $< A_X <$ 200 ft^2
3. Labor (hrs/year) $= 1,460 + 12.6(A_X)^{0.698}$ if $V > 1000$ ft^3

C. Maintenance (1983 dollars)

1. Cost $= 100 + 34.2(V)^{0.601}$ if $V < 1000$ ft^3
2. Cost $= 1,115 + 7.33(V)$ if $V > 1000$ ft^3

D. Electricity for pumping water through the GAC beds – use \$0.10 per kWh in 2008

1. Q = volumetric flow rate of contaminated water, in millions of gallons per day
2. Energy (kWh/year) $= 47,817.6(Q)$

E. Electricity for pumping water through the GAC beds – alternate method

1. Energy (W) $= (S_F/e) * (Q' \, \rho_L \, g \, H)$
2. S_F = motor size-up factor, 1.25
3. e = pump efficiency, 0.75
4. Q' = volumetric flow of contaminated water, in m^3/sec, not in mgd
5. ρ_L = density of water, 999 kg/m^3 at 10 ^{o}C
6. H = total pumping head = bed depth (in m) + head loss (assume 4.6 m)
7. Don't forget to convert watts to kWh!

F. Carbon replacement – if virgin carbon is purchased each time

1. Cost = material cost + labor cost + water cost
2. M' = mass of carbon needed per year, in lbs/year
3. Material cost per year = (unit price, in \$/lb)$*M'$
4. Labor hours per year = (0.0004 hrs/lb) $* M'$ – then multiply by labor rate to get cost
5. Water cost = (0.004 gal water/lb carbon) $* M' *$ (\$0.35/1000 gallons)