iemisc: Air Stripping By Packed Column Examples

Irucka Embry, E.I.T. (EcoC²S)

2023-02-13

Contents

Replicate the R code

Note: If you wish to replicate the R code below, then you will need to copy and paste the following commands in R first (to make sure you have all the packages and their dependencies):

```
install.packages("install.load", "iemisc", "CHNOSZ")
# install the required packages
```

Example 1 ["Appendix D Example Air Stripping By Packed Column" from Design (page D-1 - D-18)]

```
install.load::load_package("iemisc", "CHNOSZ")

# values to match the Reference document
T = 20
pTe = 1
contam1 = c("Benzene", "Toluene", "Trichloroethylene")
Cai = c(750, 1000, 750)
Cae = c(10, 100, 100)
contam2 = c("Benzene", "Toluene", "Trichloroethylene")
cas = c("71-43-2", "108-88-3", "79-01-6")
Ha = c(309.2, 353.1, 506.1)
```

```
Q = 440
loading = 45
ns = 2
DL = c(8.91 * 10^-10, NA_real_, NA_real_)
DG = c(9.37 * 10^-6, NA_real_, NA_real_)
dP = 0.0508
at = 157
Sc = 0.033
cf = 15
R = 3.5
dP_units = "inch"
at_units = "ft^2/ft^3"
Sc_units = "kg/s^2"
contaminants_table = 1
removal_requirements_table = 1
critical_contaminant_table = 1


air_stripper(T = T, pTe = pTe, contam1 = contam1, Cai = Cai, Cae = Cae, contam2 = contam2,
    cas = cas, Ha = Ha, Q = Q, loading = loading, ns = ns, DL = DL, DG = DG, dP = dP,
    at = at, Sc = Sc, cf = cf, R = R, T_units = "SI", dP_units = "inch", at_units = "ft^2/ft^3",
    Sc_units = "kg/s^2", contaminants_table = 1, removal_requirements_table = 1,
    critical_contaminant_table = 1)

## [[1]]
##          Contaminant Formula GMW (kg/kg-mole) CAS Number Ha (atm/mole/mole)
## 1:           Benzene    C6H6            78.11    71-43-2              309.2
## 2:           Toluene C6H5CH3            92.14   108-88-3              353.1
## 3: Trichloroethylene  C2HCl3           131.39    79-01-6              506.1
##    Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:                   8.91e-10                9.37e-06
## 2:                         NA                      NA
## 3:                         NA                      NA
##
## [[2]]
##          Contaminant Influent Concentration (ug/L), Cai
## 1:        Total VOCs                               2500
## 2:           Benzene                                750
## 3:           Toluene                               1000
## 4: Trichloroethylene                                750
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          NA                     NA
## 2:                                          10                   98.7
## 3:                                         100                   90.0
## 4:                                         100                   86.7
##    xai (mole/mole) xae (mole/mole)
## 1:              NA              NA
## 2:         0.17298         0.00231
## 3:         0.19552         0.01955
## 4:         0.10283         0.01371
##
## [[3]]
##          Contaminant Influent Concentration (ug/L), Cai
## 1:           Benzene                                750
```

```
## 2:           Toluene                                1000
## 3: Trichloroethylene                                 750
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          10                    98.7
## 2:                                         100                    90.0
## 3:                                         100                    86.7
##    xai (mole/mole) xae (mole/mole) Formula GMW (kg/kg-mole) CAS Number
## 1:         0.17298         0.00231    C6H6            78.11    71-43-2
## 2:         0.19552         0.01955 C6H5CH3            92.14   108-88-3
## 3:         0.10283         0.01371  C2HCl3           131.39    79-01-6
##    Ha (atm/mole/mole) Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:              309.2                   8.91e-10                9.37e-06
## 2:              353.1                         NA                      NA
## 3:              506.1                         NA                      NA
##    (Cai - Cae) / Cai    H'a QGmin/QL (m^3 / m^3)
## 1:            0.9867 0.2320                4.253
## 2:            0.9000 0.2649                3.397
## 3:            0.8667 0.3797                2.282
##
## [[4]]
##    Critical Contaminant
## 1:              Benzene
##    Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                              30.38
##    Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                         0.6216
##    Height of Transfer Unit (HTU) [m] Height of Transfer Unit (HTU) [ft]
## 1:                              2.73                               8.97
##    Number of Transfer Units (NTU) Packing Depth (m) Packing Depth (ft)
## 1:                           5.58             15.23              49.98
##    Air to Water Ratio
## 1:              14.89
```

```r
# Changes to reflect the manufacturer's values
T = 20
pTe = 1
contam1 = c("Benzene", "Toluene", "Trichloroethylene")
Cai = c(750, 1000, 750)
Cae = c(10, 100, 100)
contam2 = c("Benzene", "Toluene", "Trichloroethylene")
cas = c("71-43-2", "108-88-3", "79-01-6")
Ha = c(309.2, 353.1, 506.1)
Q = 440
loading = 45
ns = 2
DL = c(8.91 * 10^-10, NA_real_, NA_real_)
DG = c(9.37 * 10^-6, NA_real_, NA_real_)
dP = 2
at = 48
Sc = 0.033
cf = 16
R = 3.5
T_units = "SI"
dP_units = "inch"
```

```
at_units = "ft^2/ft^3"
Sc_units = "kg/s^2"
contaminants_table = 1
removal_requirements_table = 1
critical_contaminant_table = 1

air_stripper(T = T, pTe = pTe, contam1 = contam1, Cai = Cai, Cae = Cae, contam2 = contam2,
    cas = cas, Ha = Ha, Q = Q, loading = loading, ns = ns, DL = DL, DG = DG, dP = dP,
    at = at, Sc = Sc, cf = cf, R = R, T_units = "SI", dP_units = "inch", at_units = "ft^2/ft^3",
    Sc_units = "kg/s^2", contaminants_table = 1, removal_requirements_table = 1,
    critical_contaminant_table = 1)

## [[1]]
##          Contaminant Formula GMW (kg/kg-mole) CAS Number Ha (atm/mole/mole)
## 1:           Benzene    C6H6            78.11    71-43-2              309.2
## 2:           Toluene C6H5CH3            92.14   108-88-3              353.1
## 3: Trichloroethylene  C2HCl3           131.39    79-01-6              506.1
##    Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:                  8.91e-10               9.37e-06
## 2:                        NA                     NA
## 3:                        NA                     NA
##
## [[2]]
##          Contaminant Influent Concentration (ug/L), Cai
## 1:        Total VOCs                              2500
## 2:           Benzene                               750
## 3:           Toluene                              1000
## 4: Trichloroethylene                               750
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          NA                     NA
## 2:                                          10                   98.7
## 3:                                         100                   90.0
## 4:                                         100                   86.7
##    xai (mole/mole) xae (mole/mole)
## 1:              NA              NA
## 2:         0.17298         0.00231
## 3:         0.19552         0.01955
## 4:         0.10283         0.01371
##
## [[3]]
##          Contaminant Influent Concentration (ug/L), Cai
## 1:           Benzene                               750
## 2:           Toluene                              1000
## 3: Trichloroethylene                               750
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          10                   98.7
## 2:                                         100                   90.0
## 3:                                         100                   86.7
##    xai (mole/mole) xae (mole/mole) Formula GMW (kg/kg-mole) CAS Number
## 1:         0.17298         0.00231    C6H6            78.11    71-43-2
## 2:         0.19552         0.01955 C6H5CH3            92.14   108-88-3
## 3:         0.10283         0.01371  C2HCl3           131.39    79-01-6
##    Ha (atm/mole/mole) Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:              309.2                  8.91e-10               9.37e-06
```

```
## 2:              353.1                          NA                       NA
## 3:              506.1                          NA                       NA
##    (Cai - Cae) / Cai    H'a QGmin/QL (m^3 / m^3)
## 1:            0.9867 0.2320               4.253
## 2:            0.9000 0.2649               3.397
## 3:            0.8667 0.3797               2.282
##
## [[4]]
##    Critical Contaminant
## 1:              Benzene
##    Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                              30.38
##    Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                          0.6216
##    Height of Transfer Unit (HTU) [m] Height of Transfer Unit (HTU) [ft]
## 1:                              2.03                               6.66
##    Number of Transfer Units (NTU) Packing Depth (m) Packing Depth (ft)
## 1:                           5.58             11.33              37.16
##    Air to Water Ratio
## 1:              14.89
```

Example 2 (Spring 2011 Hazardous Waste Management Air Stripper Group Project)

```
install.load::load_package("iemisc", "CHNOSZ")
```

```
air_stripper(T = 20, pTe = 1, contam1 = "Ammonia", Cai = 333, Cae = 2.8, contam2 = "Ammonia",
    cas = "7664-41-7", Ha = 0.75, Q = 150, loading = 45, ns = 2, DL = 8.91 * 10^-10,
    DG = 9.37 * 10^-6, dP = 145, at = 65, Sc = 0.033, cf = 76 * 6, R = 1.5, T_units = "SI",
    dP_units = "mm", at_units = "m^2/m^3", Sc_units = "kg/s^2", contaminants_table = 1,
    removal_requirements_table = 1, critical_contaminant_table = 1)
```

```
## [[1]]
##    Contaminant Formula GMW (kg/kg-mole) CAS Number Ha (atm/mole/mole)
## 1:     Ammonia     NH3            17.03  7664-41-7               0.75
##    Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:                  8.91e-10               9.37e-06
##
## [[2]]
##    Contaminant Influent Concentration (ug/L), Cai
## 1:  Total VOCs                                333
## 2:     Ammonia                                333
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          NA                     NA
## 2:                                         2.8                   99.2
##    xai (mole/mole) xae (mole/mole)
## 1:              NA              NA
## 2:         0.35227         0.00296
```

```
##
## [[3]]
##    Contaminant Influent Concentration (ug/L), Cai
## 1:     Ammonia                                 333
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                         2.8                    99.2
##    xai (mole/mole) xae (mole/mole) Formula GMW (kg/kg-mole) CAS Number
## 1:         0.35227         0.00296     NH3            17.03  7664-41-7
##    Ha (atm/mole/mole) Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:               0.75                   8.91e-10                9.37e-06
##    (Cai - Cae) / Cai   H'a QGmin/QL (m^3 / m^3)
## 1:            0.9916 6e-04              1762.13
##
## [[4]]
##    Critical Contaminant
## 1:              Ammonia
##    Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                              28.77
##    Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                      104.5166
##    Height of Transfer Unit (HTU) [m] Height of Transfer Unit (HTU) [ft]
## 1:                             27.59                              90.52
##    Number of Transfer Units (NTU) Packing Depth (m) Packing Depth (ft)
## 1:                          11.09            305.97            1003.85
##    Air to Water Ratio
## 1:            2643.19
```

```
air_stripper(T = 25, pTe = 1, contam1 = "Ammonia", Cai = 700, Cae = 2.8, contam2 = "Ammonia",
    cas = "7664-41-7", Ha = 0.75, Q = 440, loading = 45, ns = 3, DL = 2.1e-09, DG = 9.8e-06,
    dP = 6.35, at = 940, Sc = 0.061, cf = 1600, R = 1.5, T_units = "SI", dP_units = "mm",
    at_units = "m^2/m^3", Sc_units = "kg/s^2", contaminants_table = 1, removal_requirements_table = 1,
    critical_contaminant_table = 1)
```

```
## [[1]]
##    Contaminant Formula GMW (kg/kg-mole) CAS Number Ha (atm/mole/mole)
## 1:     Ammonia     NH3            17.03  7664-41-7               0.75
##    Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:                  2.1e-09                9.8e-06
##
## [[2]]
##    Contaminant Influent Concentration (ug/L), Cai
## 1:  Total VOCs                                 700
## 2:     Ammonia                                 700
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                          NA                     NA
## 2:                                         2.8                   99.6
##    xai (mole/mole) xae (mole/mole)
## 1:              NA              NA
## 2:          0.7405         0.00296
##
## [[3]]
##    Contaminant Influent Concentration (ug/L), Cai
## 1:     Ammonia                                 700
##    Effluent Standard Concentration (ug/L), Cae Removal Requirement (%)
## 1:                                         2.8                   99.6
```

```
##    xai (mole/mole) xae (mole/mole) Formula GMW (kg/kg-mole) CAS Number
## 1:          0.7405         0.00296     NH3            17.03  7664-41-7
##    Ha (atm/mole/mole) Liquid Diffusivity (m^2/s) Gas Diffusivity (m^2/s)
## 1:               0.75                   2.1e-09                9.8e-06
##    (Cai - Cae) / Cai   H'a QGmin/QL (m^3 / m^3)
## 1:             0.996 6e-04             1798.063
##
## [[4]]
##    Critical Contaminant
## 1:              Ammonia
##    Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                              31.61
##    Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
## 1:                                                                       115.3453
##    Height of Transfer Unit (HTU) [m] Height of Transfer Unit (HTU) [ft]
## 1:                              0.99                               3.23
##    Number of Transfer Units (NTU) Packing Depth (m) Packing Depth (ft)
## 1:                          13.29             13.16              43.17
##    Air to Water Ratio
## 1:            2697.09
```

Works Cited

Design Guide No. 1110-1-3: Air Stripping Engineering and Design Appendix D: Example Air Stripping By Packed Column, Department Of The Army U.S. Army Corps of Engineers, 31 October 2001, pages D-1 - D-18, http://www.publications.usace.army.mil/Portals/76/Publications/EngineerDesignGuides/DG_1110-1-3.pdf?ver=2013-08-16-101222-003.

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