

# iemisc: Air Stripping By Packed Column Examples

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## 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
# 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](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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