iemisc: Air Stripping By Packed Column Examples

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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(c("install.load", "iemisc", "pander"))
# install the packages and their dependencies
```

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

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

panderOptions("table.continues", "")
panderOptions("table.caption.prefix", "")

# 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

air1 <- 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)



# 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

air2 <- 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)
```

Example 1: Table 1. Contaminants Table {Reference document}

```
pander(air1[[1]], missing = "")
```

	Formula	GMW (kg/kg-mole)	CAS Number
Benzene	C6H6	78.11	71-43-2
Toluene	C6H5CH3	92.14	108-88-3
Trichloroethylene	C2HCl3	131.4	79-01-6

	Ha (atm/mole/mole)	Liquid Diffusivity (m^2/s)
Benzene	309.2	8.91e-10
Toluene	353.1	
Trichloroethylene	506.1	

	Gas Diffusivity (m^2/s)
Benzene	9.37e-06
Toluene	
Trichloroethylene	

Example 1: Table 2. Removal Requirements Table {Reference document}

```
pander(air1[[2]], missing = "")
```

Contaminant	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Total VOCs	2500	
Benzene	750	10
Toluene	1000	100
Trichloroethylene	750	100

Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)
98.7	0.173	0.00231
90	0.1955	0.01955
86.7	0.1028	0.01371

Example 1: Table 3. Critical Contaminant Table {Reference document}

```
pander(air1[[3]], missing = "")
```

	Influent Concentration (ug/L), Cai
Benzene	750
Toluene	1000
Trichloroethylene	750

	Effluent Standard Concentration (ug/L), Cae	Removal Requirement (%)
Benzene	10	98.7
Toluene	100	90
Trichloroethylene	100	86.7

	xai (mole/mole)	xae (mole/mole)	Formula
Benzene	0.173	0.00231	C6H6
Toluene	0.1955	0.01955	C6H5CH3
Trichloroethylene	0.1028	0.01371	C2HCl3

	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Benzene	78.11	71-43-2	309.2

	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Toluene	92.14	108-88-3	353.1
Trichloroethylene	131.4	79-01-6	506.1

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Benzene	8.91e-10	9.37e-06
Toluene		
Trichloroethylene		

	(Cai - Cae) / Cai	H'a	QGmin/QL (m^3 / m^3)
Benzene	0.9867	0.232	4.253
Toluene	0.9	0.2649	3.397
Trichloroethylene	0.8667	0.3797	2.282

Example 1: Table 4. Air Stripper Design Table {Reference document}

```
pander(air1[[4]])
```

Critical Contaminant	Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
Benzene	30.38

Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)	Height of Transfer Unit (HTU) [m]
0.6216	2.73

Height of Transfer Unit (HTU) [ft]	Number of Transfer Units (NTU)
8.97	5.58

Packing Depth (m)	Packing Depth (ft)	Air to Water Ratio
15.23	49.98	14.89

Example 1: Table 1. Contaminants Table {Manufacturer's values}

```
pander(air2[[1]], missing = "")
```

	Formula	GMW (kg/kg-mole)	CAS Number
Benzene	C6H6	78.11	71-43-2
Toluene	C6H5CH3	92.14	108-88-3
Trichloroethylene	C2HCl3	131.4	79-01-6

	Ha (atm/mole/mole)	Liquid Diffusivity (m^2/s)
Benzene	309.2	8.91e-10
Toluene	353.1	
Trichloroethylene	506.1	

	Gas Diffusivity (m^2/s)
Benzene	9.37e-06
Toluene	
Trichloroethylene	

Example 1: Table 2. Removal Requirements Table {Manufacturer's values}

```
pander(air2[[2]], missing = "")
```

Contaminant	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Total VOCs	2500	
Benzene	750	10
Toluene	1000	100
Trichloroethylene	750	100

Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)
98.7	0.173	0.00231
90	0.1955	0.01955
86.7	0.1028	0.01371

Example 1: Table 3. Critical Contaminant Table {Manufacturer's values}

```
pander(air2[[3]], missing = "")
```

	Influent Concentration (ug/L), Cai
Benzene	750
Toluene	1000
Trichloroethylene	750

	Effluent Standard Concentration (ug/L), Cae	Removal Requirement (%)
Benzene	10	98.7
Toluene	100	90
Trichloroethylene	100	86.7

	xai (mole/mole)	xae (mole/mole)	Formula
Benzene	0.173	0.00231	C6H6
Toluene	0.1955	0.01955	C6H5CH3
Trichloroethylene	0.1028	0.01371	C2HCl3

	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Benzene	78.11	71-43-2	309.2
Toluene	92.14	108-88-3	353.1
Trichloroethylene	131.4	79-01-6	506.1

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Benzene	8.91e-10	9.37e-06
Toluene		
Trichloroethylene		

	(Cai - Cae) / Cai	H'a	QGmin/QL (m^3 / m^3)
Benzene	0.9867	0.232	4.253
Toluene	0.9	0.2649	3.397
Trichloroethylene	0.8667	0.3797	2.282

Example 1: Table 4. Air Stripper Design Table {Manufacturer's values}

```
pander(air2[[4]])
```

Critical Contaminant	Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
Benzene	30.38

Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)	Height of Transfer Unit (HTU) [m]
0.6216	2.03

Height of Transfer Unit (HTU) [ft]	Number of Transfer Units (NTU)
6.66	5.58

Packing Depth (m)	Packing Depth (ft)	Air to Water Ratio
11.33	37.16	14.89

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

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

```
air3 <- 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)
```

```
air4 <- 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)
```

Example 2: Table 1. Contaminants Table {Original Design}

```
pander(air3[[1]])
```

	Formula	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Ammonia	NH3	17.03	7664-41-7	0.75

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Ammonia	8.91e-10	9.37e-06

Example 2: Table 2. Removal Requirements Table {Original Design}

```
pander(air3[[2]], missing = "")
```

Contaminant	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Total VOCs	333	
Ammonia	333	2.8

Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)

99.2 0.3523 0.00296

Example 2: Table 3. Critical Contaminant Table {Original Design}

```
pander(air3[[3]])
```

	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Ammonia	333	2.8

	Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)
Ammonia	99.2	0.3523	0.00296

	Formula	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Ammonia	NH3	17.03	7664-41-7	0.75

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Ammonia	8.91e-10	9.37e-06

	(Cai - Cae) / Cai	H'a	QGmin/QL (m^3 / m^3)
Ammonia	0.9916	6e-04	1762

Example 2: Table 4. Air Stripper Design Table {Original Design}

```
pander(air3[[4]])
```

Critical Contaminant	Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
Ammonia	28.77

Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)	Height of Transfer Unit (HTU) [m]
104.5	27.59

Height of Transfer Unit (HTU) [ft]	Number of Transfer Units (NTU)
90.52	11.09

Packing Depth (m)	Packing Depth (ft)	Air to Water Ratio
306	1004	2643

Example 2: Table 1. Contaminants Table {Modified Design}

```
pander(air4[[1]])
```

	Formula	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Ammonia	NH3	17.03	7664-41-7	0.75

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Ammonia	2.1e-09	9.8e-06

Example 2: Table 2. Removal Requirements Table {Modified Design}

```
pander(air4[[2]], missing = "")
```

Contaminant	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Total VOCs	700	
Ammonia	700	2.8

Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)

99.6 0.7405 0.00296

Example 2: Table 3. Critical Contaminant Table {Modified Design}

```
pander(air4[[3]])
```

	Influent Concentration (ug/L), Cai	Effluent Standard Concentration (ug/L), Cae
Ammonia	700	2.8

	Removal Requirement (%)	xai (mole/mole)	xae (mole/mole)
Ammonia	99.6	0.7405	0.00296

	Formula	GMW (kg/kg-mole)	CAS Number	Ha (atm/mole/mole)
Ammonia	NH3	17.03	7664-41-7	0.75

	Liquid Diffusivity (m^2/s)	Gas Diffusivity (m^2/s)
Ammonia	2.1e-09	9.8e-06

	(Cai - Cae) / Cai	H'a	QGmin/QL (m^3 / m^3)
Ammonia	0.996	6e-04	1798

Example 2: Table 4. Air Stripper Design Table {Modified Design}

```
pander(air4[[4]])
```

Critical Contaminant	Molar Liquid (Water) Flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)
Ammonia	31.61

Molar Gas (Air) flow per unit of Stripper Cross-Sectional Area (kg mole/m^2 s)	Height of Transfer Unit (HTU) [m]
115.3	0.99

Height of Transfer Unit (HTU) [ft]	Number of Transfer Units (NTU)
3.23	13.29

Packing Depth (m)	Packing Depth (ft)	Air to Water Ratio
13.16	43.17	2697

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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