Using an Artificial Neural Network to Determine the Degradation of Acetaldehyde in a Bioscrubber

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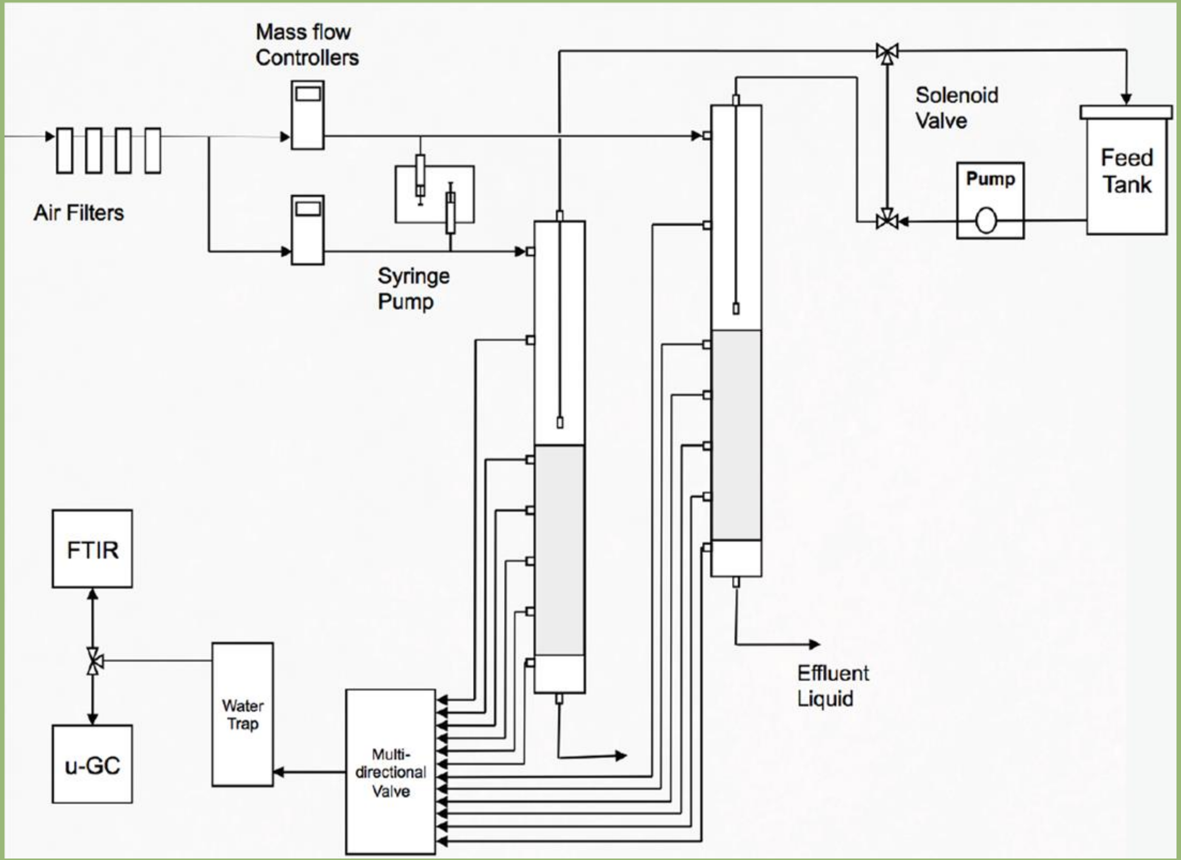
What is a Biotrickling Filter

- Column
- Contaminated air passes through
- A moistened porous bed containing microorganisms capable of degrading the pollutants.
    - Microorganisms
        - Aerobic process producing
        - CO_2
        - Water
        - Biomass.
    - This study contained two BTF columns, one at 21°C and another at 60°C.

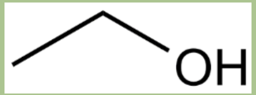
BTF

- Cold column (21°C)
- Hot BTF column (60°C)
- 6 ports along the side of the column
- Each port measured the HAP and CO_2 concentration



BTF Continued

- Many industries, such as the ethanol industry, use natural gas and water to treat hazardous air pollutants (HAPs) created from industrial facilities.
  - BTFs can treat HAPs while reducing the use of natural gas
- This research used previous data collected from the bioscrubber
  - Acetaldehyde concentration
  - CO_2 concentration
  - 178-day test run at different conditions

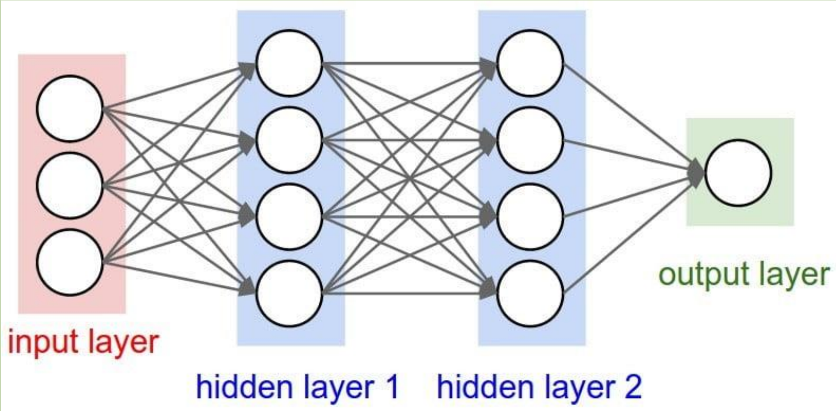


Project Goal

- Create an artificial neural network (ANN) to model the degradation of HAPs in the pilot BTF
- The collection of all data can be time intensive and complex
- ANN will reduce the expense to collect and process the data
- Essential data for modeling and understanding the BTF
    - Acetaldehyde concentration at all ports
    - CO_2 concentration at all ports
    - Loading rate
    - Inlet concentration of Acetaldehyde

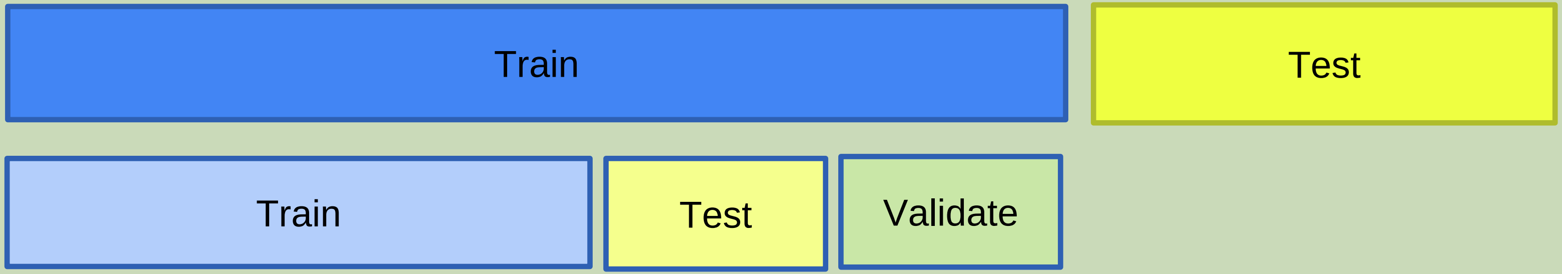
Artificial Neural Networks

- ANNs use the “back box” method
  - The black box is given certain inputs and returns outputs
  - ANNs learn how to predict outcomes based on specific given examples
  - The ANN receives the data in the input layer, passes the information on to the hidden layer, with connection weights, and then passes the information onto the output layer
  - The weights increase and decrease with the training of the system and determine which inputs/neurons influence the output more.



Artificial Neural Networks Continued

- 80% of the experimental data went to training the model, and 20% was used as a leave out group to test the model
  - Training data: 70% training, 15% validation,15%testing
- Limited experimental data to train ANN
- Fundamental biokinetic models may not be able to simulate all of the complex components of the BTF operations



Results

- The models produced were not robust
- They showed the significance of the hyperparameters and the parameters
  - Ports in series vs Ports individually
  - Training functions
    - Trainlm vs Trainbr vs Trainscg
  - 1 hidden layers vs 2
    - 4 hidden neurons vs 8
  - Day of the week and Day since the start of each concentration
  - CO_2 → Acetaldehyde vs Acetaldehyde → CO_2

Results Continued

Cold Column-ports in series (Ace -> CO2)												
Function	Hidden Layer	Hidden neuron	MSE tr	MSE val	MSE test	R tr	R test	R val	R all	MSE test2	R test2	R-squared test2
Trainbr	1	4	5.5E-05		~.0015	0.99904	0.32247		0.99176	0.05503	0.907587	0.629863
Trainbr	1	8	5.63E-05		0.036	0.9988	0.99335		0.948166	0.012	0.98166	0.899112
Trainbr	2	4	0.0215		0.119	0.51224	0.54468		0.51027	0.11283	0.42359	0.155727
Trainbr	2	8	0.0204		0.0219	0.55099	0.79697		0.5103	0.1104	0.42326	0.16877
Trainlm	1	4	9.63E-05	0.0015	0.003	0.99872	0.96808	0.98662	0.57388	0.692	0.96736	0.479049
Trainlm	1	8	0.0045	0.0102	0.002	0.94154	0.95128	0.80928	0.91444	0.1049	0.85114	0.209622
Trainlm	2	4	0.000513	0.00071	0.0188	0.99149	0.91779	0.94714	0.09876	0.0453	0.97618	0.658747
Trainlm	2	8	6.73E-05	0.0032	0.003	0.9989	0.97363	0.91974	0.98232	0.036	0.91029	0.728542
Trainscg	1	4	0.003	0.0057	0.0055	0.91894	0.93671	0.92565	0.95035	0.0714	0.93171	0.462243
Trainscg	1	8	0.0158	0.0069	0.0067	0.67753	0.67641	0.93538	0.72766	0.0557	0.89765	0.580307
Trainscg	2	4	0.0258	0.0068	0.0126	0.34115	0.43716	0.48811	0.91905	0.088	0.69423	0.336957
Trainscg	2	8	0.0042	0.0061	0.0099	0.91262	0.9277	0.82703	0.89461	0.0552	0.89585	0.584322

Hot Column-ports in series (Ace -> CO2)												
Function	Hidden Layer	Hidden neuron	MSE tr	MSE val	MSE test	R tr	R test	R val	R all	MSE test2	R test2	R-squared test2
Trainbr	1	4	0.011579		~0.1	0.83963	0.42921		0.72662	0.035842	0.604257	-0.03527
Trainbr	1	8	0.0385		0.0869	0.53132	-0.14436		0.4138	0.0183	0.76993	0.536954
Trainbr	2	4	0.036		0.1041	0.55518	-0.30357		0.41658	0.0167	0.80708	0.57737
Trainbr	2	8	0.0308		0.1159	0.39153	0.70267		0.41456	0.0249	0.77923	0.369969
Trainlm	1	4	0.0047	0.0597	0.437	0.93717	0.55186	0.80598	0.75481	0.0751	0.50933	-0.8979
Trainlm	1	8	2.89E-04	0.0849	0.0389	0.99844	0.68073	0.34769	0.80876	0.0291	0.73017	0.265599
Trainlm	2	4	0.0262	0.0423	0.0519	0.75353	0.43484	0.63099	-0.10924	0.0919	-0.43359	-1.3232
Trainlm	2	8	0.0043	0.0097	0.1337	0.96156	-0.41715	0.62223	0.74084	0.0365	0.56668	0.077507
Trainscg	1	4	0.0518	0.0172	0.018	0.49774	0.71873	0.53018	0.69389	0.0188	0.73173	-1.27659
Trainscg	1	8	0.0199	0.218	0.0376	0.70737	0.33777	0.34388	0.50721	0.0166	0.87061	0.581509
Trainscg	2	4	0.0625	0.0739	0.0694	0.27545	-0.00074	0.14415	-0.44733	0.0901	-0.13507	-0.00133
Trainscg	2	8	0.0103	0.0333	0.0601	0.88198	4.94E-01	0.82818	0.76148	0.0098	0.93323	0.751129

Cold Column-ports in series (CO2 -> Ace)												
Function	Hidden Layer	Hidden neuron	MSE tr	MSE val	MSE test	R tr	R test	R val	R all	MSE test2	R test2	R-squared test2
Trainbr	1	4	1.99E-05		0.0204	0.99974	0.93694		0.96967	0.0035	0.97478	0.947142
Trainbr	1	8	1.81E-05		7.93E-04	0.99979	0.66185		0.99834	0.0045	0.96697	0.931146
Trainbr	2	4	0.0292		0.0259	0.57185	0.76698		0.53117	0.0484	0.52027	0.261432
Trainbr	2	8	0.0311		0.0099	0.5187	0.74998		0.53099	0.0494	0.51982	0.246286
Trainlm	1	4	0.0071	8.59E-04	7.98E-04	0.94523	0.99044	0.90995	0.94465	0.0076	0.97039	0.884409
Trainlm	1	8	5.14E-09	1.23E-02	0.0061	1	0.87319	0.90444	0.96963	0.0133	0.97631	0.797389
Trainlm	2	4	0.0119	0.0063	0.0088	0.88652	0.25264	0.93744	0.85721	0.0644	0.30249	0.017877
Trainlm	2	8	3.37E-05	0.0039	0.0461	0.99962	0.085595	0.79824	0.90415	0.01	0.95213	0.846964
Trainscg	1	4	0.0011	0.0045	0.0012	0.98882	0.96008	0.97865	0.98036	0.0093	0.98207	0.858745
Trainscg	1	8	6.33E-04	6.40E-04	0.032	0.97904	0.91993	0.98224	0.94417	0.0255	0.8009	0.61131
Trainscg	2	4	0.0055	8.56E-04	0.0106	0.94342	0.59174	0.47376	0.92472	0.0495	0.72222	0.245406
Trainscg	2	8	0.0078	0.0368	0.0063	0.92047	0.17333	0.97005	0.86216	0.016	0.90069	0.756562

Conclusions

- Developed working models with limited data
- It may be cost effective method for determining HAPs reduction at an ethanol plant (when using ambient temperature)
- May be able to apply this method of detection to current treatment technology

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