Understanding Aeration to Select the Proper Technology

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Introduction

Aeration is a real need at any oxidative sulphide leach path, for example:

(A) $$Cu_2S + 4Fe^{3+} \overset{Cl^-}{=} 2Cu^{2+} + 4Fe^{2+} + S$$

(B) $$Cu^{2+} + Fe^{2+} \overset{Cl^-}{=} Fe^{3+} + Cu^{+}$$

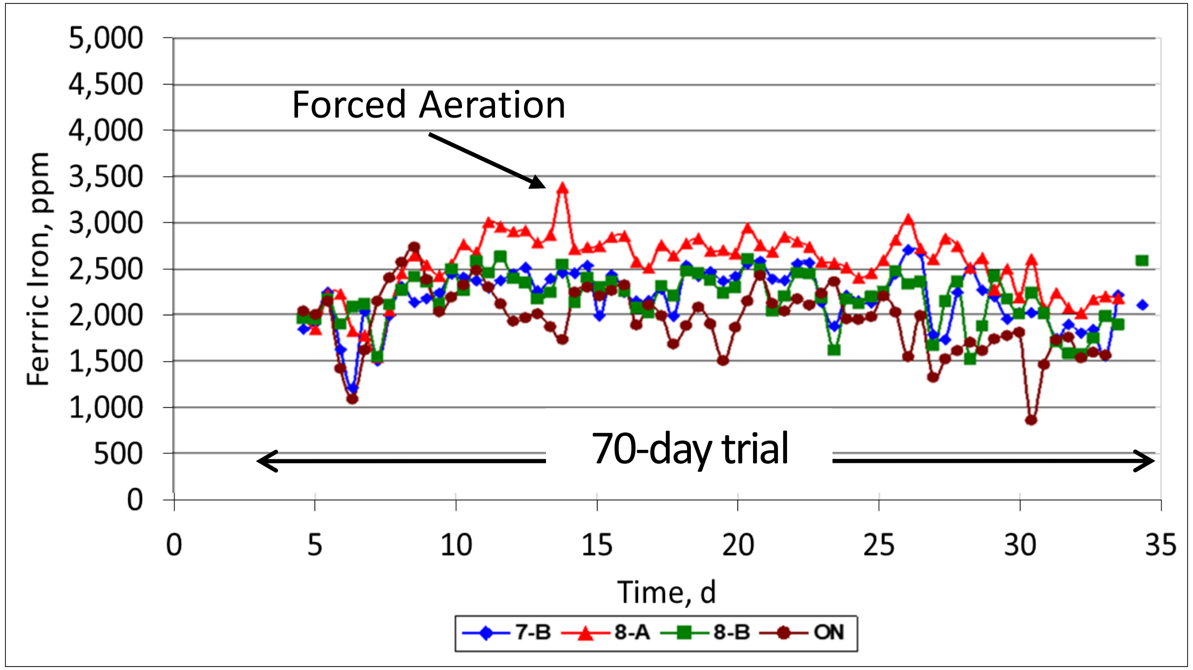
(C) $$4Cu^{+} + O_2 + 4H^{+} \overset{Cl^-}{=} 4Cu^{2+} + 2H_2O$$

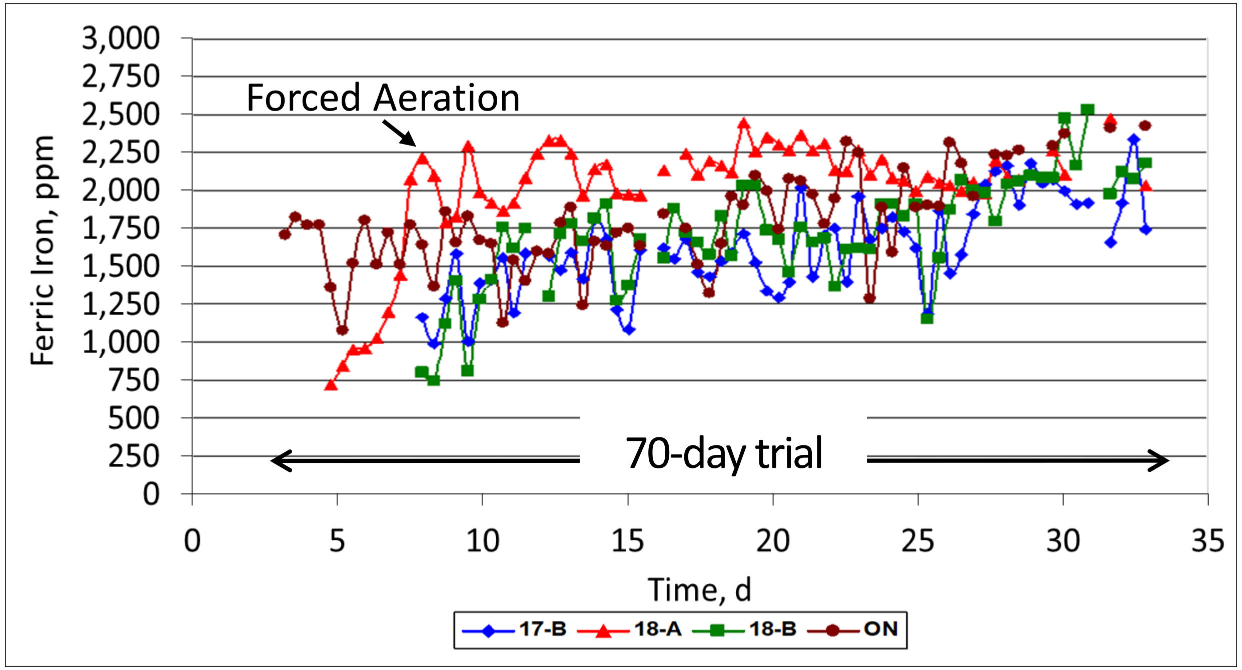
(D) $$Cu_2S + O_2 + 2H_2SO_4 \overset{Cl^-}{=} 2CuSO_4 + 2S + 2H_2O$$

- 0.25 kg O_2/kg Cu
- 1.54 kg Ácido/kg Cu

1 Nm^3 Air/kg Cu

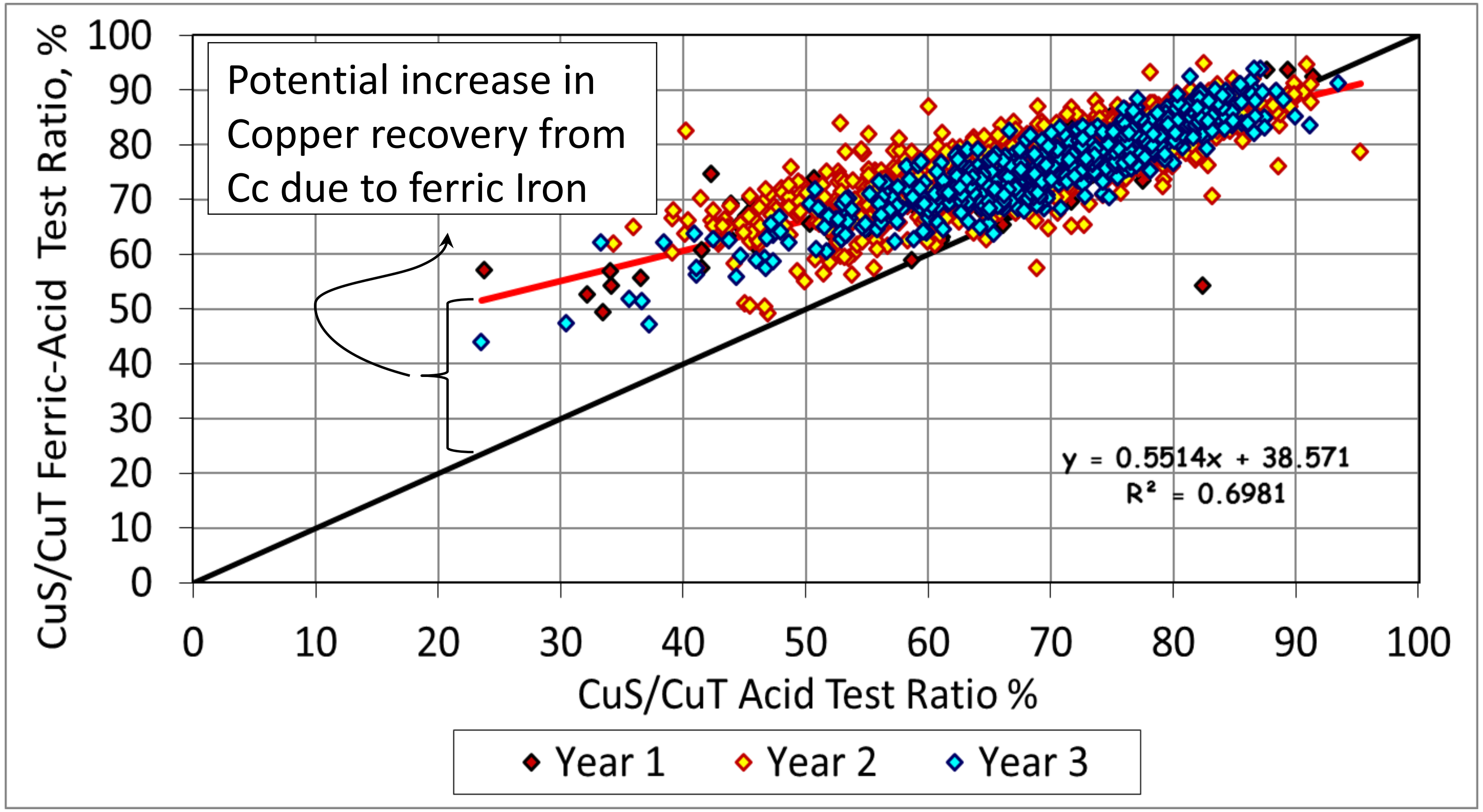
Forced Aeration Increases the Ferric Iron Levels





Increase about +500 to 750 ppm Fe^{3+} or 25 to 30% (9 m pads)

Copper Solubility is Sensitive to Ferric Iron



Pneumatic/Hydrodynamic Air System Design

- ✓ Estimate the SWCC relationship (experimental or pedotransfer method)
- ✓ Compute the saturated hydraulic conductivity, experimental or model
- ✓ Compute the overall hydraulic conductivity curve, van Genuchten model
- ✓ Compute the pneumatic conductivity curve, modified van Genuchten model
- ✓ Estimate the oxygen/aeration needs to dimension the blower capacity/piping
- ✓ Simulate dynamically the whole leach cycle under the design conditions, numerical solution of the Richards equation
- ✓ Check hydrodynamic and pneumatic acceptability conditions
- ✓ Iterate if neccesary until results are satisfying
- ✓ Check the definitive blower capacity and piping net design.

Air Requirement: Blower and Piping Net

Cpy: $CuFeS_2 + O_2 + 4H^+ \overset{Cl,Cu,Fe}{=} Cu^{2+} + Fe^{2+} + 2S + 2H_2O$

Cc: $Cu_2S + O_2 + 4H^+ \overset{Cl,Cu,Fe}{=} 2Cu^{2+} + S + 2H_2O$

Cv: $CuS + 0.5O_2 + 2H^+ \overset{Cl,Cu,Fe}{=} Cu^{2+} + S + H_2O$

Py: $FeS_2 + 3.5O_2 + H_2O \overset{Cl,Cu,Fe}{=} Fe^{2+} + 2H^+ + 2SO_4^{2-}$

Stoichometric O_2 Unit Consumption

Mineral	t O_2/t dissolved Cu
Cpy	0.50
Cc	0.25
Cv	0.25
Py	2.01

Parameter	Py	Cpy	Cc	Cv
t of ore	1	1	1	1
% Cu - % Py	2.00	0.17	0.17	0.17
kg Cu/t - kg Py/t	20.00	1.67	1.67	1.67
Metal recovery, %	30	60	80	70
kg Oxygen/t of ore	5.61	0.50	0.33	0.29
kg Air /t of ore	28.04	2.50	1.67	1.46
Air N-density, kg/m^3 Air	1.2	1.2	1.2	1.2
Nm^3 Air /t of ore	23.36	2.08	1.39	1.22
Ore bulk density, t/m^3	1.7	1.7	1.7	1.7
Pad height, m	6	6	6	6
t of ore/m^2 pad	10.2	10.2	10.2	10.2
Nm^3 Air /m^2 pad	238.30	21.25	14.17	12.40
Metal Rec. initial repose, %	16.67	40.00	40.00	40.00
Air Cons. Init. repose, Nm^3 Air/m^2	39.72	8.50	5.67	4.96
Repose extent, days	30.00	30.00	30.00	30.00
Air rate repose Nm^3 Air/h/m^2	0.06	0.01	0.01	0.01
Safety factor	3.00	3.00	3.00	3.00
Air requirement, Nm^3 Air/h/m^2	0.17	0.04	0.02	0.02
Air requirement, Nm^3 Air/h/m^2	0.25			

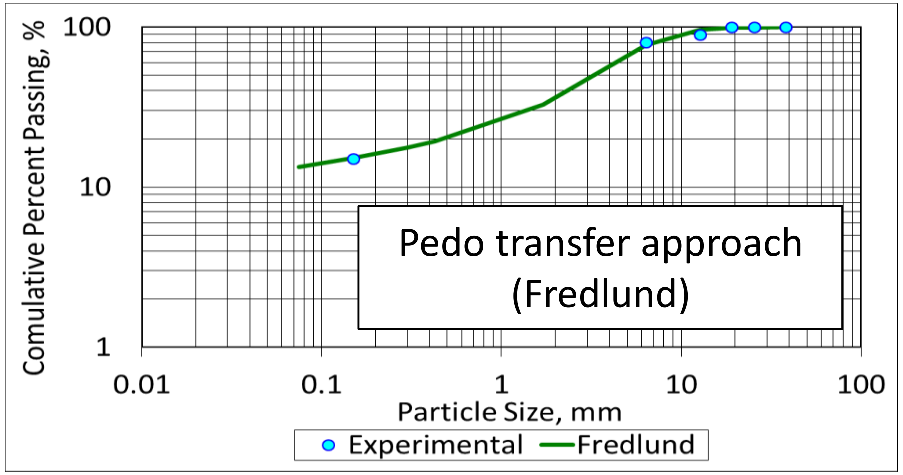
Practical Issues

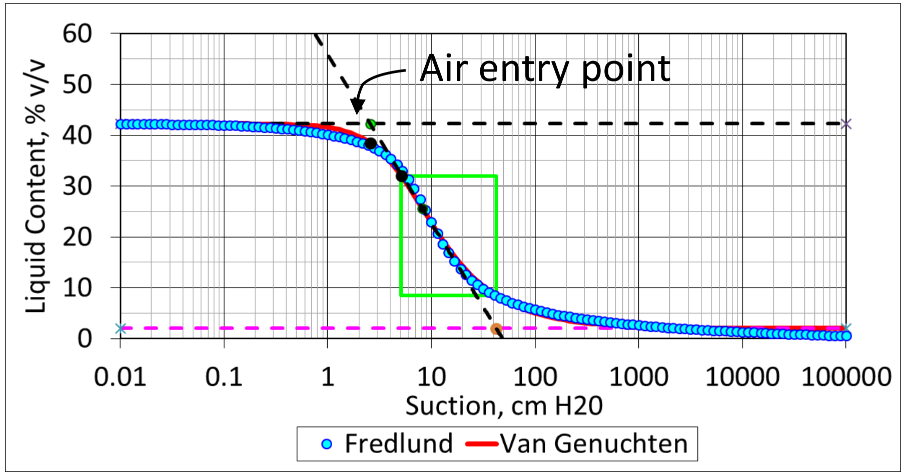
The often high air permeability has several important implications.

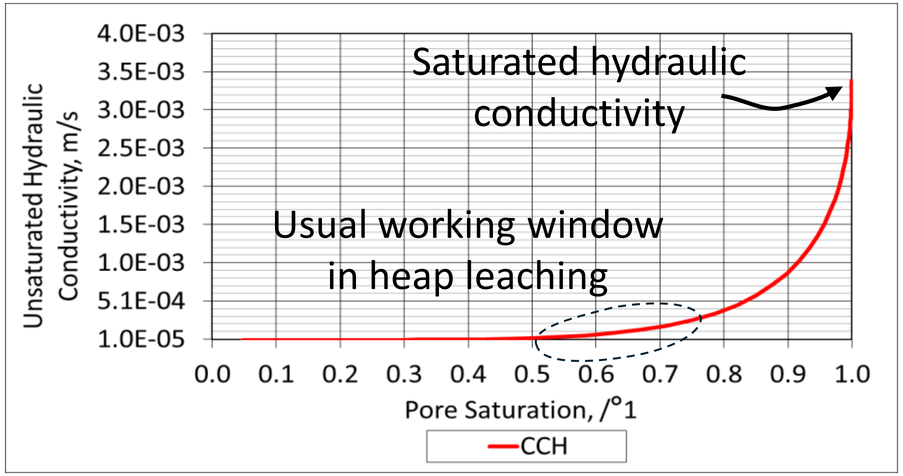
- ✓ The low resistance to flow means that large volume with very low-pressure blowers are the most economic way to supply air.
- ✓ The low back pressure in the heap or dump means that most of the pressure loss will occur in the piping. Thus, the piping system should be designed to minimize pressure losses and reduce operating costs.
- ✓ Experience has shown that air exiting a heap or dump is fully humidified. Thus, blowing an excessive amount of air will evaporate a substantial amount of water. This will reduce dissolution kinetics, it also will increase water make-up requirements. Also the evaporation will remove a significant amount of heat and could drive to cooling of the heap and, hence, the leach rate will be additionally retarded.

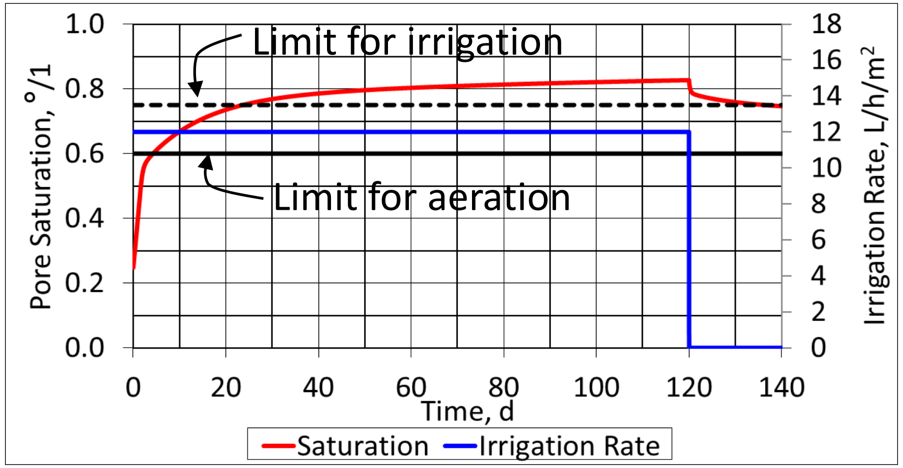
W. Joseph Schlitt, Minerals & Metallurgical Processing, Vol. 23, No. 2 • May 2006.

Case Study 1: Operation under Simultaneous Aeration and Irrigation Conditions







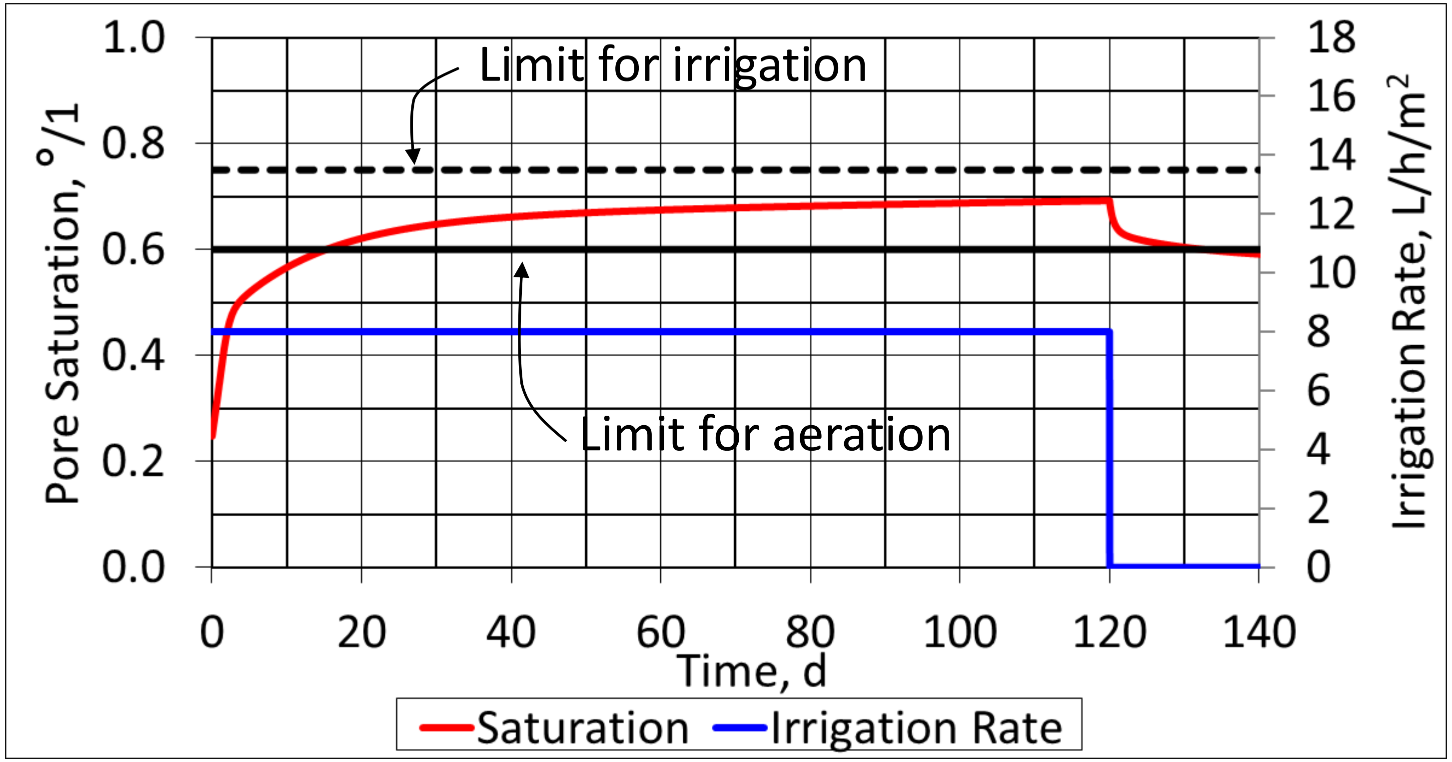


DIAGNOSIS:

- ✓ Excessive irrigation
- ✓ Lack of aeration

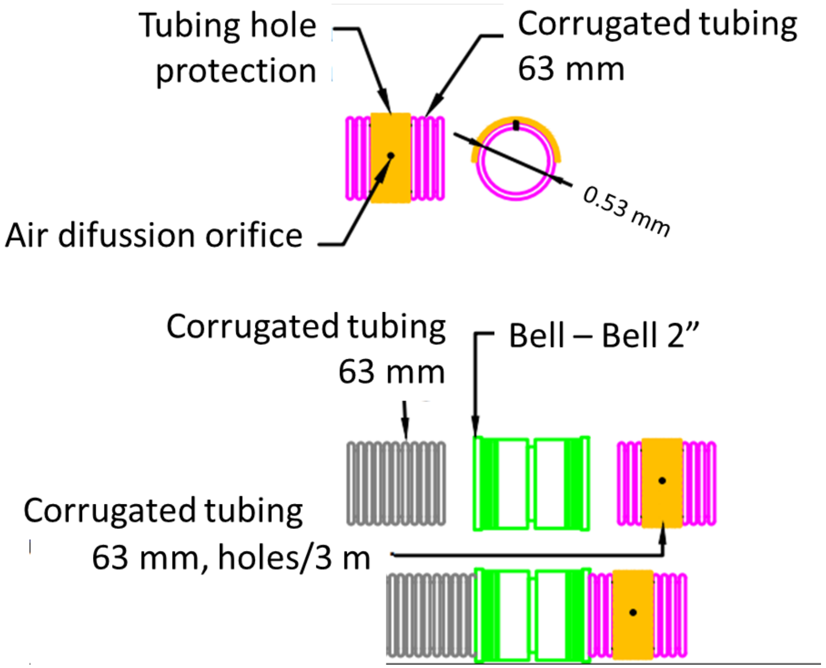
Case Study 1: Operation under Simultaneous Aeration and Irrigation Conditions

Recommendation: The irrigation rate should be reduced from 12 L/h/m² to 8 L/h/m² to enter into the safe region where aeration and irrigation operate well.



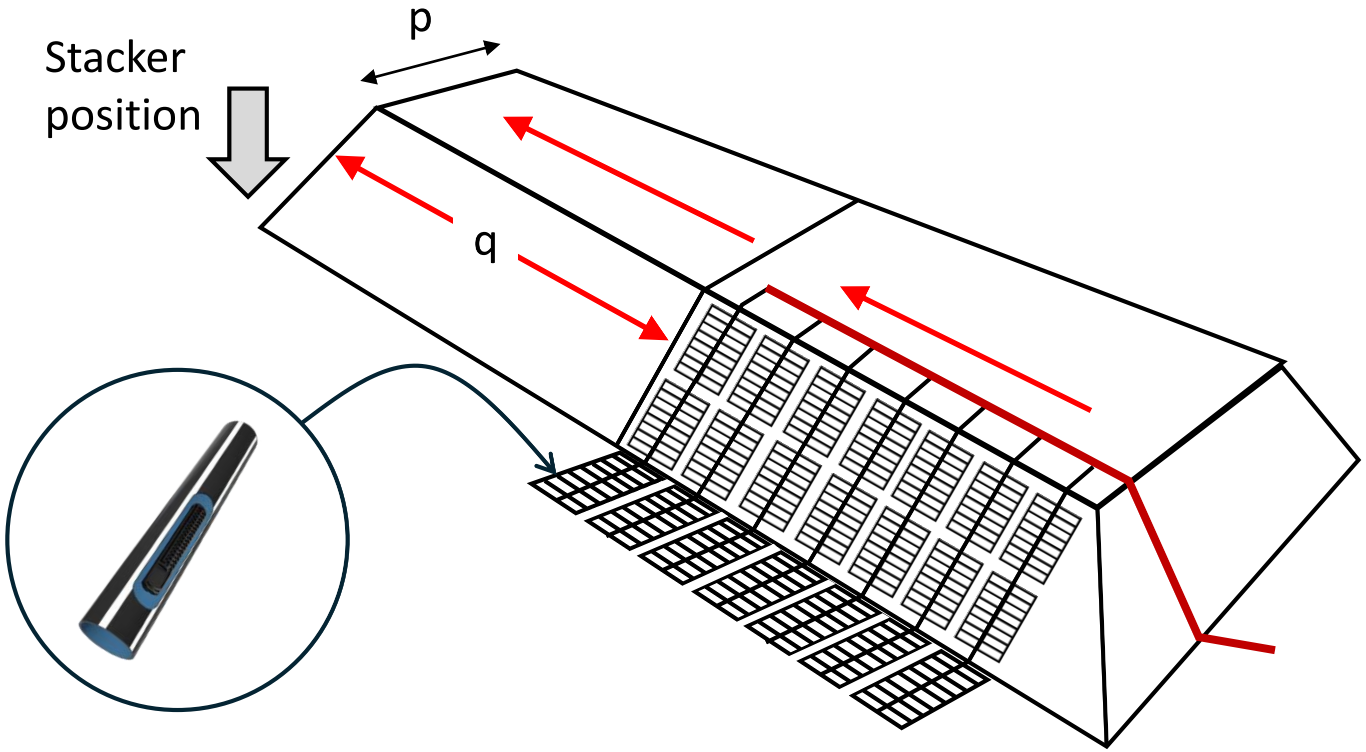
Available Aeration Technology

Perforated tubing



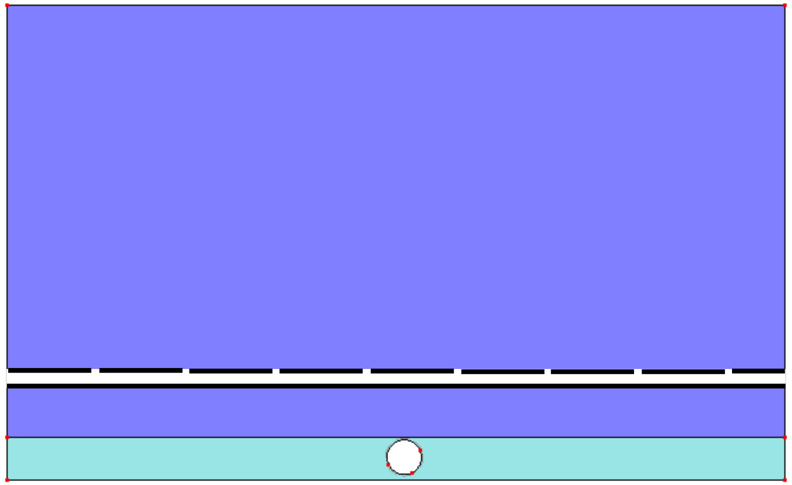
https://www.cpjservicios.cl/wp-content/uploads/2022/12/SISTEMA-DEFINITIVO-AIREACION-ZALDIVAR-2021-Model_.pdf

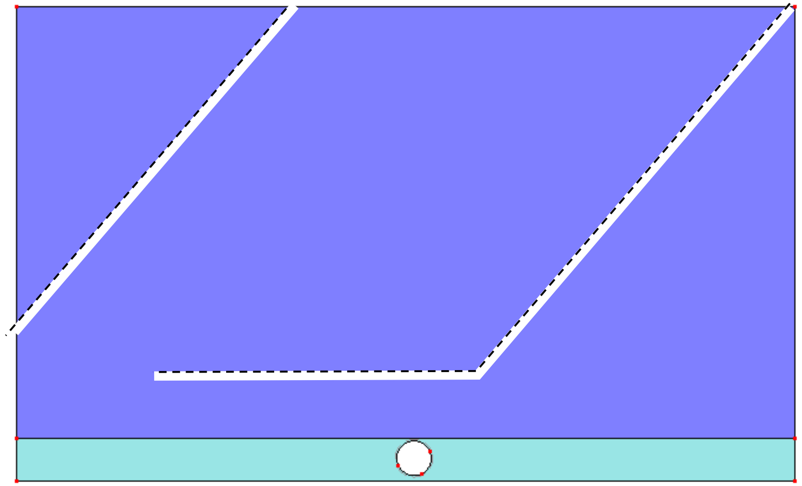
Pneumatic 3D emitter net



J. Menacho, US 2013/0106001 A1

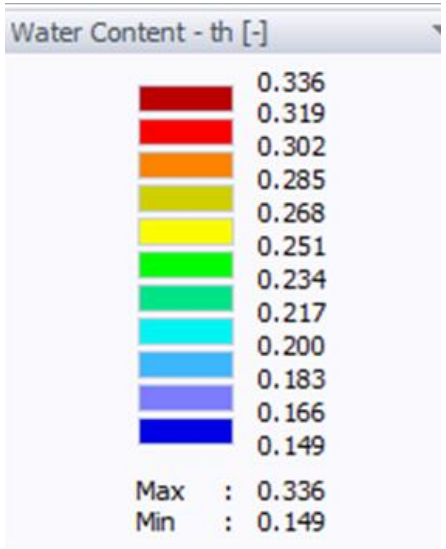
Case Study II: Perforated Tubing/Pneumatic Emitters



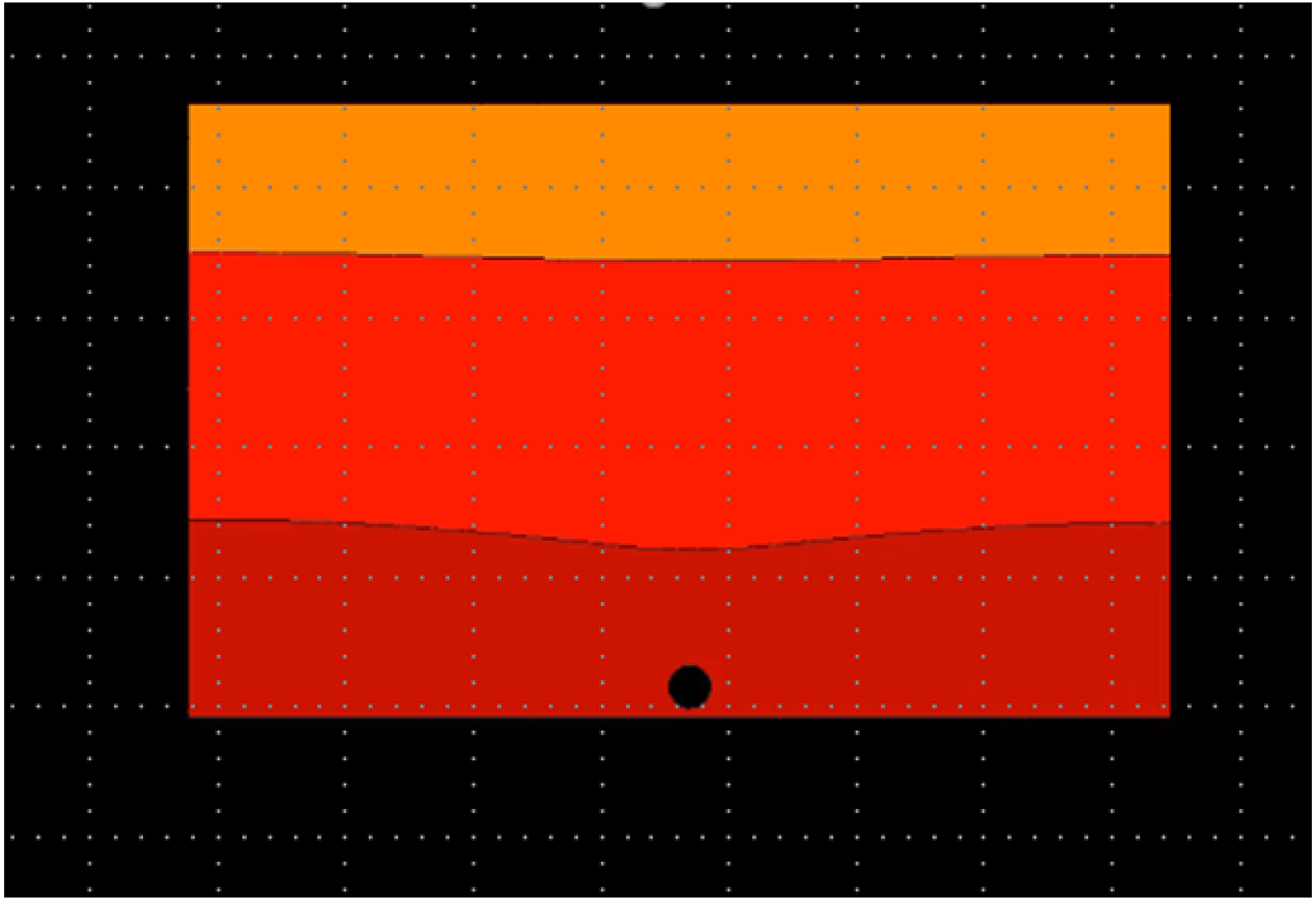


Parameter	Value
Pad height, m	5
Pad width, m	9
Ore apparent density, t/m^3	1.65
Drain diameter, m	0.4
Irrigation rate, $L/h/m^2$	12

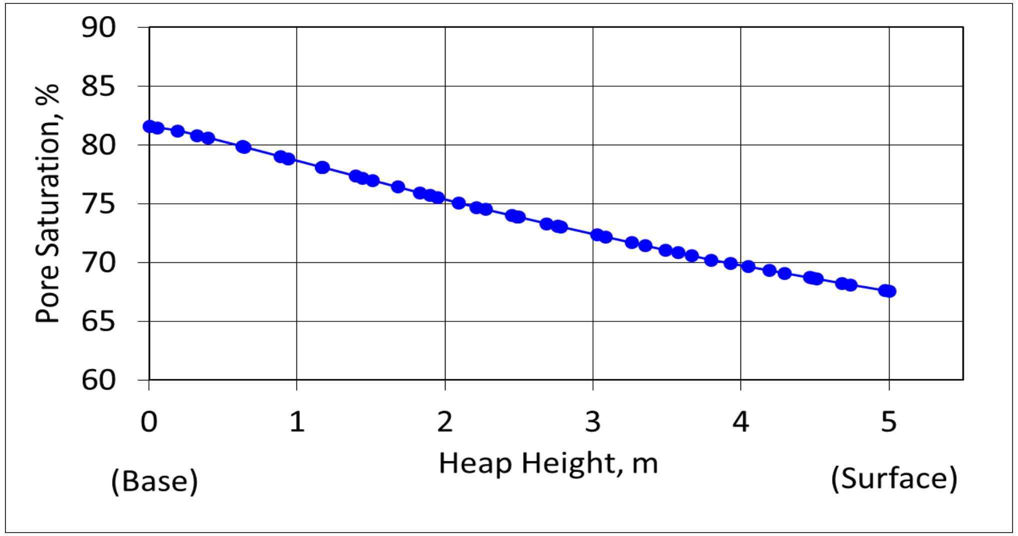
Case Study II: Simulation of Liquid Infiltration Profile

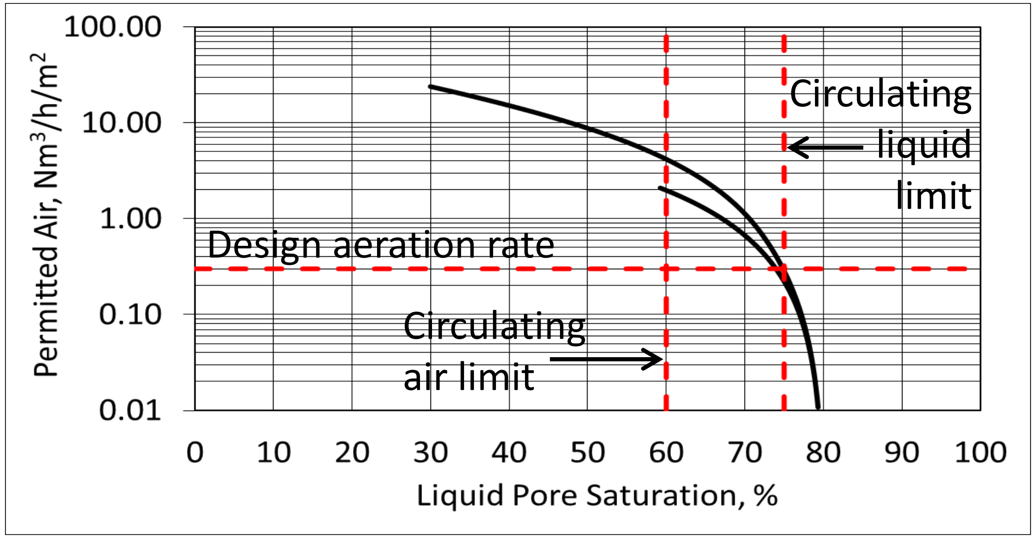


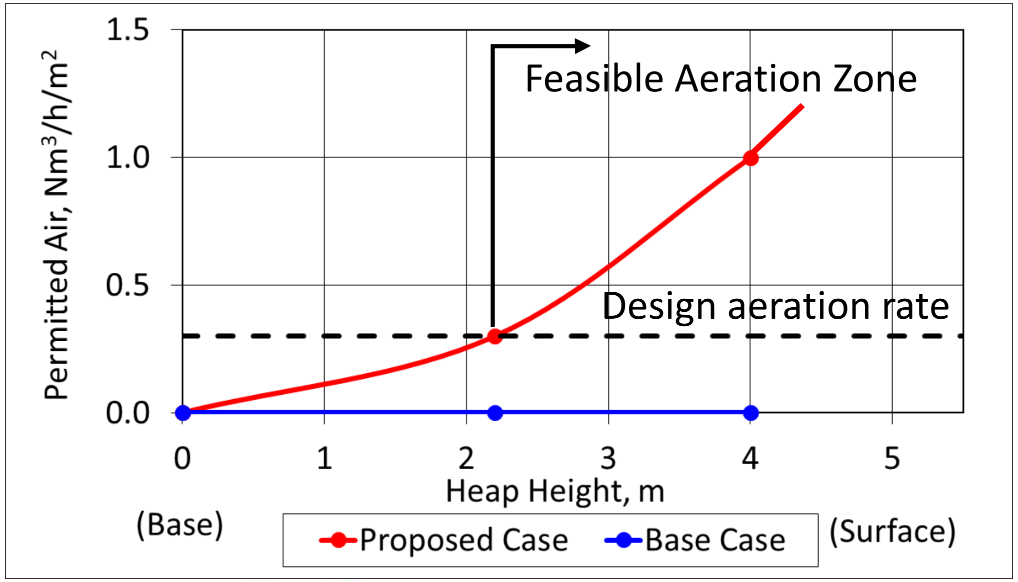
T.M. van Genuchten Parameter	
ks, m/s	5.1.E-04
Θr	0.149
θs	0.365
α	0.18
n	1.6

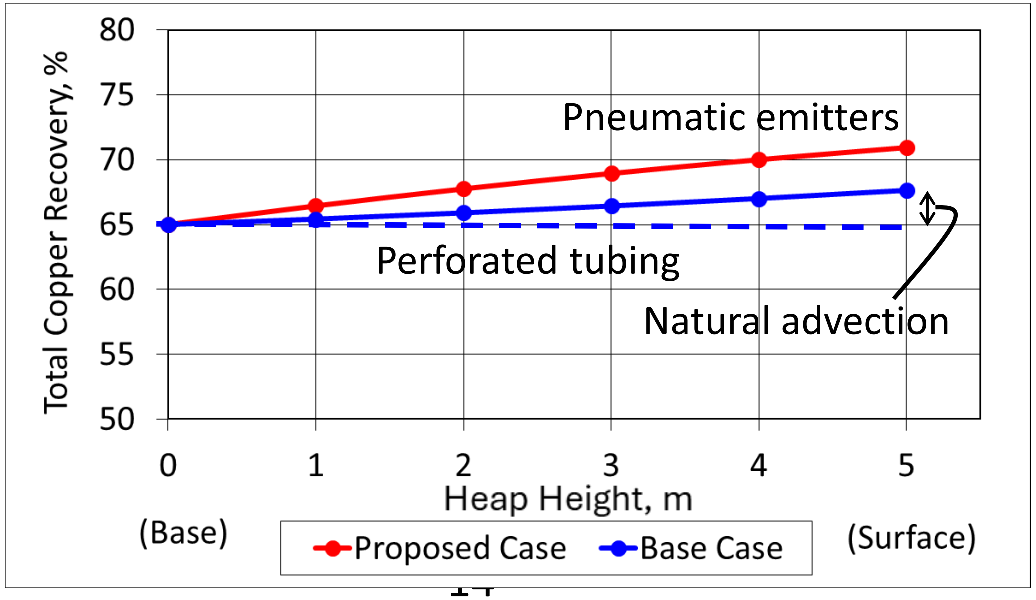


Case Study II: Aeration Efficiency









Conclusions

- The air moves according to free space in the pore structure; the higher the irrigation rate, the lower the available space and the air circulation is reduced.
- Always the lower part of the heap is more saturated by the liquid compared to the upper zone.
- Aeration by natural convection is efficient for heaps smaller than 3-4 m. For taller heaps a forced aeration system is necessary.
- A systematic procedure has been presented to estimate effectiveness of the aeration system on expected results.
- The paradigm that large blower capacity is enough to get high aeration efficiency is overthrown.

Conclusions

- The position to start aerating is variable according to changing characteristics of the ore and also changing operational conditions, then a fixed position tubing net will always be erratic.
- A tridimensional net is more efficient, not only because will always accomodate to the pore saturation conditions, but also beacause it offers 10 - 20 times more aeration points per square meter and a much more uniform application through the balanced emitters instead of the not balanced perforations.
- Advantages of using pneumatic emmiters in a 3D arrangement instead of perforated tubing located in the lower region of the heap are demostrated.