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Apêndice

Curva de Calibração por peso seco do *R. opacus*

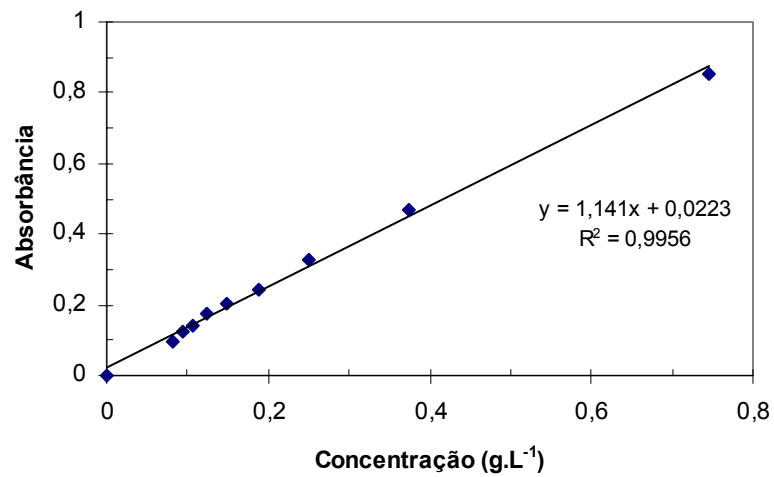


Figura A45 – Curva de peso seco das células de *R. opacus*.

Curva de Calibração do Rotômetro

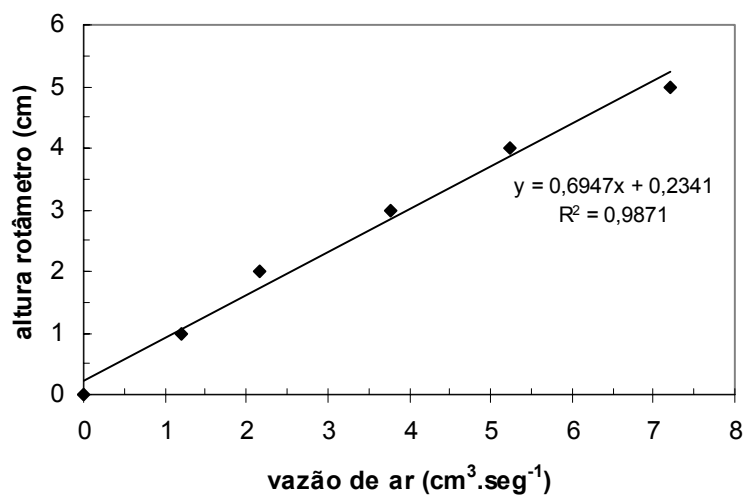


Figura A46 – Curva de Calibração do Rotômetro.

Caracterização da bactéria *R. opacus*



Figura A47- Células isoladas e colônias da bactéria *R. opacus*

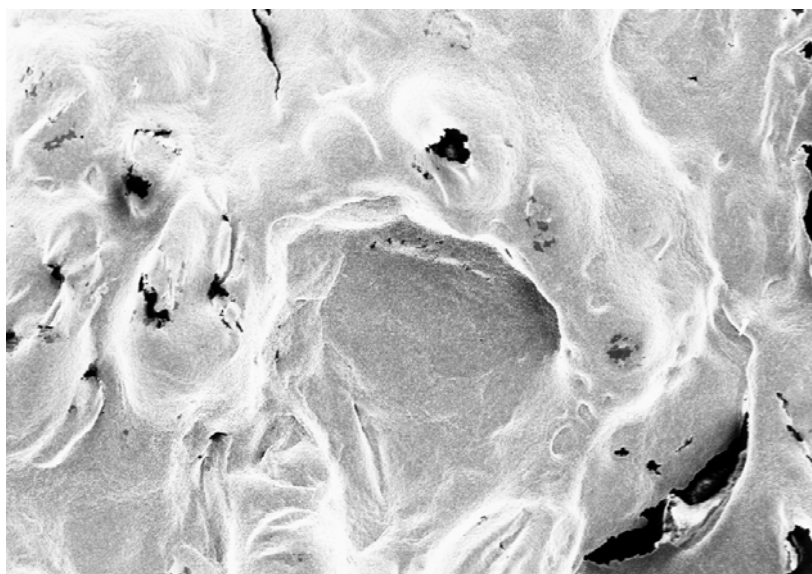


Figura A48 - Microfotografia da espuma da bioflotação de Cu(II) com *R. opacus* obtida através do Microscópio Eletrônico de Varredura. Conc. inicial do metal:100mg/l, conc da biomassa:1g/l. Aumento:100x.

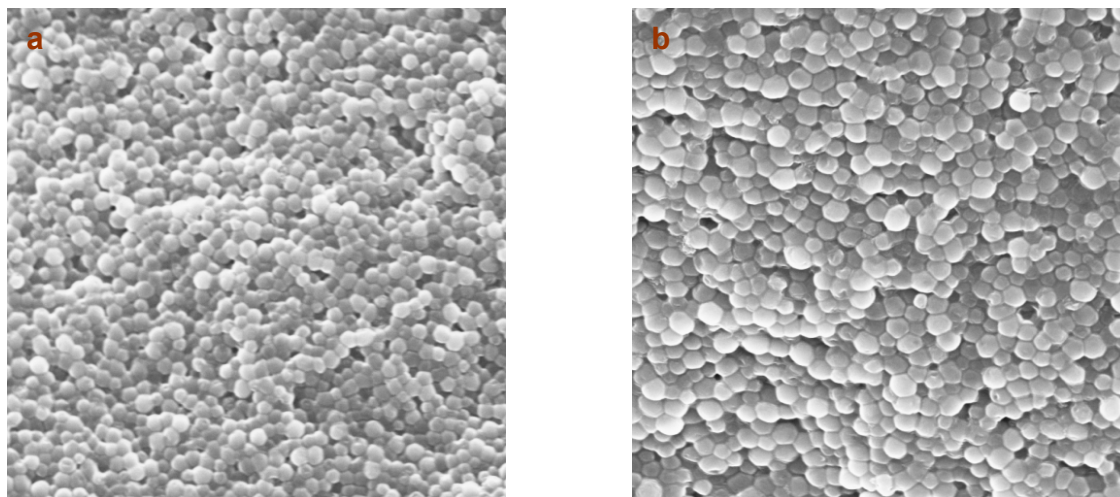


Figura A49 – Microfotografias da espuma da bioflotação de Cu(II) com *R. opacus* obtidas através do Microscópio Eletrônico de Varredura. Conc. inicial do metal:100mg/l, Conc da biomassa:1g/l. (a) Aumento:2000x, (b) Aumento: 3000x.

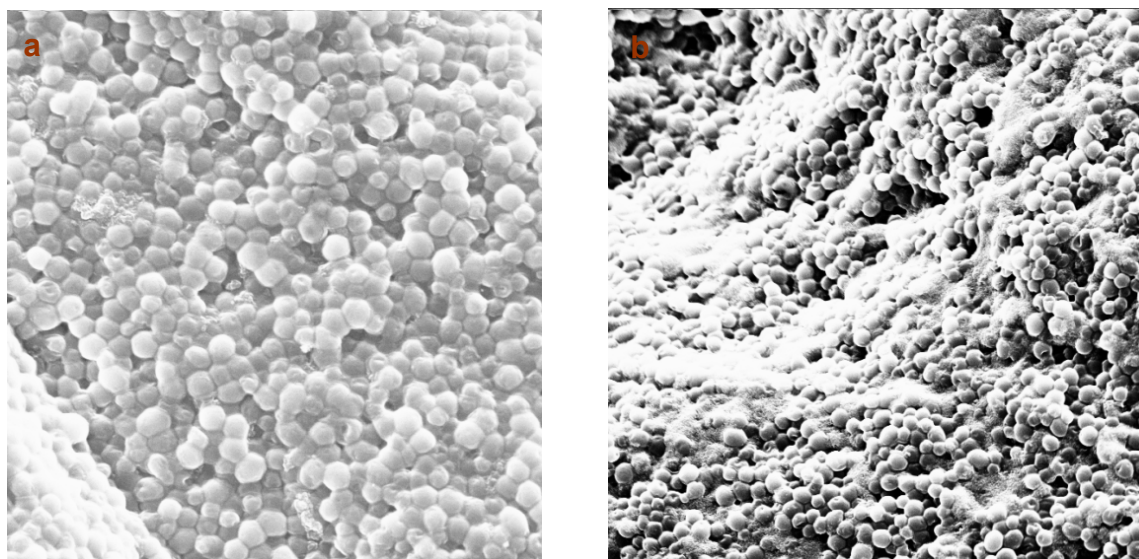


Figura A50 - Microfotografias da espuma da bioflotação com *R. opacus* obtidas através do Microscópio Eletrônico de Varredura. Conc. inicial do metal:100mg/l, Conc da biomassa:1g/l. (a) Pb(II), pH:5,0, Aumento:3000x, (b) Cr(III), pH:6,0, Aumento: 2000x.

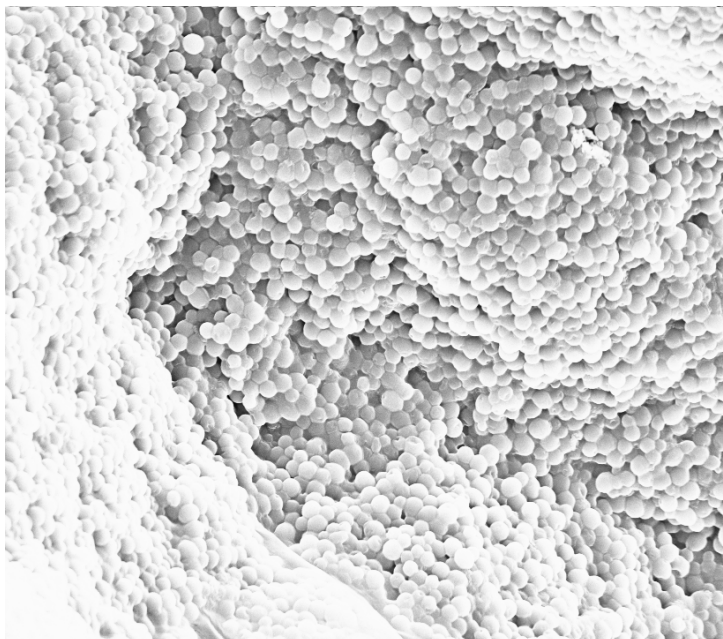


Figura A51 – Microfotografia da espuma da bioflotação da mistura: Pb(II)+Cr(III)+Cu(II) com *R. opacus* obtida através do Microscópio Eletrônico de Varredura. Conc. equimolar do metal:50mg/l, Conc. da biomassa:1g/l, pH:5,0. Aumento: 2000x.

Programa em Matlab para o cálculo das Isotermas de Adsorção em Sistemas Binários.

Langmuir – Modelo 1

```
function 1

%~~~~~
%Dominio dos Parametros <b1, b2, qm1, qm2>
%~~~~~
Lower = [0    0   30  30];
Upper = [0.5  0.5 100 100];
Bounds = [Lower; Upper];

%~~~~~
%Parametros del Algoritmo
%~~~~~
N = 500; %Numero de Soluciones
T = 200; %Numero de Iteraciones
```

```

%~~~~~
%Metodo Algoritmo Genetico
%~~~~~
[Theta] = genetico('FuncaoSSR1', Bounds, N, T)
Error = FuncaoSSR1(Theta)
return
%-----

function SSR = FuncaoSSR1(Theta)

%~~~~~
%Dados de Entrada
%~~~~~
c1 =[0 6.1 8.7 17.0 23.3 38.1 37.7 55.0 90.6];
c2 =[0 2.7 4.1 13.5 16.9 27.2 31.7 40.3 57.8];
q1 =[0 3.97 4.99 5.54 9.00 9.40 13.89 19.24 24.86];
q2 =[0 5.65 7.28 7.30 12.61 14.46 16.91 26.62 41.25];

%~~~~~
%Componente do Vetor Theta
%~~~~~
b1 = Theta(1);
b2 = Theta(2);
qm1 = Theta(3);
qm2 = Theta(4);

%~~~~~
%Avaliação do Error de Aproximação
%~~~~~
SSR = 0;
for i=1:size(c1,2)
    d = 1+b1*c1(i)+b2*c2(i);
    SSR = SSR+ (q1(i) - (qm1*b1*c1(i))/d).^2;
    SSR = SSR+ (q2(i) - (qm2*b2*c2(i))/d).^2;
end
return
%-----

```

```

function [x] = genetico(F, B, N, T)

%~~~~~
%Iterations
%~~~~~

t=1;
P = Initialize(N,B);
W = Evaluate(P,F);
X = Elitism(P,W);
P = Select(P,W);
while t<T,
    t=t+1
    P = Evolve(P,B);
    W = Evaluate(P,F);
    X = [X; Elitism(P,W)];
    P = Select(P,W);
end
x = X(end,:);
return

%-----
%                               Genetics Functions
%-----

function P = Initialize(N,B)
    P = zeros(N,size(B,2));
    for i=1:size(P,1),
        for k=1:size(P,2),
            P(i,k) = B(1,k) + rand*(B(2,k)-B(1,k));
        end
    end
return

%-----

function W = Evaluate(P,F,varargin)
    %Avaliação da Função Objetivo
    for i=1:size(P,1),
        W(i,1) = feval(F, P(i,:)); % <== No formato de Minimização
    end

```

```

%Rescalação
W = W/abs(mean(W));

%Formato de Maximização
W = exp(-W);
% S = std(W);
% if (S > 0.1)&(S < 0.75)
%     W = W.^(1/S);
% end

%Normalização
W = W./sum(W);
return
%-----
function P = Select(P,W)
%Função Aptidão
[F,I] = sort(W);

%Genitores
G = P(I,:);
x = G(end,:);

%Seleção Darwiniana
N = size(G,1);
Q = cumsum(F);
for i=1:N-1,
    k = 1;
    r = rand;
    while Q(k) < r,
        k = k+1;
    end
    P(i,:) = G(k,:);
end

%Cromossoma Elitista
P(end,:) = G(end,:);
return

```

```
%-----
function P = Evolve(P,B)
    x = P(end,:);
    P = Crossover(P,B);
    P = Mutation(P,B);
    P = Constrains(P,B);
    P(end,:) = x;
return
```

```
%-----
%               GPF Auxiliar Functions
%-----

function P = Crossover(P,B)
    N = size(P,1);
    for k=1:N,
        i = floor(1+rand*N);
        j = floor(1+rand*N);
        x = P(i,:);
        y = P(j,:);
        if x == y,
            P(i,:) = Gaussian(x,B);
            P(j,:) = Gaussian(y,B);
        else
            gamma = rand;
            P(i,:) = gamma*x + (1-gamma)*y;
            P(j,:) = gamma*y + (1-gamma)*x;
        end
    end
return
%-----
```

```
function P = Mutation(P,B)
    N = size(P,1);
    for i=1:N,
        k = floor(1+rand*N);
        if rand < 0.1, % mutação uniforme
            P(k,:) = Uniform(P(k,:),B);
        else %mutação Gaussina
```

```

        P(k,:) = Gaussian(P(k,:),B);
    end
end
return
%-----
function x = Gaussian(x,B)
    for i=1:size(x,2),
        step = abs(min(x(i)-B(1,i),B(2,i)-x(i)));
        x(i) = x(i) + sqrt(rand*step)*randn;
    end
return
%-----
function x = Uniform(x,B)
    for i=1:size(x,2),
        step = B(2,i)-B(1,i);
        x(i) = x(i) + rand*step;
    end
return
%-----
function P = Constrains(P,B)
    for i=1:size(P,1),
        for k=1:size(P,2),
            if (P(i,k) < B(1,k)) | (P(i,k) > B(2,k)),
                P(i,k) = B(1,k) + rand*(B(2,k)-B(1,k));
            end
        end
    end
return
%-----
function [x,f] = Elitism(P,W)
    [f,i] = max(W);
    x = P(i,:);
return
%-----

```

Langmuir-Freundlich : Modelo 2

```
function SSR = FuncaoSSR2(Theta)

%~~~~~
%Dados de Entrada
%~~~~~
c1 =[0 6.1 8.7 17.0 23.3 38.1 37.7 55.0 90.6];
c2 =[0 2.7 4.1 13.5 16.9 27.2 31.7 40.3 57.8];
q1 =[0 3.97 4.99 5.54 9.00 9.40 13.89 19.24 24.86];
q2 =[0 5.65 7.28 7.30 12.61 14.46 16.91 26.62 41.25];

%~~~~~
%Componente do Vetor Theta
%~~~~~
b1 = Theta(1);
b2 = Theta(2);
a1 = Theta(3);
a2 = Theta(4);
n1 = 1.45;
n2 = 1.75;

%~~~~~
%Avaliação do Error de Aproximação
%~~~~~
SSR = 0;
for i=1:size(c1,2)
    d = 1+b1*(c1(i))^(1/n1)+b2*(c2(i))^(1/n2);
    SSR = SSR+ (q1(i) - (a1*(c1(i))^(1/n1))/d).^2;
    SSR = SSR+ (q2(i) - (a2*(c2(i))^(1/n2))/d).^2;
end
return

function Caso2

%~~~~~
%Dominio dos Parametros <b1, b2, a1, a2, 1.45, 1.75>
%~~~~~
Lower = [0 0 0 0 ];
Upper = [5 5 5 5 ];
Bounds = [Lower; Upper];

%~~~~~
%Parametros del Algoritmo
%~~~~~
N = 500; %Numero de Soluciones
T = 200; %Numero de Iteraciones

%~~~~~
%Metodo Algoritmo Genetico
%~~~~~
[Theta] = genetico('FuncaoSSR2', Bounds, N, T)
Error = FuncaoSSR2(Theta)
return
```

Principais poluentes de despejos industriais

Poluentes	Origem dos despejos
Bário (acetato)	Mordente em tinturarias
Bário (cloreto)	Manufatura de tintas, operações de curtimento
Bário (fluoreto)	Tratamento de metais
Cromo (hexavalente)	Decapagem de metais, galvanização, curtumes, tintas, explosivos, papéis, águas de refrigeração, mordente, tintutaria em indústrias têxteis, fotografia e cerâmica.
Cobalto	Tecnologia nuclear, pigmentos
Cobre (cloreto)	Galvanoplastia do alumínio, tintas indelévels
Cobre (nitrato)	Tinturas têxteis, impressões fotográficas, inseticidas
Cobre (sulfatos)	Curtimento, tintura, galvanoplastia
Chumbo (acetato)	Impressoras, tinturarias e fabricação de outros sais de chumbo
Chumbo (cloreto)	Fósforos, explosivos, mordentes
Chumbo (sulfato)	Pigmentos, baterias, litografia
Mercúrio (cloreto)	Fabricação de monômeros
Mercúrio (nitrato)	Explosivos
Composto organo-mercuroso	Descargas de águas brancas em fábricas de papéis
Níquel (cloreto)	Galvanoplastia e tinta invisível
Níquel (sulfato amoniacal)	Banhos de galvanoplastia
Níquel (nitrato)	Galvanização
Zinco	Galvanização
Zinco (cloreto)	Fábrica de papel, tintas

Fonte: Braile e Cavalcanti, 1993