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The Determination Method of Soil Environmental Capacity

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Abstract We studied the method[1－7] of considering the storage, self-purification and transport capacities at the same time when we decide the soil environmental capacity.
Key words soil environmental capacity (SEC), storage capacity, self-purification capacity, transport capacity

Introduction

Soil environmental capacity means the maximum total volume of pollutants that the soil environment can accept under the certain environmental target (background, criteria, standard).

Therefore, the soil environmental capacity is related with the physico-chemical and biological character, soil environment management target, character of pollutants and soil element background value.

SEC consists of the storage, self-purification and transportation capacity [1, 7].

$$W = W_{\mathrm{s}} + W_{\mathrm{sp}} + W_{\mathrm{t}} \tag{1}$$

where W is SEC, W_{s} －storage capacity, W_{sp} －self-purification capacity, W_{t} －transportation capacity.

Storage capacity can be written as follows [5].

$$W_{\mathrm{s}} = \int_V (C_{i0} + B_i) dV \tag{2}$$

where C_{i0} －environmental standard of i^{th} pollution index, B_i －element background of i^{th} pollution index and V－unit volume.

The capacity determined by equation (2) can be solved easily because it is absolute soil environmental capacity which does not consider the self-purification capacity and transport one. But, what is important here is self-purification and transport capacities.

The self-purification, dilution, diffusion and transport are appeared as integrated effect, not individual process.

For this reason, we have to determine the soil environmental capacity with the transport-self-purification effect.

1. Calculation Model of Soil Environmental Capacity

When we analyze the mass balance relationship of soil pollutants, there is input and output relationship of pollutants; the irrigation, fertilizing of sludge, precipitation and the dust are input and absorption by crops, outflow and osmosis are output.

The soil element background value is relatively stable although it takes part in the material-cycle process as it is the value has been forming global-chemically in the soil forming process.

Above mentioned contents can be expressed as follows.

$$S_i = (B_i + Q_i' + Z_i + P_i + F_i) - (R_i' + D_i + E_i)\ , \qquad (i = \overline{1,\ m}) \tag{3}$$

where S_i —i^{th} pollutant's mass left in soil, B_i —i^{th} pollutant's background value, Q_i' —i^{th} pollutant's input by irrigation, Z_i —i^{th} pollutant's input by manuring of sludge, P_i —i^{th} pollutant's input by precipitation, F_i —i^{th} pollutant's input by dust, R_i' —i^{th} pollutant's output by crop's absorption, D_i —i^{th} pollutant's output by drainage, E_i —i^{th} pollutant's output by osmosis.

Therefore, the soil environmental capacity of i^{th} pollutant index can be written as follows by concept of soil environmental capacity.

$$W_i = W_{i0} - [f_1(Q_i',\ Z_i,\ P_i,\ F_i) - f_2(R_i',\ D_i,\ E_i)] \tag{4}$$

where $W_{i0} = C_{i0} - B_i - \Delta C_{Pi}$, $\Delta C_{Pi} = C_{Pi} - B_i$, C_{Pi} —the amount of pollutant which is inputted to the soil by natural and artificial effect.

From this physical analysis, the calculation model of SEC can be derived as follows.

The left pollutant amount in the first year:

$$C_{S1} = K(C_{Pi} + Q_i - R_i) \tag{5}$$

The left pollutant amount in the second year:

$$C_{S2} = K(C_{S1} + Q_i - R_i) = K^2 Q_i + KQ - K^2 R_i - KR_i + K^2 C_{Pi} \tag{6}$$

Thus the left pollutant amount in the n^{th} year:

$$C_{Sn} = K^n C_{Pi} + (Q_i - R_i)K\frac{1 - K^n}{1 - K} \tag{7}$$

Here, Q_i —pollutant input amount, R_i —pollutant output amount, K—left coefficient ($0 \le K < 1$), i—pollutant index($i = \overline{1,\ m}$)

So, the present SEC is

$$W_{i0} = C_{i0} - B_i - \Delta C_P \tag{8}$$

The SEC after n^{th} year is

$$W_{in} = W_{i0} - \left[K^n C_{pi} + (Q_i - R_i)K\frac{1 - K^n}{1 - K} \right] \tag{9}$$

As in equation (9) shows, the SEC becomes lower as n increases. And n when $W_{in} = 0$ is pollutant limit age, if $W_{in} < 0$, then it means that SEC became over-limited.

On the other hand, when we determine the SEC by equation (9), it is important to find out the left coefficient K.

The left coefficient by minimum square method is $K_{\text{Zn}} = 0.87$. In the case of Cd, Cu, Pb and Cr, $K = 0.89$.

2. Application Example

The present soil environmental capacity of the elements using equation (8) is in table 1.

Table 1. The present SEC (mg/kg)

	Zn	Cd	Pb	Cu	Cr
Environmental standard value	280	3	100	170	100
Soil background value	48.10	0.041	13.09	12.29	14.29
C_{pi}	52.06	0.053	15.37	14.46	15.30
Present SEC	227.94	2.947	84.63	155.54	84.70

Table 1 shows the present SEC of Zn, Cd, Cu, Cr and Pb.

The present SEC is the capacity which can accept pollutant in the present that we consider the human economic activity until now.

Present SEC is changed continuously according to the time, because it is affected by natural and artificial factors.

The change of present SEC according to the time is in table 2 when we suppose that the annual average input and output quantities of the heavy metals are const.

Table 2. The variation character of present SEC with time (mg/kg)

Time/y	Zn	Cd	Pb	Cu	Cr	Time/y	Zn	Cd	Pb	Cu	Cr
10	43.64	0.90	21.48	43.79	21.58	40	0.60	0.029 3	0.49	1.05	0.56
20	10.79	0.28	6.59	13.45	6.66	50	0.099 5	0.010 4	0.041 9	0.13	0.11
30	2.63	0.089 6	1.94	4.00	2.01						

The table 2 shows that present SEC decreases continuously. So we should continuously update the SEC through the soil environment management.

Conclusion

1) The SEC in the study period can be predicted successfully by using this model.
2) We can manage the soil environment scientifically according to the limit age of SEC.

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