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Amelioration of Soil Acidified by Air Pollutant around the Industrial Complexes

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대기오염으로 산성화된 공업단지 주변 토양의 개량

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ABSTRACT

Ameliorating effects of dolomite and sludge on the polluted soil sampled from Ulsan and Yeocheon Industrial Complexes were investigated. Ameliorating effects were analysed by changes of soil properties and plant growth after treatment of dolomite and sludge. Soil properties were investigated by analysing organic matter, N, P, K, Ca and Mg contents and pH. Growth of sample plants was investigated by leaf area calculated from length and breadth of leaves and by biomass from diameter and height of sample plants. *Quercus serrata* and *Celtis sinensis* selected as tolerant plants in field survey were used as experimental plants. Treatment with dolomite showed ameliorating effects by increasing N, Ca, and Mg contents, and pH of soil and by decreasing Al content. Treatment of sludge showed similar effects by increasing N, Ca, Mg and organic matter contents, and by decreasing Al content. But treatment of sludge did not show any effect on pH. Both soil ameliorators showed accelerating effects on the growth of experimental plants in Ulsan soil. But those effects in Yeocheon soil were somewhat different. Treatment of sludge showed accelerating effects on the growth of both sample plants but dolomitic liming did not so. From those results, we confirmed availability of sludge, a kind of industrial waste, as one of ameliorators of the polluted soil. In addition, we recognized that soil properties had to be considered to select soil ameliorators suitable for restoration of degraded ecosystems.

Key words: Amelioration effects, Cations, Dolomite, Sludge, Restoration.

INTRODUCTION

Increases of acid deposition and potential acidifying compounds have caused a decline of soil pH in forest soil and such a soil acidification has influenced soil chemical properties (Miller 1990). Cations like Ca, Mg, and K were leached and toxic ion like Al increased abnormally in acidified soil (Breedman *et al.* 1983). Even though main causes of forest decline

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were not clearly known yet, many factors like Al toxidity, ion imbalances, deficiency of basic cations have been reported as causal factors of forest decline (Johnson and Ball 1991). Deficiency of Mg induces yellowing of tree leaves (Fox 1991), and Al toxicity makes root system more susceptible to disturbances like drought, wind-break, nutrient shortage, and so on (Marschner 1991). Those changes result in weakening of buffering capacity of soil and of vegetation function and in the result, leading to degradation of ecosystem (Cumming 1991). Moreover, degraded ecosystems make their components more sensitive to pollution damage. Therefore, ecological restoration of those environmentally stressed ecosystems is required urgently.

In order to restore the degraded ecosystems, the study to mitigate environmental stresses occurring in polluted area has to be carried out (Bell *et al.* 1993). Dolomite ($CaMg(CO_3)_2$) and lime (CaO, $Ca(OH)_2$, $CaCO_3$) have been usually selected as soil ameliorators to increase vitality of both soil and vegetation under the acidic condition. As is shown in chemical formula, dolomite include Mg as well as Ca differently from lime. Moreover, Al toxicity was reduced more effectively by Mg rather than Ca (Rhyu and Kim 1996). We, therefore, selected dolomite as a soil ameliorator. The principal purposes of applying ameliorators are to neutralize the acid soil, to precipitate toxic soluble compounds, and to introduce Ca and Mg into the soil collidal complex (Ulrich 1983). In fact, treatment with dolomite and lime increased pH, and concentrations of Ca and Mg and decreased Al content in soil and plants (Kim 1997, Mun *et al.* 1997).

On the other hand, we also used sludge as soil ameliorator. Sludge, sewage remained after digestion by methane bacteria in anaerobic condition, has been used for soil amelioration, especially in crop land (U. S. EPA 1991, Garvey 1992, Tamaka 1991, Choi *et al.* 1995). Even though so sludge has been treated as toxic materials because the application of sludge containing heavy metal can cause the contamination of soil and organisms. But sludge applied to rice and corn fields resulted in increase of grain production and in decrease of heavy metal contents in grain (Choi *et al.* 1995). In addition, treatment of sludge also accelerated the growth of Altari radish (Oh *et al.* 1996).

This study was focused on evaluating the effects of soil ameliorators, dolomite and sludge on the polluted soil from the Industrial Complexes by analysing soil properties and plant growth.

MATERIALS AND METHODS

Polluted soils from Ulsan and Yeocheon Industrial Complexes were used for the control plot and soils mixed with ameliorators, dolomite and sludge were used for the experimental ones. Dolomite was obtained from manufacturing factory as a commercial product (product number; Kangwon 11-Ga-lime-3-2) and sludge was obtained from Jungrang Sewage Treatment Plant. Sludge from Sewage Treatment Plant was dehydrated cake. Sludge passed through 2 mm sieve by pulverizing after air-drying in shade condition was used in this study. Chemical properties of sludge and sample soil used in this study were shown in Table 1.

Quercus serrata and *Celtis sinensis* were used as sample plants. Sample plants were 2 year-old seedlings. Seedlings with similar size and vitality were selected as sample plants. Seedlings of *C. sinensis* and *Q. serrata* were obtained from seeds collected around Yeocheon Industrial Complex and Kwangneung arboretum, respectively. Three sample plants per pot were planted and each treatment plot was composed of 5 replicates. Contents of dolomite and sludge included in ameliorated soil were 2% (wt./wt.) of total soil weight, 3kg. Optimal amount of dolomite was determined by analysing changes of pH according to dolomite contents included in ameliorated soil. Optimal pH value of 5.5 was determined with reference to pH of natural forest soil in Korea. Addition of sludge did not affect the change of soil pH, so followed to the case of dolomite treatment (Fig. 1). All the plots were watered with simulated acid rain of pH 4 during cultivation of smaple plants, assuming that such a pH value is similar to that of rain

Table 1. Chemical properties of sludge from Jungrang Sludge Treatment Plant and soil from Ulsan and Yeocheon Industrial Complexes

Item	Content		
	Sludge	Ulsan soil	Yeocheon soil
Organic matter (%)	77.0	7.0	11.8
T-N (%)	3.2	0.4	1.0
T-P (%)	0.4	0.02	0.05
K (mmol/kg)	1.2	0.9	0.9
Ca (mmol/kg)	349.8	2.6	1.7
Mg (mmol/kg)	64.5	0.4	0.4
Cd (mg/kg)	4.07*	0.83	0.82
Cu (mg/kg)	781.1*	–	–
Pb (mg/kg)	162.7*	0.83	1.15
Ni (mg/kg)	95.5*	–	–
Zn (mg/kg)	1648.0*	0.11	0.10
Mn (mg/kg)	1682.0*	0.87	1.15

*Choi et al. (1995)
–not measured

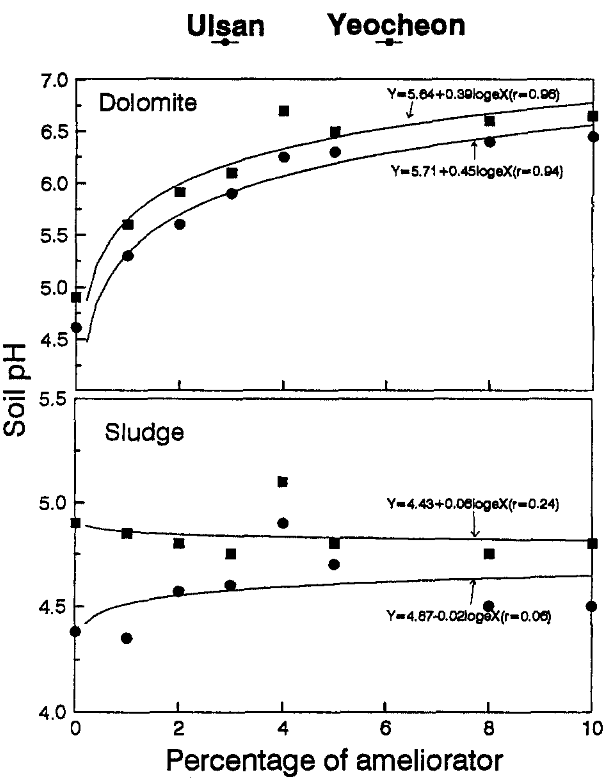

Fig. 1. Changes of pH according to ameliorator amounts of dolomite and sludge treated in acid soil sampled from Ulsan and Yeocheon Industrial Complexes.

around Ulsan and Yeocheon Industrial Complexes.

Effects of ameliorators were estimated by analysing chemical properties of soil and growth of sample plants after treatment. Soil chemical properties were analysed at 2 weeks interval for 8 weeks from the 4th week after transplant of sample plants. Organic matter contents were obtained from loss on ignition for 4 hours in 600℃ muffle furnace. Nitrogen contents were determined by micro-Kjeldahl method and phosphorus contents were by ammonium molybdate method (Allen *et al.* 1974). pH was measured by pH meter after shaking soil mixed with distilled water by ratio of 1:5 for 1 hour. Contents of K, Ca, Mg and Al were determined by ICP (inductively coupled plasma atomic emission spectroscopy, Shimadzu ICPQ-1000) after extraction by ammonium acetate solution of pH 4. Growth of sample plants was measured at 1 week interval for 8 weeks from the 2nd week after transplanting. Growths were estimated by growth indices obtained from regression equation between the times lapsed after transplanting and plant growth measured by leaf area and biomass. Area of each leaf was calculated using the equation of $A = \pi \cdot L \cdot B/4$ (L and B indicate length and breadth of leaf, respectively). Leaf area of sample plants was obtained multiplying area of each leaf by number of leaves per individual. Biomass was calculated by the equation of D^2H (D and H indicate diameter and height, respectively).

RESULTS

Ameliorating effects of dolomite and sludge on soil properties

Chemical properties of sample soils from Ulsan and Yeocheon Industrial Complexes were summarized in Table 1. Differences of soil chemical properties between Yeocheon and Ulsan soils were shown in terms of organic matter, total nitrogen, and available phosphorus contents. Yeocheon soil showed higher organic matter, N and P contents than those of Ulsan soil.

Changes of several soil chemical properties during cultivation of sample plants after treatment with ameliorators were shown in Figs. 2 (Ulsan) and 3 (Yeocheon). In initial stage of cultivation, pH, and concentrations of N, Ca, and Mg, and Al contents increased by addition of dolomite. Organic matter, N, P, Ca, Mg and Al contents increased by treatment with sludge. In changes of those soil properties, increase of N, P, Ca and Mg contents easy to be deficient in acidic soil (Francis 1989, Wolt 1990) can be explained as soil ameliorating effects.

In general, plots treated with dolomite showed higher soil pHs than those of control plots. But soil pHs in plots treated with sludge were similar to those of control plots (Figs. 2 and 3). On the other hand, in all the plot soil pH tended to slightly decreased during the experimental period.

In Ulsan plots ameliorated with dolomite, mean Al contents measured from the 4th week to the 12th week after transplant in *Q. serrata* (QS) and *C. sinensis* (CS) plots were 39% and 36% of those of control plots, respectively. Al contents in plots treated with sludge were 57% (QS) and 63% (CS) of those of control plots, respectively (Fig. 2). In Yeocheon plots treated with dolomite, Al contents in *Q. serrata* and *C. sinensis* plots decreased to 45% and 40% of those of control plots, respectively. And Al contents in plots treated with sludge showed 95% (QS) and 73% (CS) of those of control plots, respectively (Fig. 3).

In Ulsan plots treated with dolomite, Ca contents in *Q. serrata* and *C. sinensis* plots showed 448% and 432% of those of control plots, respectively (Fig. 2). Ca contents in plots treated with sludge were 261% (QS) and 238% (CS) of those of control plots, respectively (Fig. 2). In Yeocheon soil ameliorated with dolomite, Ca contents in *Q. serrata* and *C. sinensis* plots increased to 462% and 366% of those of control plots, respectively (Fig. 3). Ca contents in plots treated with sludge were 227% (QS) and 165% (CS) of those of control plots, respectively (Fig. 3).

In Ulsan plots ameliorated with dolomite, Mg contents in *Q. serrata* and *C. sinensis* plots showed 1,363% and 1,472% of those of control plots, respectively (Fig. 2). Mg contents in plots treated with sludge were 288% (QS) and 279% (CS) of those of control plots, respectively (Fig. 2). In Yeocheon soil treated with dolomite, Mg contents in *Q. serrata* and *C. sinensis* plots increased to 1,294% and 1,155% of those of control plots, respectively (Fig. 3). Mg contents in plots treated with sludge were 216%

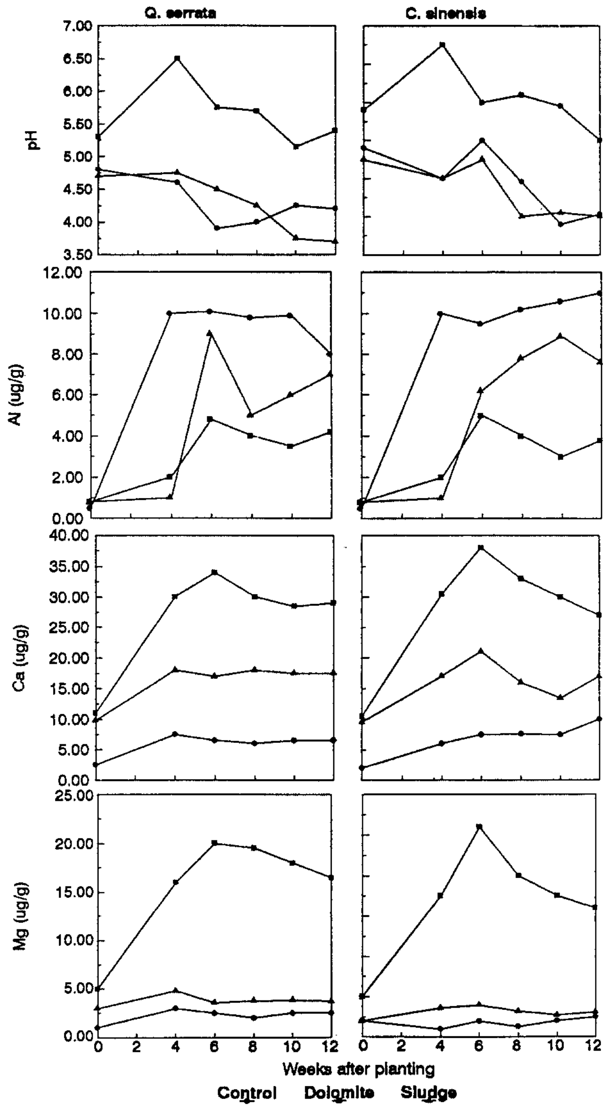

Fig. 2. Changes of soil chemical properties in Ulsan plots. Experimental plots are composed of control, dolomite and sludge plots. Control, dolomite and sludge plots indicate acidic soil, and treated soils with dolomite and sludge, respectively. Each experimental plot is divided into *Quercus serrata* plot and *Celtis sinensis* plot according to sample plants.

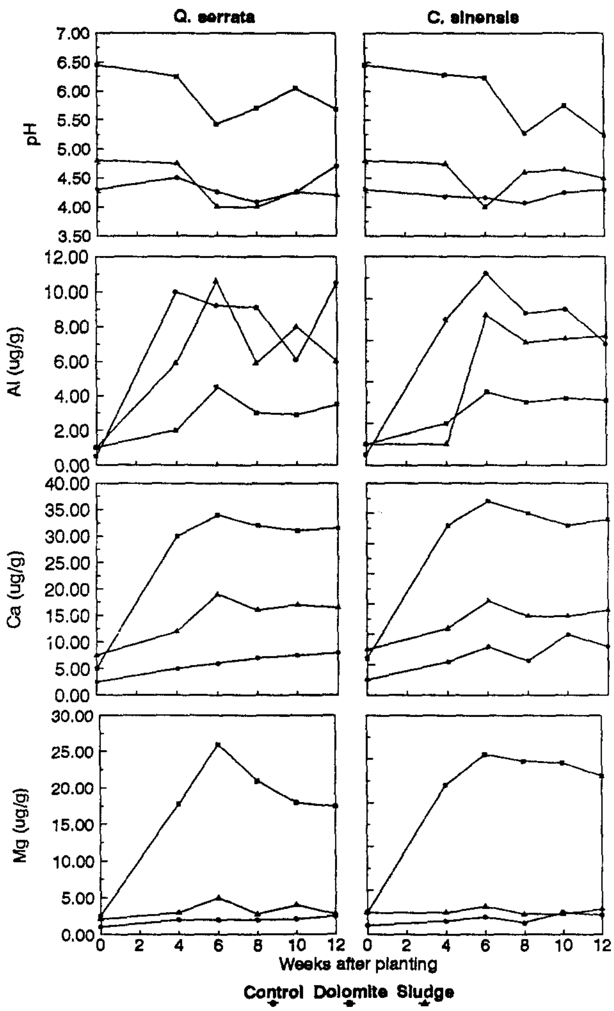

Fig. 3. Changes of soil chemical properties in Yeocheon plots. Experimental plots are composed of Control, dolomite and sludge plots. Control, dolomite and sludge plots indicate acidic soil, and treated soils with dolomite and sludge, respectively. Each experimental plot is divided into *Quercus serrata* plot and *Celtis sinensis* plot according to sample plants.

(QS) and 146% (CS) of those of control plots, respectively (Fig. 3).

Ameliorating effects of dolomite and sludge on plant growth

In Ulsan plots treated with dolomite, leaf area of *Q. serrata* (QS) and *C. sinensis* (CS) after 9 weeks from transplant were 1,515% and 312% of those of control plots, respectively (Fig. 4). Biomass of those sample plants showed 1,203% (QS) and 269% (CS) comparing with those of control plots (Fig. 5). In plots treated with sludge, leaf areas of *Q. serrata* and *C. sinensis* increased to 1,115% (QS) and 305% (CS) of those of control plots, respectively (Fig. 4). Biomass of those sample plants increased to 475% (QS) and 209% (CS) of those of control plots (Fig. 5).

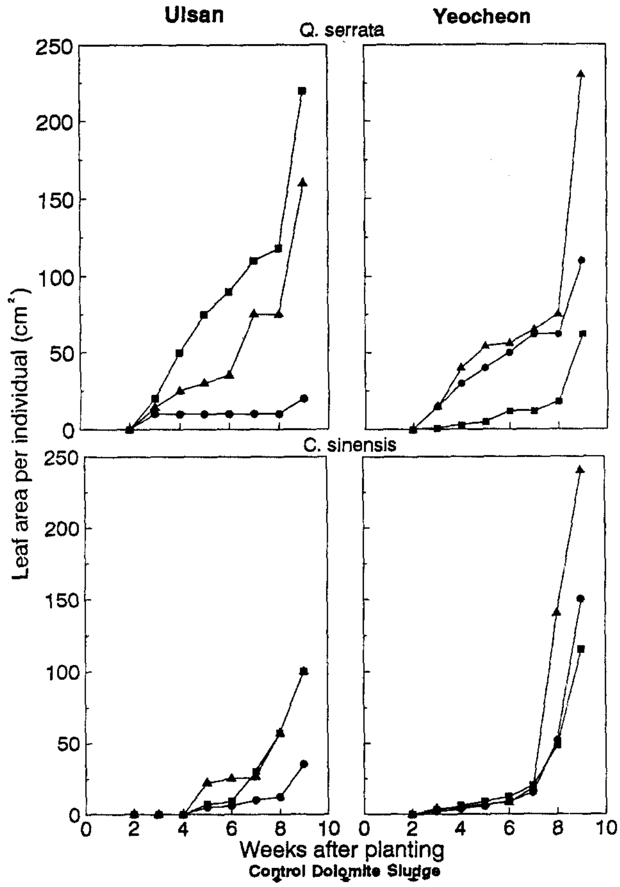

Fig. 4. Leaf growths of *Quercus serrata* and *Celtis sinensis* grown in acid soil and in ameliorated soils by dolomite and sludge, respectively from Ulsan and Yeocheon Industrial Complexes.

In Yeocheon plots ameliorated with dolomite, leaf area of *Q. serrata* and *C. sinensis* were 62% (QS) and 78% (CS) of those of control plots, respectively (Fig. 4). Biomass of those sample plants compared with those of control plots were 75% (QS) and 60% (CS) (Fig. 5). In plots treated with sludge, leaf areas

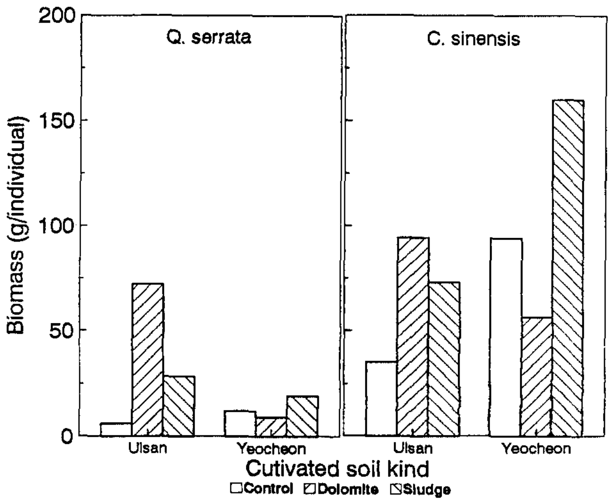

Fig. 5. A comparison of biomasses of *Quercus serrata* and *Celtis sinensis* grown for 12 weeks in acid soil and in ameliorated soils by dolomite and sludge, respectively from Ulsan and Yeocheon Industrial Complexes.

of *Q. serrata* and *C. sinensis* increased to 182% (QS) and 168% (CS) of those of control plots (Fig. 4). Biomass showed 160% (QS) and 170% (CS) of those of control plots (Fig. 5).

DISCUSSION

Treatment with dolomite increased pH, and N, Ca, and Mg contents in both Ulsan and Yeocheon soils. Increase of N content after dolomitic treatment might be originated from recovery of activity of nitrifying bacteria decreased in acid soil (Francis 1989). Increase of pH, and Ca and Mg contents can be explained by the following responses (Kreutzer 1995):

The first stage : $CaMg(CO_3)_2 + 2H^+$
$\rightarrow 2HCO_3^- + Ca_2^+ + Mg_2^+$
The second stage : $2HCO_3^- + 2H^+$
$\rightarrow 2CO_2 + 2H_2O$

$$CaMg(CO_3)_2 + 4H^+ \rightarrow Ca_2^+ + Mg_2^+ + 2CO_2 + 2H_2O$$

Treatment with dolomite increased Al content in initial stage of plant cultivation but decreased it from the 4th week after transplanting of sample plants. It is known that increase of Al content is a general phenomenon occurring in initial stage after dolomitic liming (Kreutzer *et al.* 1989, Marschner *et al.* 1989). On the other hand, decrease of Al content since the 4th week after transplanting can be interpreted by above mentioned mechanism explaining increase of pH, and Ca and Mg contents by treatment with dolomite considering that release of toxic Al from acidified soil is related to its pH (Ulrich 1983, Rhyu and Kim 1994). In fact, Toxic Al in acidic soil can be decreased by treatment of Ca and Mg, especially, Mg showed higher antagonistic effect against Al (Rhyu and Kim 1996).

Sludge treatment increased organic matter, N, P, Ca, and Mg contents, those results are related to component of sludge. For example, organic matter (77.0%), total nitrogen (3.2%), P (0.4%), Ca (285.0 mmol/kg) and Mg (41.5 mmol/kg) of much higher concentration are included in sludge comparing with sample soil (Table 1). Increase of organic matter, N, P, Ca and Mg contents, therefore, is originated from such ingredients of sludge. On the other hand, treatment with sludge decreased Al content like effects of dolo-
mitic treatment. Decrease of Al content by sludge treatment also can be explained as ameliorating effect originated from ingredients of sludge, such as organic matter, Ca, and Mg of high concentration. It is generally known that organic matter can mitigate toxic effect by chelation with toxic ion like Al (Odum 19 83). In fact, Al toxicity was significantly ameliorated by addition of humic substances such as litter extract (Rhyu and Kim 1994).

Growth of sample plants in Ulsan plots increased by addition of sludge as well as dolomite. But the effects in Yeocheon plots depended on soil ameliorators. For example, sludge increased growth of sample plants but dolomite did not so.

These dissimilarities can be explained from above mentioned differences of soil properties. That is, in

Ulsan soil, which is in short of organic matter, N and P contents comparing with those in Yeocheon plots, treatment of soil ameliorators could accelerate growth of sample plants. But in Yeocheon plots with relatively high fertility, it might not be contribute to increase of plant growth. Therefore soil properties have to be considered to select optimal soil ameliorators. In addition, from these results, we confirmed availability of sludge, a kind of industrial waste, as an ameliorator of the polluted soil.

적 요

울산 및 여천 공업단지 주변에서 채취한 오염토양에 대하여 토양개량제로 선택한 돌로마이트와 슬러지의 개량 효과를 평가하였다. 개량 효과는 토양의 특성을 분석하고, 시료 식물의 생장을 측정하여 파악하였다. 시료 식물은 오염지역 현지조사에서 내성 식물로 선발된 졸참나무와 팽나무로 삼았다. 토양 특성은 pH와 유기물, 질소, 인, 칼륨, 칼슘, 마그네슘 및 알루미늄 함량을 분석하여 파악하였다. 시료 식물의 생장은 잎의 길이와 폭을 측정하여 계산한 엽면적과 줄기의 직경과 높이를 측정하여 계산한 생물량으로 평가하였다. 돌로마이트 처리는 시료 토양의 pH와 질소, 칼슘 및 마그네슘 함량을 증가시키고 알루미늄 함량을 감소시켜 오염토양 개량 효과를 나타내었다. 슬러지는 유기물, 질소, 인, 칼슘 및 마그네슘 함량을 증가시키고 Al 함량을 감소시켜 개량 효과를 나타내었으나 pH에는 뚜렷한 효과를 나타내지 못하였다. 시료식물의 생장은 시료 토양에 따라 개량제에 대해 다른 반응을 보였다. 울산 토양에서 시료 식물의 생장은 두 개량제 처리구에서 모두 뚜렷한 생장증가 효과를 나타내었다. 여천 토양에서 시료 식물의 생장은 슬러지 처리에 대해서는 증가 효과를 보였으나 돌로마이트 처리에 대해서는 감소 효과를 보였다. 이러한 결과로부터 오염토양 개량제로서 슬러지의 사용 가능성을 확인할 수 있었고, 오염지역의 훼손된 생태계를 복원하기 위한 토양 개량에서 토양개량제의 선택은 토양 특성을 고려하여 선택해야 한다는 사실을 알 수 있었다.

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