Impact Assessment of Nano-Silver Materials on the Soil Quality Parameters

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Introduction

Bionanotechnology – Nano Silver Materials

-Bionanotechnology has emerged up as integration between biotechnology and nanotechnology for developing biosyntheric and environmental-friendly technology for synthesis of nanomaterials

-Bionanotechnolgy has been utilized in various areas including biomedical, pharmaceutical, cosmetic, environmental, and agricultural fields

-Among other nanomaterials, silver nanoparticles have proved to be the most effective for antimicrobial efficiency against bacteria, viruses and other eukaryotic micro-organisms

-However, there is still a lack of information is available for the effect of nano-materials on the environment

Objectives

- **Evaluate soil quality after nano-silver materials are applied in soil**
- **Examine the sorption characteristics of nano-silver materials in soil**

Materials and Methods

1. Nano-Silver Materials

- Nanover™ (1,000 mg L^{-1}) from Pohang University of Science and Technology (POSTECH)

Table 1 Physicochemical properties of Nanover™

Particle Size	pH	EC	Ca	Mg	K	Na	Ag
nm		dS m^{-1}	.....	.....	mg L^{-1}	.....	.....
10-30	4.26	11.02	ND	ND	0.10	0.90	998

ND: Not detected

2. Soil quality assessment with nano-silver application

- Treatment concentration of nano-silver solution in soil: 0, 80, 500 mg kg^{-1}
- Nano-silver solution was applied every week for 5 weeks
- Sampling period: 0, 7, 14, 21, 35 days

Table 2. Analytical methods for soil analysis

pH, EC	1:1 Method	CEC	Ammonium acetate method
Soil organic matter	Walkely Black	Soil respiration	Alkali absorption method
Total Nitrogen (T-N)	Kjedahl Method	Microbial Biomass C and N	Fumigation Method
Available P	Bray No. 1 method	Potentially mineralization N	Keeney method

Table 3. Physicochemical properties of soil

Soil texture			pH	EC	OM	P_2O_5	CEC	Micro-C	Micro-N	PM-N
Sand	Silt	Clay		μS cm^{-1}	g/kg	mg kg^{-1}	$cmol_c$ kg^{-1}	.....	mg kg^{-1}	.....
46.3	29.7	24.0	6.04	965.33	51.94	3,691.2	28.09	289.78	38.78	321.06
85.5	0.5	14.0	6.52	174.70	24.62	225.6	12.84	115.56	20.53	115.38
34.7	29.3	36.0	6.38	867.67	41.06	2,714.4	20.63	175.11	29.94	197.11

Micro-C and Micro-N: Microbial biomass C and N, PM-N: Potentially mineralization N

3. Batch Experiment

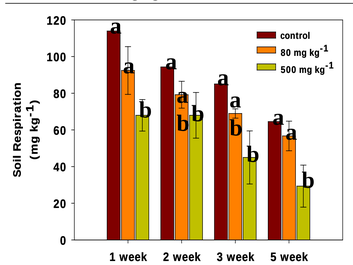
A. Liquid/solid ratio - 10:1, B. Nano-silver concentration – 30, 50, 100 mg kg^{-1}

C. Temperature: 15, 25, 35℃, D. Shake the samples at 150 (rpm), filter through 0.45μm filter paper and measure the silver concentration

Results

Table 4. Change of chemical properties in soil after nano-silver application

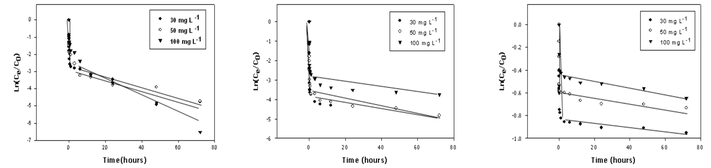
		$pH_{(1:1)}$	$EC_{(1:1)}$	Exc-Ca	Al	Mn	Zn	Fe
			μS cm^{-1}	$cmol_c$ kg^{-1}		-------- mg kg^{-1} --------		
	Soil Texture	CL	CL	L	L	CL	L	L
1 week	control	6.94	438.67	4.63	913.33	52.37	87.00	66.17
	80 mg kg^{-1}	6.89	386.67	4.81	861.67	67.33	93.67	62.50
	500 mg kg^{-1}	6.90	333.03	5.11	826.67	137.50	96.50	57.00
2 week	control	6.41	596.00	4.61	1008.33	74.17	89.50	62.00
	80 mg kg^{-1}	6.63	447.47	5.24	875.00	152.47	95.67	52.05
	500 mg kg^{-1}	6.70	396.33	5.28	733.33	245.55	93.67	40.98
3 week	control	6.55	657.67	5.64	953.33	62.00	82.17	58.67
	80 mg kg^{-1}	6.81	551.33	6.03	830.00	142.00	88.50	48.32
	500 mg kg^{-1}	7.01	368.33	6.22	651.67	307.63	90.17	34.25
5 week	control	6.45	723.00	4.23	1170.00	87.17	86.00	61.83
	80 mg kg^{-1}	6.55	557.33	4.78	935.00	99.00	95.17	47.22
	500 mg kg^{-1}	6.66	508.33	4.89	895.00	257.95	93.67	44.18



- Result of ANOVA test showed that **pH, EC, exchangeable cation, and concentration of Al, Mn, Zn, Fe** were significantly different ($p < 0.05$) when nano-silver was applied in soil.
- Among 4 different biological soil properties, only **soil respiration** was significantly different as nano-silver material was applied in soil.

Sorption characteristics of nano-silver materials in soil

(1) Initial nano-silver concentration effect

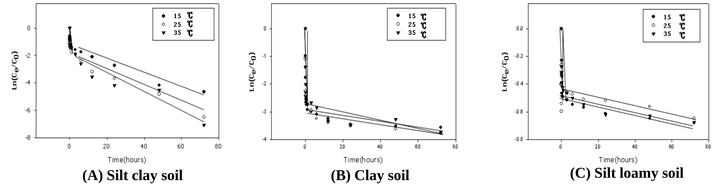


(A) Silty clay (B) Clay (C) Silt loam

Table 5. The kinetic model (Multiple first order) of the nano-silver adsorption in different soil textures

Soil texture	Concentration (mg kg^{-1})	Rate constants (h^{-1})		R^2	
		k_1	k_2	Step I	Step II
Silty clay	30	89.9	0.04	0.83	0.90
	50	73.0	0.03	0.76	0.79
	100	56.1	0.07	0.65	0.97
Clay	30	135.6	0.01	0.92	0.71
	50	131.0	0.02	0.95	0.75
	100	123.8	0.15	0.93	0.69
Silt loam	30	29.5	0.01	0.73	0.65
	50	23.9	0.01	0.95	0.81
	100	35.2	0.01	0.82	0.91

(2) Temperature effect



(A) Silt clay soil (B) Clay soil (C) Silt loamy soil

Table 6. The kinetic model (Multiple first order) of the nano-silver adsorption in different temperature

Soil texture	Temperature (℃)	Rate constants (h^{-1})		R^2	
		k_1	k_2	Step I	Step II
Silty clay	15	43.0	0.05	0.69	0.98
	25	56.1	0.07	0.65	0.97
	35	61.6	0.07	0.75	0.91
Clay	15	98.1	0.01	0.85	0.71
	25	123.8	0.01	0.93	0.69
	35	127.3	0.01	0.79	0.71
Silt loam	15	21.2	0.01	0.77	0.87
	25	35.2	0.01	0.82	0.92
	35	16.5	0.01	0.70	0.80

Summary

1. **Soil variables affected by nano-silver application**
   - **Chemical properties: pH, EC, exchangeable cation and concentration of Al, Fe, Zn, Mn**
   - **Biological properties: Soil respiration**
2. **Sorption of nano-silver materials in soil was followed multiple first order kinetic model**
3. **Sorption of nano-silver materials in soil was increased as initial applied concentration and temperature were increased**