River basin protection against organic agricultural waste.

Matichenkov V.V.

Institute of Basic Biological Problems RAS, Pushchino, Russia, e-mail: vvmatichenkov@rambler.ru

ABSTRACT

River basins soils which characterized by soil with high level of fertility are intensively used for agriculture include animal farming. Utilization of solid (manure) and liquid agricultural wastes are biggest environmental problems in many countries. Organic agricultural waste contains a lot nutrients (N, P, K, Ca and et.) and organic matter, which can be used for optimization of plant nutrition and as soil amendment. Unfortunately the direct using of both liquid and solid organic agricultural wastes concerned with pollution and toxicity. Usually the standard organic agriculture waste treatment reduces the effectiveness of these substances as fertilizer or soil amendments, because part of nutrients lost and organic matter are decomposed. Two technologies for treatment of the solid and liquid organic agricultural wastes were elaborated and tested. Both technologies based on the using Si-rich substances. First technology includes the mixing of Si-rich materials (natural sources or Si-rich environmental friendly industrial by-products) with manure. In the result the toxicity of fresh manure was reduced, the leaching of P, N and K were reduced and all these nutrients were kept in plant available forms. This technology was tested in the field scale in the North Florida in the basin of the Savanna River. Two field characterized by deep sandy soil was treated by mixture of Si fertilizers (two type of Si-rich slags) with fresh manure. During one year every month soil samples were collected from 0-10 cm, 20-25 cm and 30-35 cm depths. The content of water and acid soluble P and N were determined in soil samples. The level of CEC was determined as well. The obtained results have demonstrated high effect of suggested technology. The leaching of P was reduced from 30- to 50%, N leaching was reduced form 40 to 80%. CEC of soil was increased from 10 to 30%. The effect on the quality of cultivated plant was observed also. The demonstration test was conducted with cow manure and Si-rich slag from metal industry. By this means the suggested technology allows to utilize both types of the by-products and give both economical and environmental benefits. Second technology requires the installation of the filtration system, where filter will contain Si-rich substances. The selected Si-rich substances has unique property to fix soluble phosphate (reduce P leaching from 80 to 95%), but kept it in to plant-available forms. After saturation such filter can be used as complex and high effective P-Si fertilizer. The main parameters for filter was calculated and approbated in the laboratory.

INTRODUCTION

Manure or compost from hourses, pig, chiken, beef or dairy cattle farms serve as an excellent source of mineral nutrients and organic matter when added to soils, but can cause environmental pollution. Runoff from cropland areas receiving manure or compost may contribute to increased P and N concentrations in streams, rivers and lakes (Sims et al., 1998). The increasing nitrates, phosphates and organic compounds from manure or compost have a toxic effect on plants and animals. Some manure contains active forms of heavy metals, because the metals are included in animal feeds or comeout from residual of pesticides. Lime applications and manure treatments containing active Al or Fe for reducing the concentration of mobile P result in the P deficiency and results in the need to purchase additional P fertilizers. By this means, there is a complex of ecological and economical problems, which are related to utilization of fresh or composted manure. The movement of P through soil is a complex process, controlled by biological, chemical, and physical soil conditions. Plants and microorganisms can absorb, transform and fix mobile P to organic form. P reacts with Ca, Al, Fe, or Mn and forms slightly soluble or plant-unavailable P (Lindsay, 1979). Using liming materials for reduction of P mobility often decreases P leaching but results in a reducing in P plant nutrition. Si-rich biogeochemically active substances (Si fertilizers) usually exhibit very good adsorption properties (Rochev et al., 1980). The leaching of potassium and other mobile nutrients from the surface soil horizon is reduced by Si fertilization (Matichenkov, 1990; Tokunaga, 1991). Commercial Si soil amendments also may contain other elements like Al, Fe, Ca, which reduce P leaching (Lindsay, 1979; Matichenkov et. al., 2001). Al, Ca and Fe transform P from plant-available forms to plant-unavailable forms, while solid Si-rich substances, with high surface areas, adsorb mobile P and keep it in a plant-available form (Matichenkov, 1990; Matichenkov et al, 1996; 1997; Olivera et al., 1986). It is necessary also to note that monosilicic acid can transform fixed P to plant available form thought exchange reaction between Ca-, Al- and Fe-phosphates and monosilicic acid (Matichenkov 1990). In the result the increasing of the monosilicic acid concentration in the soil solution increased the content of plant-available P (Matichenkov et al., 2001).

Two main types of organic wastes are main source for natural water pollution: solid waste (manure or compos) and liquid wastewater from animal farms. Therefore necessary have at least two approaches for elaboration of the technologies for resolving of these problems. Literature data and our preliminary investigations have demonstrated that Si-rich substances can be used for both technologies (Matichenkov et al., 2000; 2001; 2002). Two technologies were elaborated and suggested. First technology implies that Si-rich material will be mixed with solid organic waste directly on the field. Second technology based on the using of the Si-rich filter for purification of the agricultural waste-water. In the result, the P from waste-water will be fixed and the saturated filter can be classify as phosphate fertilizer.

The aim of the investigation was to test both technologies for reduction of the level of organic waste pollution.

MATERIALS AND METHODS

First technology

Field demonstration of the mixing Si-rich material with manure was conducted on the two commercial fields (North Holstein, Suwannee River Basin, Florida). Pro-Sil (specialty product from steel production, PRO-CHEM Chemical Company, FL, USA) was used for demonstration of this technology. Soils on the both fields were determined as Lakeland fine sand, typic Quartzipsamments, thermic, uncoated. Pro-Sil was applied at the rate 4 t/ha by broadcasting on the area 1 hectare for each field. Another hectare was used as control, where only manure was applied. Manure was applied to both plots (treated and untreated by Pro-Sil) at the rate 20 t/ha for first field and 1 t/ha for second field by broadcasting after Pro-Sil incorporation. After that the disking was occurs for mixture the applied material with soil. The mixed grass were grown on the both field and both fields were irrigated by standard methodology with circle pivot systems. Soils were sampled at the depth of 0-20 cm, 20-40 cm, and 40-80 cm. The content of water-extractable P and Nitrogen, acid extractable P and CEC (Cation Exchange Capacity) were determined in the collected samples with using the standard methodology. The soil samples were collected on the fifth month after beginning of the experiment.

Second technology

Waste water from animal dairy farm was used in the approbation the second technology. This waste-water had 35 ppm of soluble P, dark view and unpleasant smell. The commercial Si-rich materials Sil-Lock was presented by Terra Tech Corp (Miami) USA) and used in this study. The technology adaptation had tree parts. During first part, the tested material was used for filtration of the waste-water. One hundred gram (100) of Sil-Lock was putted to column with diameter 2 cm. Then 20 (twenty) liters of waste-water were passed through this column. The content of P was determined in the percolated solution in the dynamic after each liter passing. The potential adsorption capacity of Sil-Lock for P was investigated and the content of potentially adsorbed P was calculated. For this investigation 1 g of Sil-Lock was added to 100, 500, 1000, 5000, 10000 and 20000 ml of liquid waste water, mixed during 1 hour. After that the solid material was centrifuged. The content of soluble P was tested in the purified solution. The total content of adsorbed P was tested also with using dissolving of solid material in the NaOH (furnace).

Finally, the saturated Sil-Lock after column was dried and used in the greenhouse test as P fertilizer. The triple superphosphate used in the greenhouse test as well. Both fertilizer were applied at the 50 and 100 kg/ha of P_2O_5 (or 100 and 200 kg/ha for saturated Sil-Lock and 100 and 200 kg/ha for triple superphosphate). Sand was used in the greenhouse and barley was tested plant. The duration of the experiment was 4 weeks. During the experiment the percolated water was collected and content of soluble P was determined. After harvesting the biomass of barley was determined. The total content of P in the plant tissues and content of water and acid-extractable P in the sand were determined as well.

RESULTS

First technology

The content of water- and acid extractable P is present in the table 1. The application of the Si-rich soil amendment dramatically reduced the content of leacheable P (water and acid-extractable P). By this means the application of this soil amendment can reduce the risk for water pollution from cultivated area treated by manure. The content of leacheable nitrogen also was reduced under Pro-Sil application (Table 2). The highest effect in relative was obtained on the second field, but in highest effect in absolute data was obtained for first field. Probably the high rate of applied manure saturated the Pro-Sil by nitrogen.

Using the data about content of Ca, Mg, K and Al in the soil the CEC was calculated (Table 3). CEC was increased under Pro-Sil application on the both field. It is important that the CEC was increased not only in upper horizon, but also in the deep horizons, which probably can be explain by leaching of mono and polysilicic acids, which can improve the soil adsorption capacity (Matichenkov and Bocharnikova, 2001).

Table 1. The content of water- and acid extractable P in the soil samples from field test, mg/kg.

Depth, cm	Field 1		Field 2	
	P water extractable	P acid extractable	P water extractable	P acid extractable
Control				
0-20	24,5	780	3,8	362
20-40	24,4	354	3,1	133
40-60	18,3	115	3,1	105
Pro-Sil				
0-20	17,1	664	2,6	125
20-40	15,0	287	1,2	73
40-60	5,6	107	1,1	15
LSD_{05}	0,45	10	0,30	10

Table 2. The content of leacheable N (NO_3^-) in the soil samples from field test, mg/kg.

Depth, cm	Field 1		Field 2	
	Control	Pro-Sil	Control	Pro-Sil
0-20	19,5	17,1	3,7	2,1
20-40	6,2	4,0	3,1	1,8
40-60	4,3	1,2	2,5	0,4
LSD_{05}	0,3	0,3	0,1	0,1

Table 3. The content of CEC in the soil samples from field test, meq/100 g.

Depth, cm	Field 1		Field 2	
	Control	Pro-Sil	Control	Pro-Sil
0-20	4.51	5.86	2.94	5.31
20-40	2.70	5.35	3.09	3.12
40-60	1.23	2.30	1.46	1.76

Second technology

The concentration of the P in the percolated solution after column passing is present on the figure 1. The concentration of P in the percolated solution was around 20-30 ppb. By this means Sil-Lock practically removed all P from agricultural waste-water. The result of the laboratory experiment with Sil-Lock is present on the table 4. This data allowed calculating the potential adsorbing capacity of Sil-Lock to P. About 200-250 kg of P may be absorbed by one ton of Sil-Lock. By this means the saturated Sil-Lock can be classified as P fertilizers, witch content of P_2O_5 about 40-50%.

Figure 1. The dynamic of P in the percolated solution.

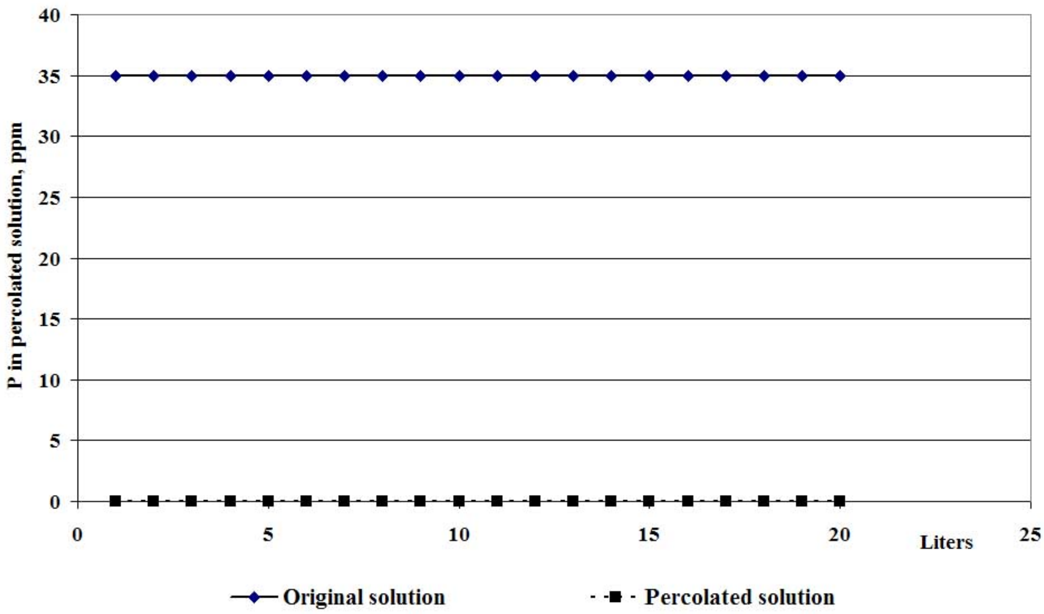


Table 4. The content of P in the purified solution after contact with Sil-Lock, ppm.

Parameter	Original volume of waste-water					
	100	**500**	**1 000**	**5 000**	**10 000**	**20 000**
Initial concentration of P, ppm	35	35	35	35	35	35
Final concentration of P, ppm	0,01	0,02	0,02	0,03	11	12,5
Adsorbed P, kg/t of Sil-Lock – tested	3,2	15,7	35,4	180,2	244	249
Adsorbed P, kg/t of Sil-Lock - calculated	3,4	17,4	34,9	174,9	240	250

The effect of the tested P fertilizer on the barley biomass is present on the figure 2. The obtained data has demonstrated that the application of the saturated by P Sil-Lick had more effect on the barley then triple superphosphate effect. The content of the both water and acid extractable P in the soil after greenhouse test also was higher in the plot with application of the saturated Sil-Lock, then in plot with triple superphosphate application (Table 5). But in the contrast, the content of P in the percolated solution from pots with application of saturated Sil-Lock was less then from pots with triple superphosphate application (Figure 3).

Figure 2. Effect of the saturated Sil-Lock and triple superphosphate on the fresh barley biomass.

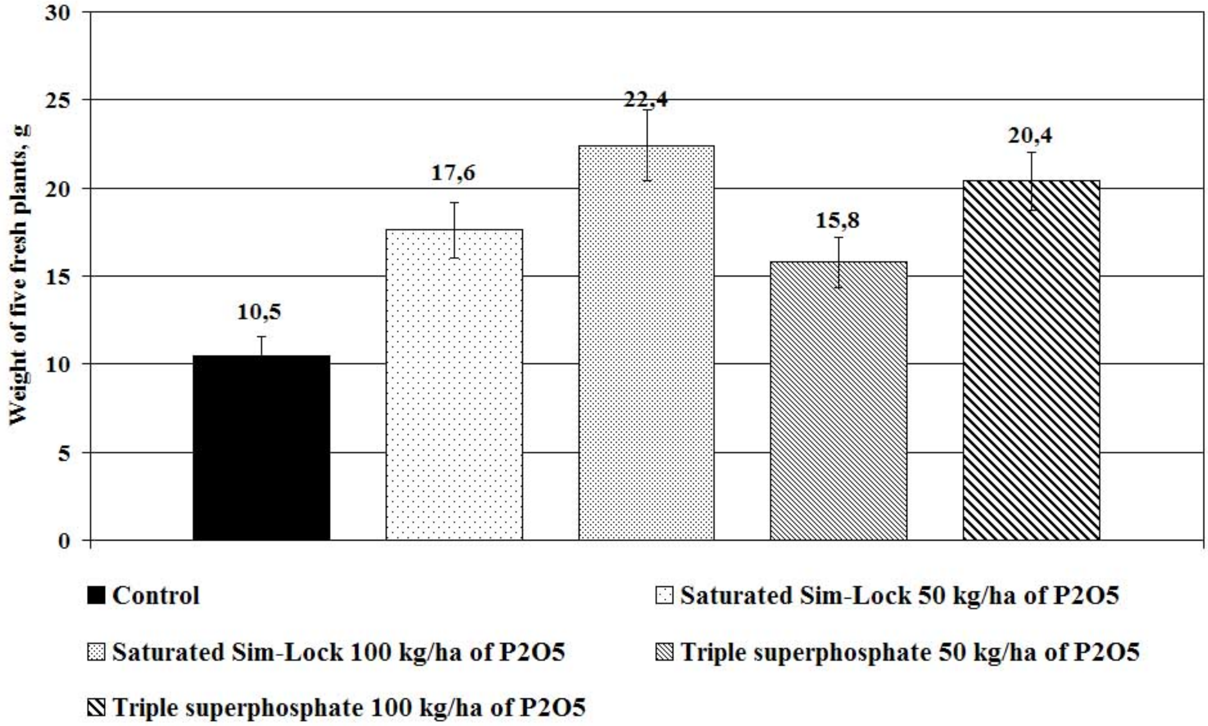
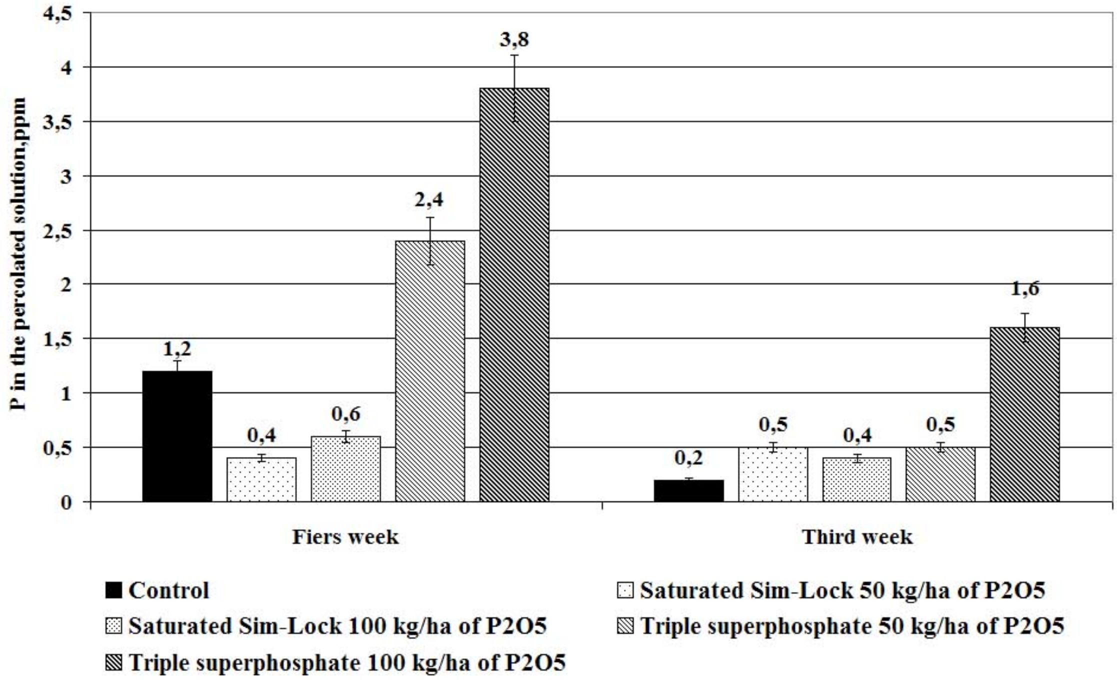


Table 5. Effect of the saturated Sil-Lock and triple superphosphate on the content of water- and acid extractable P in the sand after greenhouse test, mg/kg.

	50 kg/ha of P_2O_5		100 kg/ha of P_2O_5	
	P water extractable	P acid extractable	P water extractable	P acid extractable
Control	2,4	94,3	-	-
Saturated Sil-Lock	3,8	244	6,5	367
Triple Superphosphate	3,3	210	4,4	320
LSD_{05}	0,3	10	0,4	12

Figure 3. Effect of the saturated Sil-Lock and triple superphosphate on the P in the percolated solution, ppm.



DISCUSSION

The obtained data has shown that the both technologies are very prospective and can reduce the negative ecological impact of the agricultural activity on water quality in rives. It is important that both technologies based on the using of the Si-rich substance with high content of active forms of Si.

First technology includes the mixing of manure or compost with Si rich materials. This technology is very simple for using. It is necessary only to apply the right Si-rich material at the right rate before the manure or compost application. In the result the leaching of the P and N will be reduced. It is not a question that if solid organic water will be mixed before the application to soil the efficiency of Si-rich material and organic material will be increased, because Si and organic material has synergetic influence on the both cultivated plants and soil microorganisms (Matichenkov et al., 1999).

Second tested technology allows producing high quality P fertilizer directly on the animal farms. By this means farmer can safe money for P fertilizers and resolve the problem of P fertilization on his land. The produced P fertilizers has very active P (better then in triple superphosphate), but not leacheable P. It is possible to install the filtration system on the each farm, because this technology can be modified for each specification of the farm.

Our investigations have shown that the application of active Si has both environment and economical effects. By this means the reduction of the nutrient leaching will give to farmer the additional economic benefits. The main economic effect will occur thought increasing crop production (10-25%) and reduction of the other agrochemical application (P fertilizer, N fertilizers, fungicides, insecticides et al.). For example, the application of the Si-rich materials allows reducing the fungicide and insecticide application up to 30-50% with same level of plant protection (Datnoff and Nagata, 1999).

The suggested technologies are necessary to adapt to local weather and soil conditions and farmer operation. However, the mechanisms of Si effect on the P behaviors on the soil is not completely investigated and require additional studies. But the technologies can be recommended for practical implication, especially on the river basins, where the risk of the pollution by products of agricultural activities is very high.

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