

Phosphorus-rich organic amendments and release of soil phosphorus to runoff

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Eutrophication of continental surface waters is mainly attributed to elevated nutrient concentrations (N and P). But new insights have recently shown that P might be the key nutrient limiting aquatic plant growth.

High concentrations of phosphates in surface water is usually ascribed to punctual sources of pollution. But, in some region the excess of organic amendments usually result in P over-fertilization that might affect water quality. Therefore, a better assessment of the impact of no-point source pollution is needed, and the fate of phosphorus (P) applied on cultivated soils has become an issue of major interest (Robert, 1996).

Among organic fertilizer, sewage sludge, as a product of waste water treatment, deserves interest because of its high P content, especially in regions sensible to eutrophication where water treatment plants are requested to remove P from their effluent (which results in P enrichment in the sludge).

The purpose of our work was to investigate the effect of sludge application on phosphorus content in runoff.

Samples and methods

Phosphates release to runoff from a soil fertilized with a sewage sludge, has been measured in a corn field. Two devices were used in order to follow both the average release during one year of cultivation and the evolution of P concentrations during simulated rainfalls on different soil surface aspects. These device have been developed by Gascuel-Oudoux *et al.* (1996)

Five kinds of sludge were studied. They were all produced by biological treatment plants fitted for P removal (which guaranteed their high P concentrations); but differed by the P treatment applied and by their conditioning.

The soil chosen for these investigations was a loamy acid brown soil, slightly leached and based on a shaly bedrock. The initial soil P content was high (1.7 g P/kg). The slope of the field surface was 4%. The lines of corn were cultivated parallel to the slope in order to enhance the recovery of runoff water.

The particulate and dissolved fraction were

separated through 0.2 μm filtration. Total dissolved carbon organic mater (DOC) was determined after combustion on a C analyser. Dissolved P was analysed by colorimetry (Murphy and Riley, 1962). Concentrations of major ions in the solution were measured by capillary electrophoresis. The particle-bound P was determined after an acid oxidation of the particulate fraction.

P released from the soil

The total P concentrations (dissolved P + particle bound P) in runoff have not significantly increased on the corn rows supplied with sludge. This main result is partly explain by the fact that sludge formed aggregates on the soil surface and that these aggregates were not shattered by rainfall or mobilized by the erosion process.

Regardless of the presence of sludge, total P losses per rainfall ranged over a wide field (from 50 to 50 000 mg P/ha). The relevant factors explaining this variation appeared to be the intensity of the rain, the soil surface roughness, its moisture and the vegetal cover, but also the P concentration of the particulate matter in the runoff to be related to the heterogeneity of the soil.

Most of the P release was represented by particle-bound P whose mean fluxes accounted for 90% of the P losses (Fig. 1).

The only direct impact of sludge application was observed after a high intensity simulated rainfall (40 mm/h intensity during 90 minutes) on a row supplied with liquid sludge (97% moisture). Then, a slight redistribution of sludge appeared in the water puddles, at the end of the rain. Rainfall simulations also showed that the application of sludge can affect surface roughness and limit runoff.

Chemical composition of the runoff water

Although it accounts only for 10 % of the total P release, the soluble P fraction is likely to play a key role in the process of continental water eutrophica-

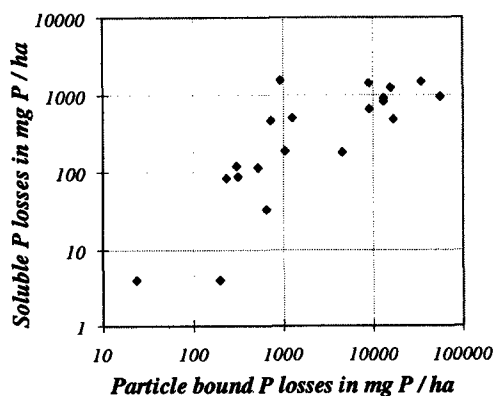


FIG. 1. Phosphorus losses during the main rainfall episodes.

tion. It is representative of the runoff water characteristics, when it is discharged in the river, while part of the solid load of the runoff might have decanted. Furthermore, the dissolved P is directly available for aquatic plants.

The dissolved P concentrations showed positive correlation with the pH, the solid load of the runoff and the particle-bound P concentration. This behaviour is typical of a solute whose activity in the water is controlled by sorption phenomena. The relation between the P concentration and the solid load of the runoff water appeared to be well described by Langmuir or Freundlich isotherms. This is consistent with the fact that P is usually considered to adsorb onto runoff particle surfaces via at least two mechanisms: specific adsorption based on a ligand exchange mechanism and outer-sphere complexation (Freese *et al.*, 1992).

The other major anions (NO_3^- , Cl^- and SO_4^{2-}) are considered to adsorb mainly as diffuse-ion swarm (Sposito, 1989). However, NO_3^- was characterized by

a strong relation with the solid load, while Cl^- and SO_4^{2-} were only related to pH. The dissolved organic matter that mainly consists into organic anions (for pH near neutrality), followed the same tendency.

By contrast, the concentrations of cations correlated neither with pH, nor with the solid load of the water. Instead, their activity seemed rather controlled by dissolution and precipitation.

Conclusions

Direct observation do not show any noticeable contribution of the organic amendment to the P release to runoff. But, the study of mechanisms involved in the water composition shows that phosphorus concentration is controlled (as other anion contents) by sorption processes.

Intensity of P desorption of the runoff particles depends on the P concentration of the particulate matter. Therefore the slow increase of P concentrations in soils over-fertilized with organic amendment might result in a slow increase of the dissolved P concentration background in the rivers, even if dispositions are taken to avoid particulate matter erosion.

References

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