Influence of amendments and soil roughness on nutrient transport from soil under different rainfall intensities

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Abstract
Continuous application of P fertilizers to saturated soils occurs to such an extent that P loss in surface runoff has become a priority management concern. To reduce P transport to surface water bodies, many strategies and management practices have been investigated. There is a need to work out strategies for the soil that are already rich in P. In many areas, soils are so P-enriched that without further P addition, 16 to 18 years of cropping would be needed to deplete it. Residues from water treatment facilities (WTR) have been extensively tested for this purpose under crop or grass cover, but less is known about what happens when it is applied to bare soil. Similarly, blast furnace slag (BFS) has been studied for its use as a filtering material in wastewater treatment plants, but its use on agricultural land for P control has not been reported. In this study, bare soil was amended with these two industrial wastes to observe the P concentration in runoff water. Soil was amended with P at 400 kg/ha, while BFS and WTR were applied at 50 g/kg soil. Bare soil surface, with two roughnesses (low and high), was exposed to two simulated rainfall intensities (30 and 65 mm/h). Each rainfall treatment was conducted three times on each amended soil surface with a constant rainfall amount of 60 mm. Regardless of rainfall intensity and soil roughness, there was an increasing trend of P concentration in runoff water from unamended control plots over the time of runoff, while the trend of P concentration tended to decrease from the BFS and WS amended soils. Though the trend was declining, the P concentrations were higher from BFS amended plots as compared to control and WTR amended plots. The P concentration was lower in both amended plots during the third run under both rain intensities. However, P concentrations were lower with high rainfall intensity, mainly due to the dilution factor. This study affirms the ability of WTR to reduce P mobility from bare soils however further studies are needed to test the effectiveness of BFS under field conditions.

Key Words
Phosphorus runoff, soil roughness, rainfall intensities, nutrient transport

Introduction
Chemical fertilizer application to land has increased, especially in developing countries, and world P fertilizer demand was predicted to increase by approximately 2.7% per year from 2004 to 2008. Continuous application of P fertilizers saturated the soils to such an extent that without further P addition, 16 to 18 years of cropping corn or soybean would be needed to deplete the soil test P content (Mehlich III) of soil from 100 mg P/kg to the threshold agronomic level of 20 mg P/kg. To reduce P transport to surface water bodies many strategies and management practices have been investigated that include the use of different amendments. Our knowledge on the effectiveness of different amendments on bare soil is scarce. Therefore, in the current study, some amendments have been used to reduce the P lost from the soil. Blast furnace slag (BFS) is one of the materials which has been used for P removal from waste waters. But BFS has not yet been used to reduce P mobility from agricultural lands. Similarly, drinking water treatment residuals (WTR) are also effective due to their high P-sorbing capacity. Several field and lab studies have been conducted to evaluate the use of WTR as a P sorbent and have reported that WTR significantly reduces P losses. However, the performance of these amendments under changing soil surface roughness has not been fully explored. The objectives of this study were to evaluate i) the effect of different rainfall intensities on P concentration in runoff from amended soil ii) potential use of BFS in reducing P concentration in runoff and iii) effect of soil roughness and rainfall intensity on the performance of WTR and BFS.

Methods
Tohaku loam soil (Fulvudand) was air dried, passed through a 2 mm sized sieve and packed in a steel pan (100cm x 50cm x 15.2cm). Each pan was part filled with a gravel filter to facilitate lateral flow. Top 5 cm of soil was amended with blast furnace slag (BFS) and residues from water purification facility (WTR) at the rate of 50 g/kg soil. Phosphorus (P) fertilizer in the form of KH_2PO_4 was applied at the rate of 400 kg P/ha and was mixed in the top 5cm soil. Slop was adjusted at 8%. Two rainfall intensities 30 and 65 mm/h were

used with the rainfall application of 60 mm. Each treatment was subjected to three consecutive runs. The soil surface of each treatment was made with low or high roughness. To achieve the low soil roughness a spade with a blade 2cm in length was used, while for high soil roughness a spade with a blade of 5 cm length was used. Three soil amendments, two soil roughness, two rainfall intensities and two replications with three runs gave a total of 72 runs. Water samples from runoff water were collected at different time intervals after the runoff started. Immediately after the collection, water samples were filtered through a 0.45 µm filter. Concentration of DRP, K, Fe and Al in runoff water was recorded with an Inductively Coupled Plasma Spectrometer (ICP).

Results

Effect of low rainfall intensity (30 mm/h)

Dissolved reactive phosphorus (DRP) concentration in runoff varied greatly under all treatments. Irrespective of soil roughness, the concentration of DRP in unamended (control) plots was lower at the start of first run (Figure 1) and DRP concentration increased with the increase in time of water runoff over the surface. Contrary to the unamended plots, DRP concentration started to decrease with the time of runoff over the plots amended with sludge from water purification plant (WTS) and blast furnace slag (BFS). In WTS amended plots, DRP concentration was higher at the start of first run under low soil roughness condition and a declining trend was observed (Figure 1). A similar trend was observed for the second run while in the third run DRP concentration was relatively stable. In BFS amended plots with low soil roughness (LSR), DRP concentration was higher at the start of first run and the concentration started to decrease with runoff time. In the second runs, DRP concentration remained almost steady while in the third run DRP concentrations were lower than first and second runs. The change in soil roughness from low to high did not change the overall trend of DRP concentration in runoff water under 30 mm/h rainfall intensity (Figure 2). For high soil roughness (HSR), DRP concentration from the control plot increased in first dry run with the passage of runoff time and remained steady during second and third runs. For the WTR treatment DRP concentration was higher at the start of each run but with runoff time DRP concentration decreased. Similarly, for BFS amended soil, the concentration of DRP also decreased with the passage of runoff time in all three runs.

Effect of high rainfall intensity (65 mm/h)

The trend over time of DRP loss did not change significantly with the increase in rainfall intensity. Under low soil roughness, DRP concentrations in the control treatment increased with the time of runoff in all three runs (Figure 3). For the WTS amended plot, DRP concentrations also decreased in the first run. In the second run, DRP concentrations were higher at the start, but later the trend was linear, while in the third run the DRP concentration in runoff water was relatively steady. In BFS amended plots, the DRP concen-tration decreased with time of runoff for all three runs and minimum DRP concentrations were recorded for the third run. Under high soil roughness, the DRP concentration remained stable with runoff time for the control plot (Figure 4). Plots amended with WTR showed a decrease in DRP concentration during the first run, while in second and third run the DRP concentration remained relatively stable. For BFS amended plots, a decrease in DRP concentration was sharp in first run, but in the second run the DRP concentration remained steady. In the third run, the DRP concentration was steady, but slightly declined toward the end of runoff.

Iron, aluminium and potassium concentration in runoff

Generally, Al and Fe concentrations did not show any specific trend with runoff time in the three runs of different treatments (Figure 1 to 4). Overall mean concentration of Al in runoff water was higher under low rainfall intensity. Increasing the soil roughness from low to high also increased the Al concentration in runoff. Among the amendments, Al concentration was slightly higher in WTR as compared to BFS. A trend similar to Al was observed for Fe concentration. In the case of K, concentrations were higher during the first run for all the amended plots and K concentration reduced with runoff time for each subsequent run. Overall mean K concentration in runoff water did not change with change in rainfall intensity or soil roughness however in WTR amended plots K concentration was slightly higher than BFS.

Conclusion

The data showed that under the bare soil condition, the likelihood of P runoff is higher. It was observed that in control plots the DRP concentrations were lower at the start of runoff and higher at the end of rainfall. Application of soil amendments showed a reverse trend where DRP concentrations were higher at the beginning of runoff and lower at the end. Among all treatments, the DRP concentration was lowest in the WTR amended plots, followed by the control and BFS amended plots. The DRP concentrations were higher under low rainfall intensity (30 mm/h) as compared to high rainfall intensity (65 mm/h) especially under the low soil roughness condition. Lower concentration under high rainfall intensity is due to the dilution factor. WTR could be an effective amendment to reduce the P runoff from bare soils.

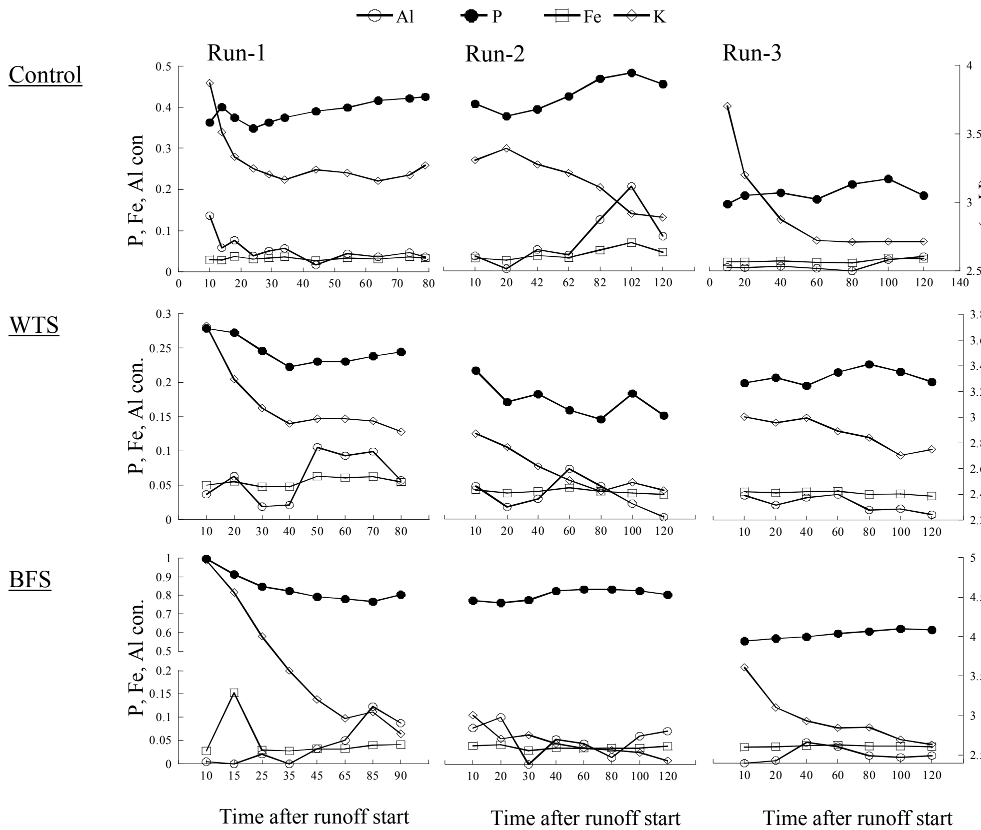

Figure 1. Effect of low rainfall intensity (30 mm/h) and low soil roughness on DRP, K, Fe, and Al concentration in runoff water

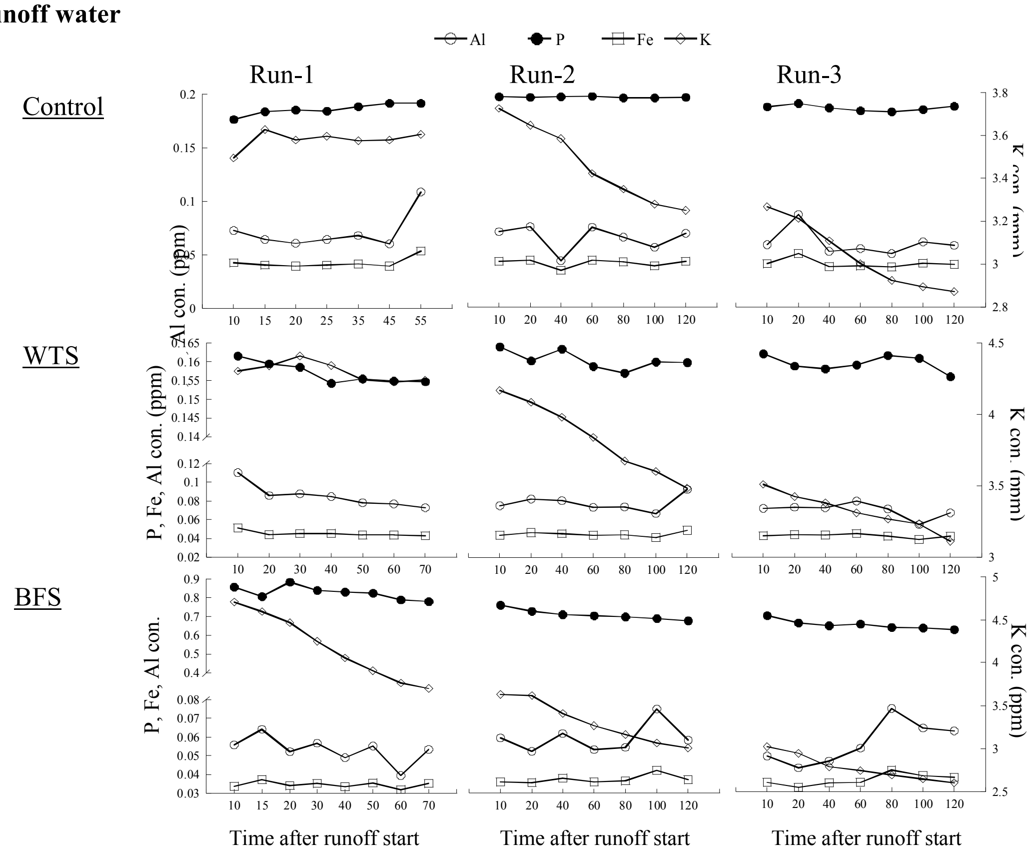

Figure 2. Effect of low rainfall intensity (30 mm/h) and high soil roughness on DRP, K, Fe, and Al concentration in runoff water.

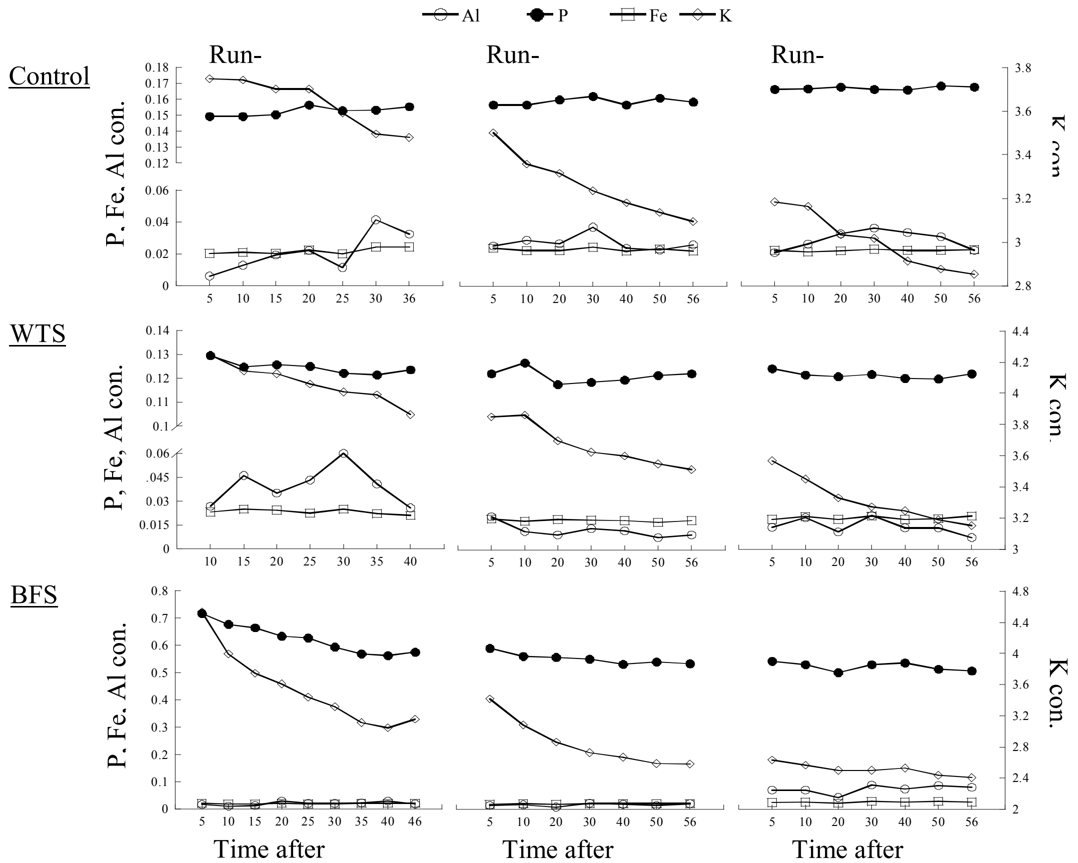

Figure 3. Effect of high rainfall intensity (65 mm/h) and low soil roughness on DRP, K, Fe, and Al concentration in runoff water

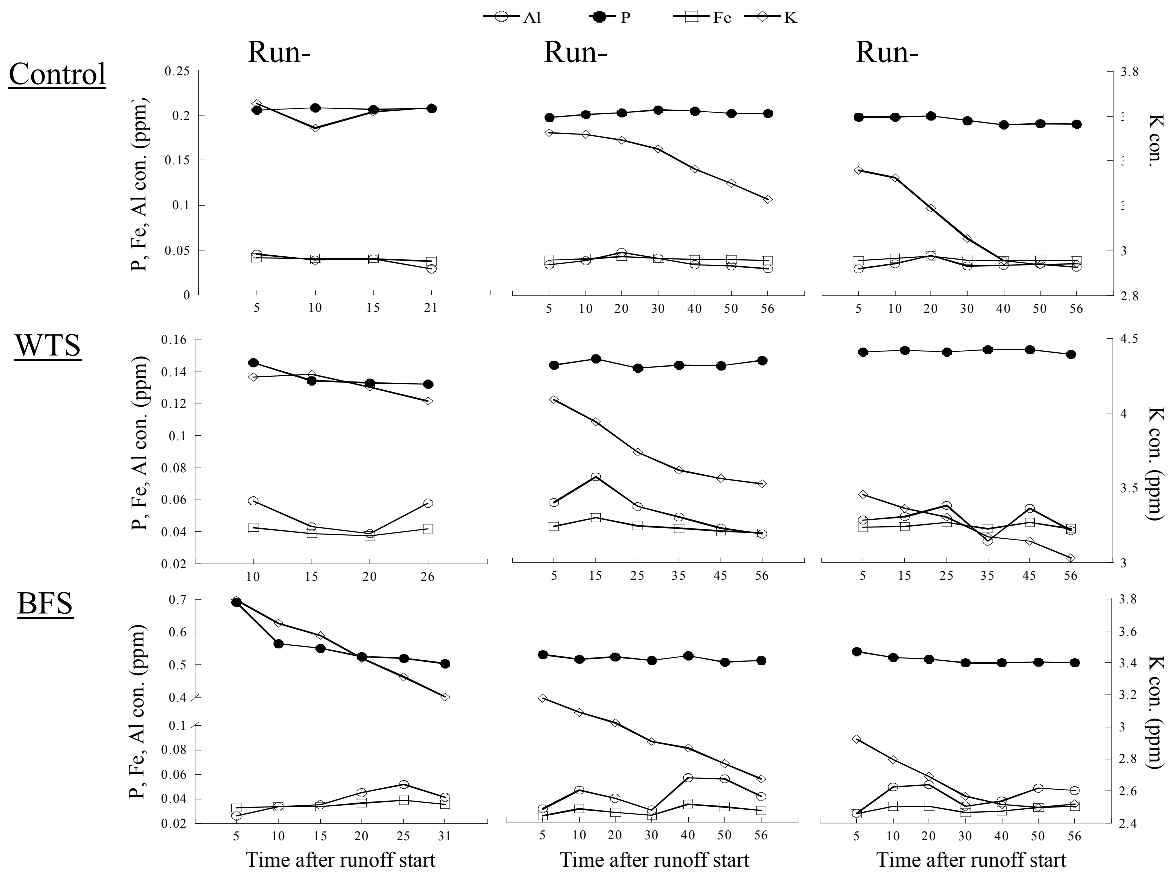

Figure 4. Effect of high rainfall intensity (65 mm/h) and high soil roughness on DRP, K, Fe, and Al concentration in runoff water.