The Role of Fluvial Sediments in Modifying Phosphorus in a Stream Environment

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Introduction

The role of phosphorus (P) as the primary nutrient responsible for accelerating eutrophication of fresh waters is well documented (Schindler et al., 2008). Surface transport of fluvial P to overlying waters is of concern particularly from agricultural and urban areas. Phosphorus entering fresh waters from surface runoff includes particulate and dissolved P. Once these forms of P enter a stream system, they have the potential to act strongly with sediments. These sediments then have the ability to act as sources and sinks of P to the overlying water column. This is important for overall watershed management as this reactivity will influence the amount of P that is ultimately transported through the streams and into the lakes of the watershed. Within Northwest Arkansas recent population expansion has increased urbanization of the area, while poultry production and subsequent land application of litter and surface runoff has remained a concern to the water resources of the region.

Objectives

The objective of this research was to study P adsorption and desorption characteristics of select stream-bed sediments from the Upper Illinois River Watershed (UIRW) in a simulated stream environment (fluvarium).

Methods and Materials

- Five stream sites (riffles and pools) in the UIRW were selected representing urban, agricultural, and forested land uses (Fig. 1). At each stream site, sediment was collected to a depth of 3-5 cm at equal intervals along a reach. A reach was defined as a representative riffle and pool from a stream and averaged 50-m. Three streams representing urban, agricultural, and forested sites are discussed for sorption experiments.
- Sediments were sieved to <20mm and immediately transported to an indoor fluvarium where water flow was initiated at a rate of 1.0 $L s^{-1}$ at a 1% slope corresponding to average measurements across all streams (Fig. 2). The experiment consisted of 3 phases: (1) a release phase with initial water at <0.005 mg P L^{-1} circulated over the sediment, (2) a high P solution of 1.8 mg P L^{-1} reflecting runoff from fields receiving poultry litter, and (3) a re-release phase with water at <0.005 mg P L^{-1}. Water samples were collected at frequent intervals with an ISCO 4712 Autosampler and dissolved reactive P (DRP) concentration of filtered water measured colorimetrically.
- Langmuir P sorption parameters of the <2mm sediments were determined. Sorption properties were determined via end-over-end shaking of 1.5 g fresh sediment (dry weight) with 30 mL of deionized water with P (added as KH_2PO_4) at concentrations of 0 to 50 mg P L^{-1}. After 24 hours, mixtures were centrifuged at 4000 rpm for 15 min, filtered (0.45 μm) and DRP measured. From the Langmuir isotherm equilibrium P concentration (EPC_o – the concentration at which no net sorption or desorption occurs) and P sorption maximum (P_{max}) were calculated.
- Mehlich-3 (M3) extractable nutrients were determined on an initial sub-sample of <2mm sediment. From this a modified phosphorus sorption ratio (PSR_{mod}) as described by Haggard et al. (2007) was calculated and is defined as: M3P /[M3Fe + M3Mg + M3Mn].

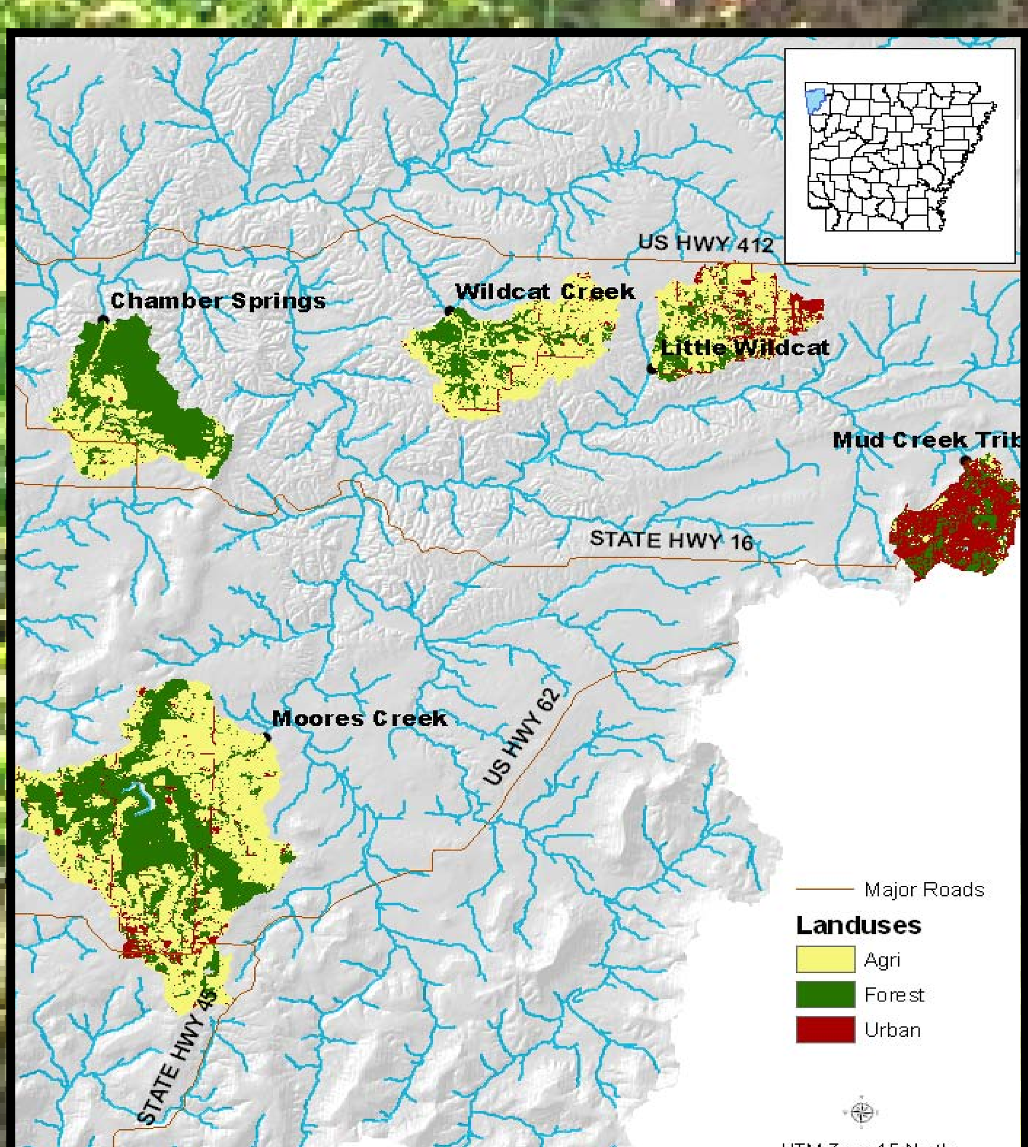

Figure 1: Land use/land classification of 5 streams sites within the Illinois River Watershed.

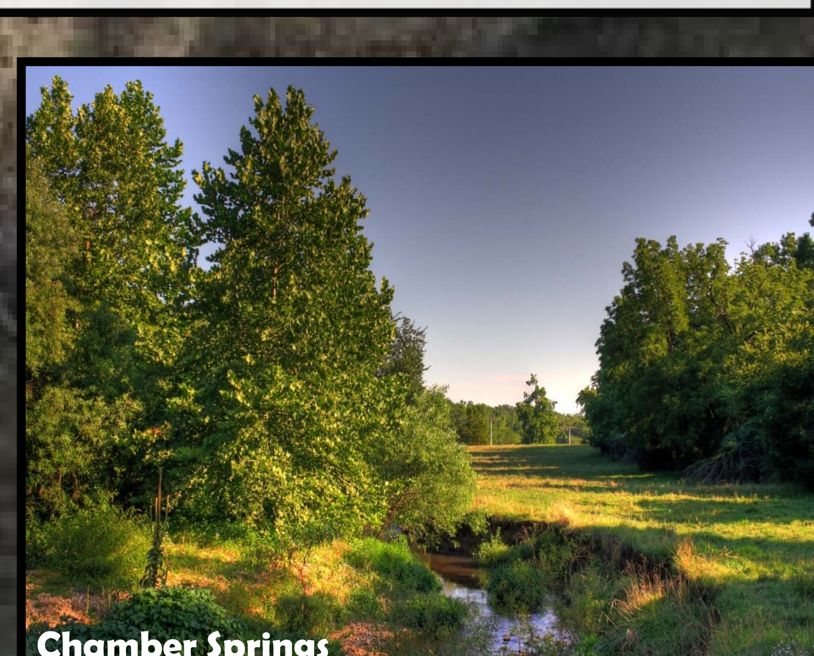

Figure 2: Purpose Built Fluvarium

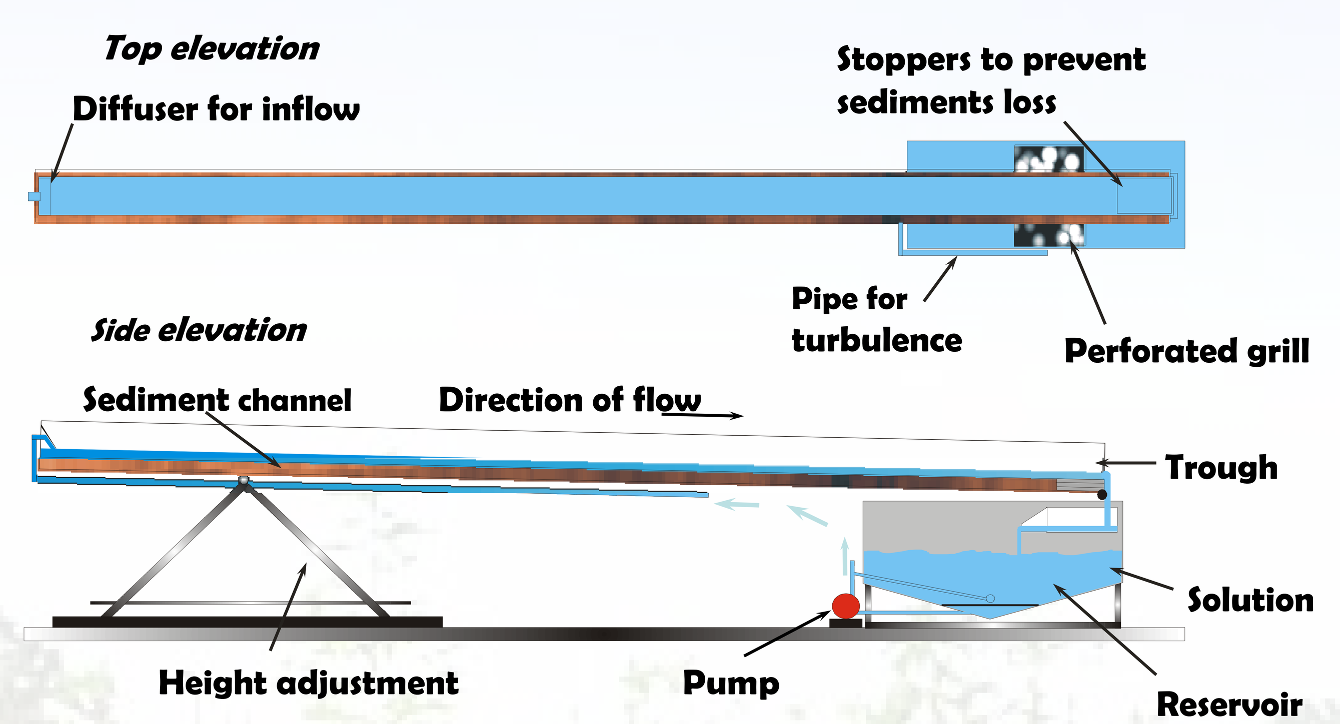

Figure 3: Relationship between PSR_{mod} and DRP

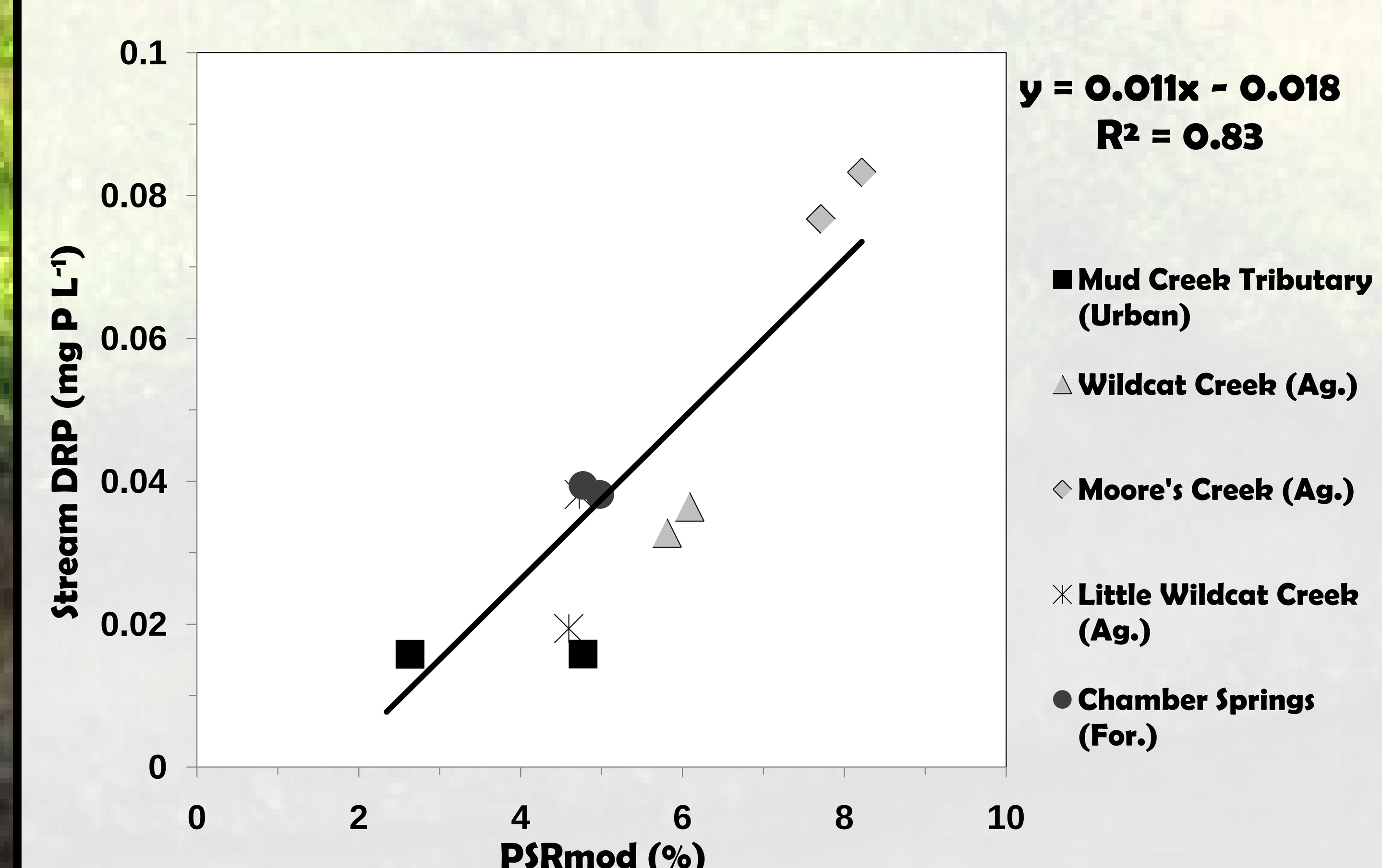

Figure 4: Phosphorus-Sorptio1n Isotherms

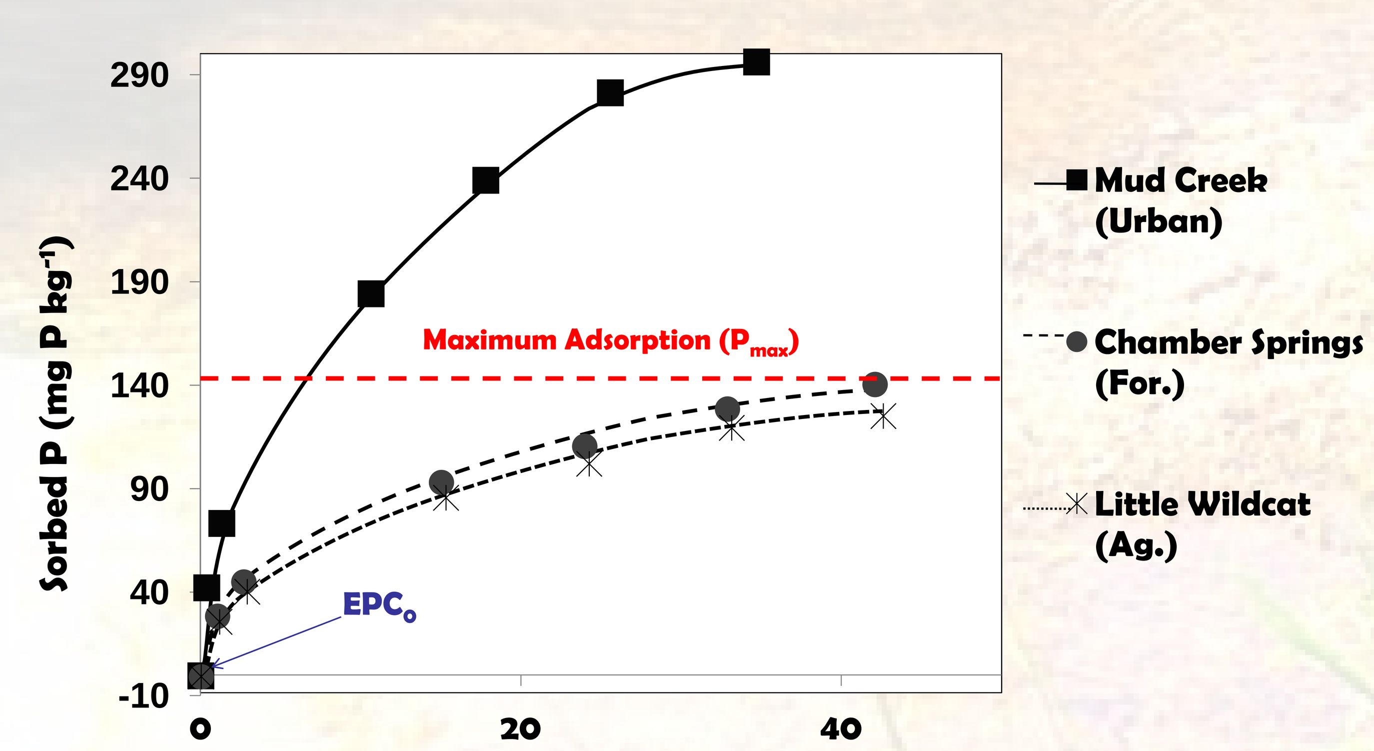

Table 1: Initial Sediment and Water Characteristics

Location	M-3 P (mg P kg^{-1})	DRP (mg P L^{-1})	EPC_o	P_{max} (mg P kg^{-1})
Mud Creek Tributary	12	0.016	0.014	323
Little Wildcat	12	0.021	0.045	136
Chamber Springs	15	0.039	0.041	149

Figure 5: Phosphorus Uptake from Poultry Litter

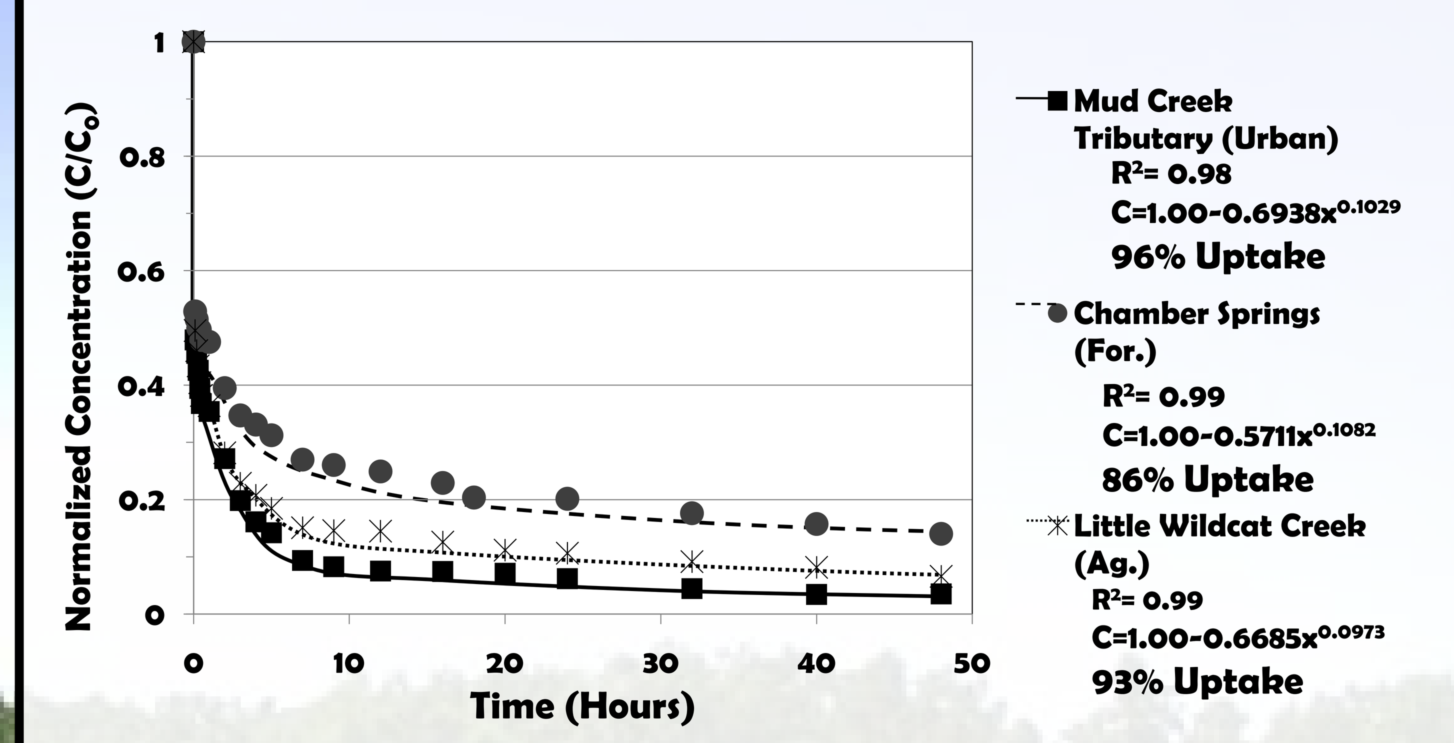

Table 2: End of Phase Values and Final Uptake

Location	Land use	End Phase 1 DRP (mg L^{-1})	Uptake Phase 2 (%)	Release Phase 3 (%)	Final Uptake (%)
Mud Creek Tributary	Urban	0.014	96	1	95
Little Wildcat Creek	Ag	0.028	93	4	89
Chamber Springs	Forest	0.032	86	7	79

Conclusions

- Base flow concentrations of DRP related to PSR_{mod} suggest M3 soil testing as an estimator of a stream sediment's ability to maintain base flow DRP (Fig.. 3).
- During base flow one of the selected streams was acting as a sink for P (Mud Creek Tributary) and two as sources (Little Wildcat Creek and Chamber Springs) (Table 1).
- An inverse relationship between EPC_o and P_{max} is apparent from sorption parameters. Streams with lower EPC_o concentrations will act as greater sinks for P entering a stream as they have a greater ability to uptake P into the sediment. Therefore, streams with high EPC_o and low P_{max} values will have less ability to act as transient storage sites for P during high input times (Table 1, Fig. 4).
- Based on the fluvarium flow experiment, stream sediments within the watershed act as transient storage for P during periods of high P inputs, such as from point sources and nonpoint runoff and have a regulating effect on water column DRP levels during base flow (Table 2, Fig. 5).

References

Haggard, B.E., D.R. Smith, and K.R. Brye. 2007. Variations in stream water and sediment phosphorus among select Ozark catchments. J. Environ. Qual. 36:1725-1734.

Schindler, D.W., R.E. Hecky, D.L. Findlay, M.P. Stainton, B.R. Parker, M.J. Patterson, K.G. Beaty, M. Lyng, and S. E. M. Kasian. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen inputs: Results of a 37-year whole-ecosystem experiment. Proc. Nat. Acad. Sci. 105:11254-11258.

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