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Commentary

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Floods and Pollutants Cycling in a River System: Will Pollutants be More Rapidly Remobilized in the Future?

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Introduction

Floods play a principal role in the dispersal of pollutants in a river system. Whereas most pollutants associated with very fine sediments settle down in a channel during the average water stages, they are already entrained when the raising limb of a flood wave passes downstream. During a flood, polluted sediments are transferred onto a floodplain forming overbank sequences of sediments, which progressively decline toward valley sides. With time they become a historical pollution source as the period of sediment storage can, in some floodplain locations, far exceed a thousand years. And this is just the beginning, as in the river valleys of most industrialized areas the sediments are polluted with persistent chemicals like heavy metals or PCB, which can be remobilized for many years to come. In particular, overbank sediments in catchments with active mines of the 19th and 20th centuries constitute serious secondary source of pollutants which are released mainly during floods both by leaching and erosion [1].

Thus we can draw a conclusion that every single flood can accumulate pollutants in one place of the floodplain having removed them from another place. The places, whose functioning can change with time and flood magnitude, are unevenly dispersed both along the river course and across a floodplain. The places from which pollutants are removed in significant amounts are called “hot spots”, whereas flood episodes with pollutants mobilized in larger amounts are called “hot moments”. When the amount of sediments accumulated and eroded in a river reach is constant over a long period of time, the river is in equilibrium. Unfortunately, man-made manipulations of the river channel induce a loss of such balance. Channel straightening increases the stream gradient and the river incises further into the floodplain, intensively eroding sediment-associated pollutants and exposing them in the river banks. The river reach becomes a source of pollutants. Damming of a river decreases the upstream channel gradient favouring the net sediment accumulation and pollutant storage, in most cases with the exception of the largest flood episodes. Bank reinforcements also change pollutant cycling due to lateral channel stabilization. Such laterally stable reaches, with the floodplain protected from erosion, constitute a sink for pollutants, which can be mobilized almost solely by leaching due to water table fluctuations.

Floods are a phenomenon which in moderate climates in natural river channels occurs on average every 2 years. The depth of flood waters can reach several meters and results in the saturation of the entire soil profile. Such case is rarely observed in non-inundated soils, which can be saturated solely during long-lasting and heavy rains. Mobilization of pollutants, in particular - heavy metals, is related to the duration, height and frequency of floodplain inundation. Their mobilization is the most intensive at the depths close to groundwater level with the highest frequency of water table fluctuations. Moreover, water stagnation on the floodplain fosters the formation of reducible conditions when metals associated commonly with iron hydroxides are dissolved and progressively transferred back to the channel with groundwater. Therefore the most intensive metal redistribution in sediment profiles can be observed when the floodplain height is low, water stagnation is long-lasting and also in the floodplains with coarse-grained deposits which favour the exchange of water between the channel and the floodplain. Metals can migrate either in a dissolved form or when they are associated with very fine particles with a diameter measured in µm. The migration is particularly effective in coarse-grained sediments.

Whereas it seems to be obvious that water is a medium transferring all pollutants between the floodplain and the channel, their transfer intensity is currently not quantifiable. Actually the deliberations on the relationship between the transferred amount of pollutants, flood frequency and its magnitude are rather more speculative than based on any direct measurements, as there is no scientist brave enough to measure the transfer of metals during a flood. Considering possible consequences of global warming and assuming the simplest, direct relationship between pollutant transfer in a floodplain - channel system and rainfalls, we may expect an increase of pollutant mobilization in many moderate- and high-latitude regions of the Northern Hemisphere, where, according to the IPCC Report, annual rainfalls will increase by 20-30%. This may be feasible, as we expect that rainfalls will increase during winter when bare soils are more prone to erosion and lack of transpiration is conducive to water infiltration. However, the processes of leaching are slow and the migration of pollutants down the soil profile does not mean that they enter surface waters immediately. Secondary river pollution is rather a result of many cycles of wetting, mobilization, desiccation and reprecipitation or readsorption lasting for dozens of years. Thus the identification of the effect of the increased rainfalls seems to be very difficult mostly because of extremely variable nature of hot spots within particular catchments. Possible effects of flooding will be mitigated by river stabilization in most industrial regions where bank erosion is minimized and pollutant transfer takes place only through dissolution.

Sediment erosion in many river reaches is the most effective way to release sediment-associated pollutants. The average annual rate of undercutting of river banks varies from 1m in case of small rivers to several hundred meters - in case of the largest ones. In dry or semi-dry climates where bare soils are not reinforced with plant roots, during one flood river channels can enlarge to as much as double or even three times their original size. In the subtropical regions of Southern Europe or North America a significant progress of desertification will be associated with rainfall reduction by as much as 40% as an effect of global warming [2]. Resultant sparse vegetation in alluvial river

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valleys will favour rapid sediment reworking and intensive downstream pollutant transport during short storm events, which today are typical of North Africa or Arizona. It seems that in a longer perspective these events could affect the quality of water in some reservoirs in southern regions. However, unequivocal identification of global warming effects on pollutant release may very well prove to be exceedingly difficult.

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