Water Knowledge #2

The impacts of Hydropower and Mining on Water Quality: an example from the Nam Ngum Catchment, Lao PDR

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RESEARCH PROGRAM ON Water, Land and Ecosystems

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Introduction: Water quality

Water quality can be thought of as a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. The water quality of rivers and lakes changes with the seasons and geographic areas. There is no single measure that constitutes 'good' water quality. For example, water suitable for drinking can be used for irrigation, but water used for irrigation may not be suitable for drinking. Typically, water quality is measured against standards for particular uses. Thus, water for drinking needs to be of very high quality, but water used for transport does not need to be of high quality at all.

Very poor quality water can be highly toxic to life. Water of this kind may be contaminated with chemicals, pollution and/or pathogens, rendering it poisonous to fish and other aquatic organisms; trees and other vegetation along river banks; and to humans who may come into contact with it or consume it. Industrial waste and sewerage and common sources of water contamination. Because all life depends on water, its quality is therefore essential to sustaining it.

Water quality is closely linked to the surrounding environment and land use. Unless it is in vapour form, water is never 'pure', and is affected by community uses such as agriculture, urban and industrial use, and recreation. The modification of natural stream flows by dams and weirs can also affect water quality. The weather, too, can have a major impact.

The water quality of rivers is generally best in the headwaters, where rainfall is often plentiful. As they travel into lowland areas, however, they encounter areas of high human activity, and quality typically deteriorates.

Rivers frequently act as conduits for pollutants by collecting and carrying wastewater from catchments to the ocean. Storm water can also carry heavy loads of nutrients, organic matter and pollutants into streams, rivers, lake, and, eventually, the ocean.

Evaluating water quality typically focuses on the following indicators:

- Biological: bacteria, algae.
- Physical: temperature, turbidity and clarity, colour, salinity, suspended and dissolved solids.
- Chemical: pH, dissolved oxygen, biological oxygen demand, nutrients (including nitrogen and phosphorus), organic and inorganic compounds (including toxins).
- Aesthetic: odours, taints, colour, and floating matter.
- Radioactive: alpha, beta and gamma radiation emitters.

Clearly, if the quality of water is too poor to sustain life, then it is a major problem. Water resources are of major environmental, social and economic value everyone, and if water quality becomes degraded this resource will lose its value. Water quality is important not only to protect public health: water provides ecosystem habitats, is used for farming, fishing and mining, and contributes to recreation and tourism. If water quality cannot be maintained, then the uses for which we need it cannot be met.

Water quality in the Mekong River

Existing data suggest the quality of the water in mainstream is good, even though the concentrations of suspended sediment are high - especially during the wet season. There are valid concerns over specific threats arising from current and future land use in the basin, but these have not been scientifically demonstrated. There is little evidence about specific threats to water quality coming from outside or within the basin. An exception is the Delta region; here, good-quality data raises concerns over problems arising from acidification, salinity and organic pollution (MRC, 2007).

The Nam Ngum River

The Nam Ngum is a tributary of the Mekong River in northern Lao PDR. The first dam on the tributary, the Nam Ngum 1, was completed in 1971. Since then, the catchment has experienced rapid, additional, development. A total of four hydropower dams now operate in Nam Ngum's catchment area and more are being built.

While the production of clean, green energy is important for the development of the country, hydropower dams may create problems with water quality and quantity. The sediments that are normally carried by the river water are trapped in dam reservoirs. This removal of clay and silt from the water can have positive and negative effects. The high dam walls also create a barrier for fish that would otherwise migrate upstream.

In addition to hydropower development, mining is also increasing in the area. Northern Lao PDR has rich, unexploited, mineral deposits. Mining nearly always has an impact in the quality of surface waters around mine sites. The type of pollution and its extent depends on many factors and is different for each individual mine. Possible problems can, for example, be increased suspended solids in nearby streams (which can carry pollutants and pathogens), high concentration of metals and chemicals and low pH (high acidity) in streams and ponds. Currently, there are 39 registered mines in the Nam Ngum catchment area and a number of unregistered, mostly artisanal miners.

While development in the catchment has been rapid, river management has not kept pace. Modelling of the river's hydrology and water quality are important tools to determine the environmental impacts of various projects.

The origin of Nam Ngum is located in the mountains in northeastern part of the catchment area, near a plateau of more than 1,000 meters above sea level. The river meanders through the Plain of Jars and through valleys between mountains. The valleys are ideal for the construction of hydropower dams, and this is where the largest reservoirs in the catchment are located. Currently operating dams on the river are the Nam Ngum 1, 2 and 5, while the Nam Ngum 3 is under construction. When the water is discharged from Nam Ngum 1, the oldest and last of the dam cascade, the river enters the Vientiane Plains, where it flows in a meandering pattern through the most densely populated area of the catchment. This is also where most of the agriculture and industry in the watershed is located. After passing the Ban Hai Bridge, the Nam Ngum releases its waters into the Mekong.

Upon entering the Vientiane Plains, nearly a kilometer lower than its source, the Nam Ngum is joined by Nam Lik and Nam Song, which carry water from the west. On the

Nam Lik, there is currently one operational dam, the Nam Lik 1-2; the Nam Lik 1 is presently under construction. In addition, on the Nam Song there is a diversion dam, which directs water away from this river and into the Nam Ngum 1's large reservoir.

Mining sites in the catchment are mostly located in the mountainous upper catchment area. The Vientiane Plain is home to only a few potassium mines, whereas lead, zinc, gold, copper and coal are being mined in the more northern part of the catchment. Additionally, quarries of barite and limestone exist in the watershed.

Water quality in the Nam Ngum Reservoirs

There is a network of five sampling stations distributed across the Nam Ngum 1 and 2 reservoirs. Both of these reservoirs suffer from 'stratification'. Here, layers of water of different temperatures form. The line between these two layers is called a 'thermocline', which forms a barrier between them, and prevents mixing. Mixing only occurs during the winter months, when the upper layer cools, and therefore comes close to or equals the temperature of the bottom layer. This lack of mixing causes oxygen to be reduced from the lower layer of water ('hypoxia'). The result is elevated concentrations of metals and phosphorus that are dissolved from the bottom sediments.

Similar conditions of stratification that exist in the Nam Ngum 1 and 2 reservoirs can be expected in the other, non-monitored, reservoirs of the watershed. Whether or not stratification occurs in reservoirs usually depends on the height of the dam wall. The higher the wall, the more water it can hold behind it. All dams in the Nam Ngum catchment have dam wall heights of more than is required for stratification to occur, except for the under-construction Nam Lik 1 (dam wall height of 30m), where it remains to be seen if stratification will occur.

The Nam Ngum 1 and 2 reservoirs also have large nutrient loads. These nutrients may be derived from chemical fertilisers washed into the reservoirs; or organic materials (mainly vegetation) either brought into the reservoir by its river; or left over from when the reservoir was being filled. Organisms (often algae or various bacteria) take advantage of this increased nutrition, and their populations can grow extremely fast, causing, for example, 'algal blooms'. Such blooms can use up a tremendous amount of oxygen from the water, causing hypoxia, which can then kill fish and other aquatic animals. Together, these conditions are known as 'euthrophication', and the Nam Ngum 1 and 2 reservoirs are considered to be eutrophic. The other reservoirs are possibly eutrophic as well due to the large amounts of organic material that was inundated when they were filled.

Water Quality in the Lower Nam Ngum

The un-dammed tributaries of Nam Ngum exhibit great variation in their stream flow between the dry and wet seasons (some may even dry up entirely in the dry season). Downstream of the Nam Ngum 1 Dam, a certain minimum level of water is assured because of water releases from the dam. The river runs with a low slope and a comparatively slow pace as compared to the more mountainous part of the river course.

The water discharged from Nam Ngum 1 is of good quality in all respects other than in dissolved oxygen concentration. Although the Nam Lik River brings water with higher oxygen content to the river, low oxygen concentrations were observed

throughout the lower Nam Ngum. Oxygen concentrations in the wet season were so low, that fish kills could be expected as a result. Oxygen conditions, however, improve downstream towards the outlet to the Mekong. The low oxygen concentration in river water is probably a result of the very low oxygen concentration of discharge water from Nam Ngum 1, but also of high nutrient load and its resultant oxygen demand in the river. The low oxygen concentration and high nutrient load in the river are the main challenges in this part of the river.

Impacts of Mining

The seasonality of the weather in Nam Ngum catchment area is a big challenge to the management of mining pollution. The biggest risk of most of mining operations is the creation of Acid Mine Drainage. It is produced when sulphide minerals come in contact with air and water. The wet season brings very high precipitation and challenges with water content in the waste piles. The dry season is also, however, problematic due to the very low quantity of water in unregulated streams that are often found near mining sites. The small amount of water means that the ability of streams to receive and neutralize the pollutants from mining sites is also low.

The location of the mining sites in relation to the reservoirs of the hydropower dams are important in respect of the transportation of the pollutants. Metals have an affinity to attach to the suspended clay and silt particles in the water (In general, metals stay in particulate form as long as pH remains near neutral and water is oxygenated). Because reservoirs trap sediment, any metals from mining discharge and site runoff accumulate in reservoirs and lakes. Since most of the mining operations are located in the upper part of the watershed, the cascade of reservoirs effectively 'protect' the lower Nam Ngum from pollution from mining operations. Available data, even if only from a few samples, support this interpretation. The main challenges for water quality in the lower Nam Ngum is potential pollution from urban and industrial areas and agricultural runoff.

In the upper part of the river basin, potential water quality problems exist in the Plain of Jars (ferrous mining), the reservoir of Nam Ngum 2 (gold, copper and silver mining in close proximity, ferrous mining), at the town of Kasi (lead mining) and towns of Keo Kouang and Pha Tang (lead-zinc mining). Currently, however, there are not a lot of data available to evaluate the true impact of mining operations on the environment in the Nam Ngum catchment area. Water quality problems exist, as reported by stakeholders and some indications (very high conductivity) of mining related pollution from a gold mine near Nam Ngum 2 have been documented.

Water Quality Monitoring Plan

The water quality study suggests a network of new monitoring stations to fill in the data gaps in the river basin. All data available for the study concentrates in the lower part of the catchment or in the reservoirs of NN1 and Nam Ngum 2. Virtually no other water quality data exists in the basin. Hydropower stations and some mines have environmental protection programs in place, but data exchange with them needs to be established. The suggested monitoring network includes 7 new stations in the upper Nam Ngum watershed. The locations were chosen for ease of access and representativeness. The stations are shown in the Figure 1 on the next page.

Figure 1. A suggestion of a Water Quality Monitoring Network based on the findings of the study. Yellow circles correspond to the established water quality stations of EMSP, red stars correspond to hydropower dams in the NNRB. Green boxes indicate new stations. Hydropower dams of Nam Lik 1, Nam Ngum 1 and Nam Ngum 2 not shown in the map. Base map of sub-basins from Idom (2013).

Current State of Modelling

Modelling of the water quality in the Nam Ngum river basin is being done with an Integrated Water Resources Management Model developed by Environmental Impact Assessment of Finland Ltd. The model is a distributed grid-based GIS application with a horizontal resolution of 1km.

At the present, the model includes land use and soil data and meteorological and hydrological data from January 1995 to December 2008. The model has been calibrated for hydrology and, with data from the Mekong River Commission (MRC), for total suspended solids and soluble and total phosphorus. Data of the current and under-construction reservoirs are included in the model. Locations of some of the main mining sites have been integrated. Development of scenarios to be modelled is underway. Development of the core GIS application is also continuing.

In its current state, the model may help in modelling of nutrients and suspended solid load especially in the lower Nam Ngum. Calibration for these variables have been made for only this part of the basin, because no data exists for the upper Nam Ngum. The suggested new water quality monitoring stations address this lack of data in the water shed.

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Water Knowledge

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