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Mongabay Series: Amazon Infrastructure

Brazil's Sinop Dam flouts environmental legislation (Commentary)

Commentary by **Philip M. Fearnside** on 1 March 2019

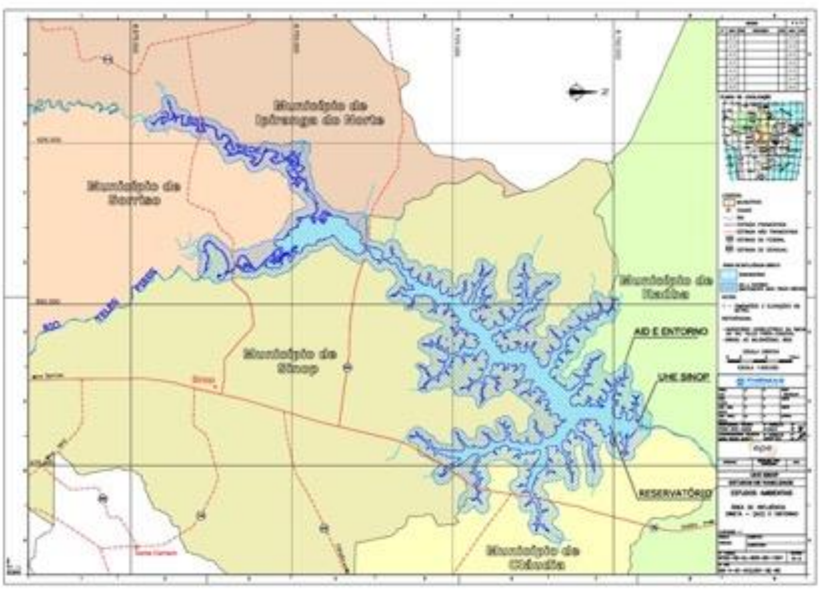
- *The reservoir of Brazil's Sinop Dam began filling in January 30, 2019, killing fish in the river below the dam. Oxygen levels in the water were minimal. Only 30 percent of the vegetation had been removed from the reservoir area, rather than the 100 percent required by law – a law that has been widely ignored.*
- *Permission to fill the reservoir was granted based on a consultant report commissioned by the power company with modeling results predicting good water quality in the portion of the reservoir from which water is released to the river.*
- *The fish dieoff at Sinop draws attention to the inadequacy of the licensing system, to the responsibility of paid consultants, and to the continuing efforts of Brazil's judicial system to return the country to legality in the environmental area.*
- *This post is a commentary. The views expressed are those of the author, not necessarily Mongabay.*

The Sinop Dam has become a critical test case — not only on the question of clearing reservoirs before filling, but also on the real effect of Brazil's environmental legislation as a whole. Legislation that is on the books but is, in practice, unenforced is a longstanding issue in Brazil, and it has come to a head with the Sinop Dam.

The Sinop hydroelectric dam, located on the Teles Pires River 70 kilometers (about 43 miles) north of the city of Sinop in Brazil's state of Mato Grosso, has just been built by the French multinational Electricité de France (EDF) through the Brazilian firm known as "Sinop Energia" (officially "Companhia Energética Sinop, SA"), in which EDF holds a 51-percent stake. The minority shareholders of Sinop Energia are Centrais Elétricas do Norte do Brasil S.A. (Eletronorte) and Companhia Hidro Elétrica do São Francisco S.A. (Chesf), with 24.5 percent each. Sinop Energia has the concession to operate the hydroelectric dam over the next 35 years.

The dam has an installed capacity of 401.9 MW and the reservoir, currently in the process of filling after the state environmental agency granted authorization on January 24, 2019, will have an area of 337.3 square kilometers (about 130 square miles). The authorization accepted the company's argument that it was necessary to remove only 30 percent of the vegetation of the future reservoir, not the 100 percent required by law. Reservoir filling began on January 30.

Location of Sinop, Mato Grosso in Brazil. Source: Wikipedia.



The reservoir of the Sinop hydroelectric project. Source: EPE & Themag Engenharia (2010. Vol. 1, Ilustr.1.1 SIN-V-61-612.001-DE-R0).

Fish die-off

Shortly after the reservoir began filling, fish mortality in the river downstream of the dam shocked local residents. The quantity of dead fish in the first 27 kilometers of river below the dam was estimated at 13 tons. Of this total, 5 tons were collected for burial by the hydropower company and the remainder, estimated at 8 tons, was left in the river.

Dead fish collected by the hydropower company on the Teles Pires River below the Sinop Dam on February 7, 2019 during the filling phase of the reservoir. Photo Credit: N. Flausino Júnior.

Dead fish on the Teles Pires River below the Sinop Dam on February 7, 2019 during the filling phase of the reservoir. Photo Credit: N. Flausino Júnior.

The hydroelectric company submitted modeling results made by consultants indicating that the oxygen content in the main body of the reservoir (the part from which the water is released downstream by the spillways) would be above the minimum standard of 5-milligrams-per-liter specified by Resolution 357/2005 of the National Council for the Environment (CONAMA) (see here (pp. 130-197) and here).

However, the actual events were different from the modeled results: On February 6, the water being released from the reservoir contained only a tiny amount of oxygen. Three measurements made by the Cuiabá office of Politec (Perícia Oficial e Identificação Técnica) found levels of 0.13, 1.32, and 1.56 milligrams of dissolved oxygen per liter — that is, an average of only 1.00 milligram per liter. Another measurement on the same day, made by the Sinop office of Politec, found 1.96 milligrams per liter.

Measurements by Politec indicating levels of 0.13, 1.32 and 1.56 milligrams of dissolved oxygen per liter in the water leaving the dam on February 6, 2019. Photo Credit: Politec.

With rare exceptions, fish cannot survive in water with so little oxygen. Oxygen demand depends on the water temperature: the warmer the water, the higher the oxygen level that fish need. When measurements of oxygen levels were made at the outlet of the reservoir, the water temperature was 28.3 °C, a relatively high temperature, implying a high requirement of oxygen by fish. The requirements of the fish species in the Teles Pires River were certainly much higher than the levels found in the water. For example, as a general rule, 5 milligrams of dissolved oxygen per liter is considered necessary for tropical fish in fish farming.

To make matters worse, there was a high sediment load in the water below the dam, which was attributed to the turbulence at the outlet of the spillways having mobilized sediments from the river bed. However, the fish would have died under the observed oxygen conditions even without the additional sediments.

The Mato Grosso Environment Secretariat (SEMA) has fined Sinop Energy R$50 million (US$13 million) for the fish die-off, but insists that the cause is limited to the excess sediments and is therefore due to a management error by the company in the way it opened the spillway gates. However, a public civil suit initiated by the Public Ministry of the State of Mato Grosso accuses not only Sinop Energia but also the consulting firm it hired for a study modeling water quality as well as SEMA for allowing the dam to be filled based on the study without adequately clearing the reservoir; the case has been transferred from the state to the federal courts.

SEMA, which had authorized filling the reservoir without suppressing all of the vegetation, expressed "profound indignation" about mortality being considered an effect of the low oxygen content that, in turn, was aggravated by the lack of removal of vegetation. SEMA claimed that the mortality was due only to the excess sediment: "the event has no relation to the vegetation suppression for reservoir formation. ... The fish mortality was caused by the change in water turbidity due to the sediments downstream of the dam." But the modeling study that was used as the basis for the permit to fill the reservoir with only 30 percent of the vegetation suppressed was done precisely to show the relation between the percentage of suppressed vegetation and the oxygen content, and showed that greater suppression improves the oxygen content in the water – the oxygen content being better with 30 percent removal than it would have been with 0 percent removal.

Mortality of fish downstream of dams has been frequent in recent Amazonian history, such as at the Estreito Dam on the Tocantins River in 2011 and the Teles Pires Dam in 2014-2015. There was mortality at the Colíder Dam on the Teles Pires River when the reservoir was filled, although other causes were also alleged. There was also mortality during construction in the case of Colíder before the filling of the reservoir began.

Worldwide, dams in a disastrous series of hydroelectric projects in the Mekong River basin in Southeast Asia are best known for their impacts on fisheries and consequent sacrifice of the livelihoods of local residents. The Nam Theun 2 (NT2) Dam in Laos is the best known; this dam, like Sinop, is also a project of Electricité de France (EDF). At NT2 "according to a source close to the project, at the time biomass clearance was pending, NTPC [Nam Theun 2 Power Company] staff and Électricité de France (EdF), the largest NTPC shareholder, provided misleading information to the GoL's [Government of Laos's] Science, Technology and Environment Agency in order to avoid the time of expense of full clearance," as Hunt et al. write in an essay published in the 2018 book *Dead in the Water: Global Lessons from the World Bank's Model Hydropower Project in Laos*.

The licensing process

The Sinop Dam is being licensed by the Mato Grosso state government rather than by Brazil's federal environmental agency, IBAMA (Instituto Brasileiro do Meio Ambiente dos Recursos Naturais Renováveis). This is under the policy imposed by Complementary Law 140/2011, giving states licensing responsibility for dams with reservoirs entirely within the state's borders. When this law came into effect in 2011, the licensing of the Sinop Dam was already being carried out by the state agency, an arrangement that was being challenged by the Public Ministry of the State of Mato Grosso (MPE-MT) due to the regional impact of the dam complex of which Sinop is part.

The change in the licensing of many of the dams in the Amazon from the federal to the state level occurred at a time when one of the top priorities of the government, and especially of then-President Dilma Rousseff, was the rapid approval of the controversial Belo Monte Dam (see here and here), but the government lost a legal battle in an attempt to transfer the licensing of this dam to the state sphere. The 2011 complementary law changing the competence for licensing many of the dams represents a setback because state environmental bodies are generally less rigorous and more subject to political interference than is the federal agency. (However, federal licensing is currently undergoing an abrupt process of “flexibilization”). In addition, the history of federal licensing has shown that the IBAMA system is also inadequate and easily circumvented in the case of recent dams such as Santo Antônio, Jirau, Teles Pires, Belo Monte, and São Manoel (see here, here, here, here, here, and here). The licensing of the Sinop Dam, being one of the first performed by a state agency for a large Amazonian hydroelectric project, represents an important test of the current licensing modality for these projects.

Legislation on removal of vegetation

Law 3.824/60 makes it “compulsory to clear and consequently clean the hydraulic basins of farm ponds, dams or artificial lakes.” This law allows leaving vegetation that is necessary for the “life of fish,” but there is no mention in the law of the obligation of removing the vegetation to be conditioned on modeling studies showing that the water quality would be below some level defined as acceptable. The requirement of a minimum level of dissolved oxygen is a demand that is additional to having the vegetation removed. This author does not know of any subsequent changes to the requirement in Law 3.824/60, and the documents submitted by the electricity company proposing to leave most of the forest without removal do not mention any such alteration to support the proposal.

Although it is obvious that a number of Amazonian dams have been built without observing the law requiring vegetation removal, the country is moving to return to legality in this regard.

Effects of dead forest in reservoirs

Death of fish due to lack of oxygen

The decomposition of litter, leaves, and other easily degraded organic material leads to a decrease of the oxygen dissolved in the water, especially during the reservoir filling. This can cause fish mortality, especially by the release of this water through the turbines and spillways, killing fish downstream of the dam.

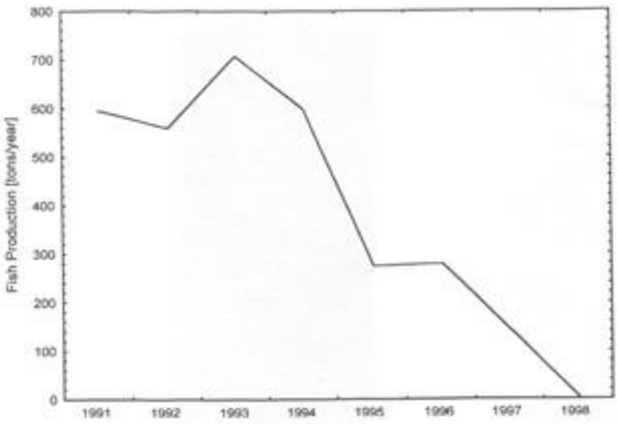
Mortality below the Tucuruí Dam in 1984 is a classic example. The fisheries losses in the Tocantins River caused by the Tucuruí Dam were not limited to the initial mortality, but lasted permanently with a large reduction in fish production in the river, mainly downstream (but also upstream) of the dam, and this loss was never offset by fish production in the reservoir.

Exaggerated benefits of dead wood as a shelter for fish

There is reason to doubt that it is necessary to leave standing trees for the benefit of fish in Amazonian reservoirs. The consultant report on fish commissioned by Sinop Energia (see here, pp. 129-197) highlights the role of dead trees left in the reservoir as shelters to protect small fish from predators. Although dead wood has this role in certain situations, the advantage in the case of a graveyard of standing dead trees in a reservoir such as that of the Sinop Dam would not be so great. Generally, this shelter is provided by trunks and branches that lie horizontally on the bottom, as in the case of the 2011 study by Sass et al. on a lake in the United States that was used as an illustration in the consultant report (see here, p. 154). In the case of vertical trunks of standing trees, as in the Sinop reservoir, this role would be much smaller.

Also, it is probable that the Sinop reservoir will be stratified thermally, with water without oxygen at the bottom. This would result in the fish not being able to take advantage of any branches and trunks lying horizontally on the bottom of the lake. Fish that stay at the bottom, such as catfish, do poorly in reservoirs, and the species that predominate stay close to the surface, such as tucunaré (*Cichla ocellaris* and *C. Temensis*). This is clear in Amazonian storage reservoirs, such as Tucuruí and Balbina. The consultant report on fish (see here, pp. 129-197) presents the example of the Mourão reservoir, in the Paraná River basin, where there are more fish in a part of this reservoir with dead trees than in a part without dead trees. The consultant report (see here, p. 152) suggests that a major factor would be the availability of periphyton, that is, a slime that grows on the surface of the submerged trunks and is consumed by some species of fish. Periphyton does grow on submerged logs, as in the case of the Balbina reservoir. Although periphyton utilization by fish does occur, this factor may play a modest role in maintaining fish stocks in a reservoir.

The case of Balbina illustrates how the presence of a graveyard of dead trees in the reservoir does not guarantee the production of fish. The Balbina reservoir was filled between October 1987 and March 1989, creating what may be the largest graveyard of dead trees in the world. Even so, fish production has always been extremely low. Production collapsed, and the reservoir had to be closed to commercial fishing beginning in 1997.



Commercial fish landings at the Balbina reservoir. The reservoir had to be closed to commercial fishing beginning in 1997, despite having almost 3000 km^2 of standing dead trees. Source: Weisser (2001).

Greenhouse gases

Amazonian dams can emit fairly large amounts of greenhouse gases, including methane (CH_4), which has a much larger impact on global warming per ton than carbon dioxide (CO_2). Hydroelectric dams have large emissions in the first few years after reservoir filling, and methane also has its global-warming impact concentrated in the first few years after it is emitted. These two facts make tropical hydroelectric dams especially damaging to ongoing efforts to control global warming, which needs to be contained in the next few years to avoid much greater damage.

Especially in storage dams, such as Tucuruí and Sinop, water in the reservoir tends to stratify into layers that are separated by temperature. There is a superficial layer 2-10 meters thick (epilimnion) with warmer water that, because it is in contact with the air, contains dissolved oxygen. A partition, called a thermocline, separates this layer from the deeper layer (the hypolimnion), which has water that is cold and does not mix with the surface water. In this deep water, the first decomposition of plant organic matter and of labile carbon in the soil forms CO_2, thus removing the oxygen from the water. After the oxygen is used up, decomposition necessarily must end with the carbon in the form of methane, thus enriching the water with this greenhouse gas.

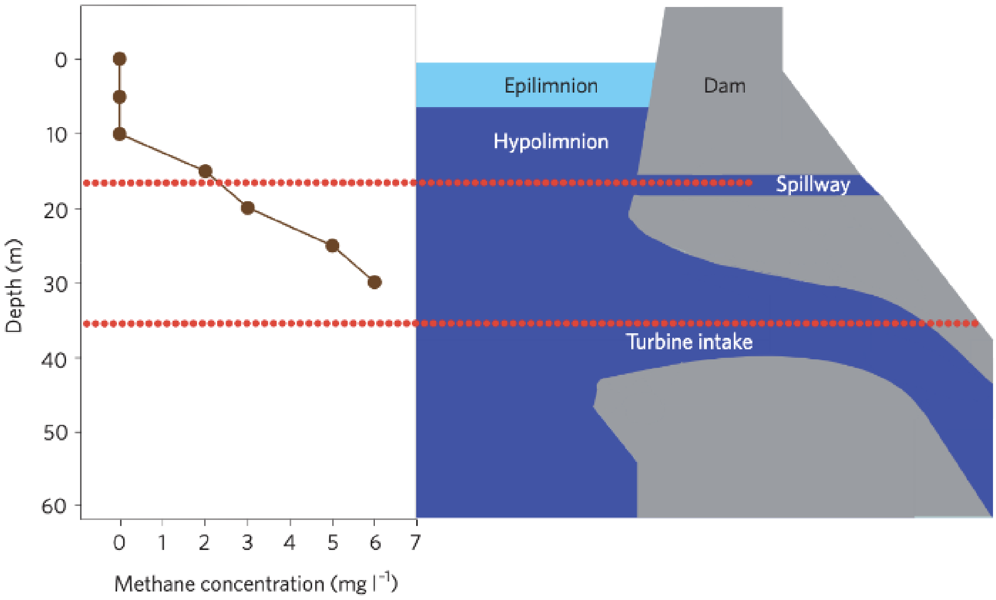


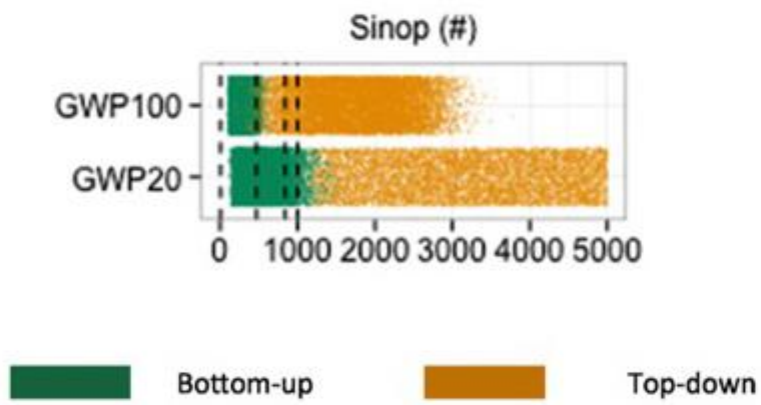
Diagram of the Tucuruí Dam, with methane (CH4) in the water indicated in the graph at the left. Water passing through the spillways and turbines is taken from depths with high methane concentrations. This methane is released into the air below the dam. Source: Fearnside & Pueyo (2012).

The Sinop Dam has spillways and water intakes for turbines located at depths that imply high levels of methane.

The Sinop Dam seen from the upstream side with the river at its natural level without a dam. The three spillway gates, and the two sets of three stop-logs at the intakes of the two turbines, are all located at depths that would draw water below the level of the thermocline dividing the water column in a stratified reservoir, generally at 2-10 meters depth. The water at the depths of the intakes at the Sinop Dam would have high methane content, which would be released to the air when the water emerges below the dam and is exposed to a pressure of only one atmosphere. Photo Credit: P.M. Fearnside, November 13, 2018.

The Sinop Dam is expected to have very high emissions of greenhouse gases, as shown by the 2015 study published by de Faria et al. in the journal Environmental Research Letters. This study showed that, even considering the global warming potential (GWP) of methane for 100 years, “most of the simulated emission factors for Cachoeira dos Patos, Cachoeira do Caí and Sinop are higher than those for thermal power plants” (see Faria et al. (2015), p. 8). This difference is even greater when considering the GWP for 20 years, which is the relevant value for complying with the global temperature limit “well below 2 °C above the pre-industrial mean” of the Paris Climate Agreement. After all, we do not have 100 years to control global warming.

The Sinop Dam was the record holder among all of the 18 Amazonian dams analyzed by de Faria et al., and these estimates are conservative because they underestimate part of the emission below the dams. As is evident in the figure below, the impact of the Sinop Dam may be much greater than fossil fuels, even when the 100-year GWP favored by the hydropower industry is used for the comparison.



Emission factors (kg CO_2-eq / MWh) generated by “bottom-up” and “top-down” simulations, considering the global warming potential (GWP) of methane for 100 years (value = 34) and for 20 years (value = 86). The points in green or orange indicate the result of each of the 10,000 simulations performed. The vertical dashed lines indicate the median global values that would be emitted to generate the same energy by the following options: hydroelectric (4), natural gas (470), oil (840) and coal (1000) according to Moomaw et al. (2012), p. 982 (see: here). Source: de Faria et al. (2015).

One of the important factors in the emission of greenhouse gases from hydroelectric dams is the magnitude of the variation in the water level in the reservoir. When the water level is lowered to take advantage of this volume to generate energy during the low-flow season, a mud flat (the drawdown zone) forms around the reservoir. Non-woody vegetation grows in this area, and when the water level rises again, these plants, which are rooted in the bottom, decompose rapidly in an oxygen-free environment, producing methane. When they are growing, plants remove carbon from the atmosphere in the form of CO_2, but this carbon then returns to the atmosphere in the form of methane, which has far more impact than CO_2 on global warming. Thus, the reservoir becomes a "methane factory," transforming CO_2 into CH_4, and this process is sustained throughout the life of the dam.

At a meeting on November 14, 2018 with Sinop Energia employees at the company headquarters in the city of Sinop, this author obtained answers on the reservoir management plans. The water level must be maintained between the maximum normal and minimum operating levels, with water being drawn for power generation. However, when the water level is lowered to the minimum normal operating level, water would continue to be withdrawn from the reservoir to maintain the required sanitary flow downstream. Thus, the level in the reservoir could be dropped to a much lower level, thereby opening a larger drawdown zone and increasing methane generation.

It should be remembered that, in addition to dropping to a lower level to maintain the sanitary flow, in cases of extreme drought the water level can be drawn down even more than planned, as happened in Balbina and Samuel during the 1997-98 El Niño drought. In this case, the bottom of the reservoir was exposed in large areas with dead trees, resulting in fires in these two reservoirs. It is also important to remember that predicted climate change implies a substantial reduction in the flow of the Teles Pires River.

At our meeting with employees at the company's headquarters in Sinop on November 14, this author asked if the company was planning to have a project for obtaining carbon credit. We were informed that the possibility of preparing such a project in the future had been discussed in the company, but that there would only be a decision on this after the hydropower plant is in operation. This shows that the dam does not rely on carbon credit to justify its construction in financial terms, which is the critical issue with respect to carbon "additionality" and consequent eligibility for credit under the Climate Convention.

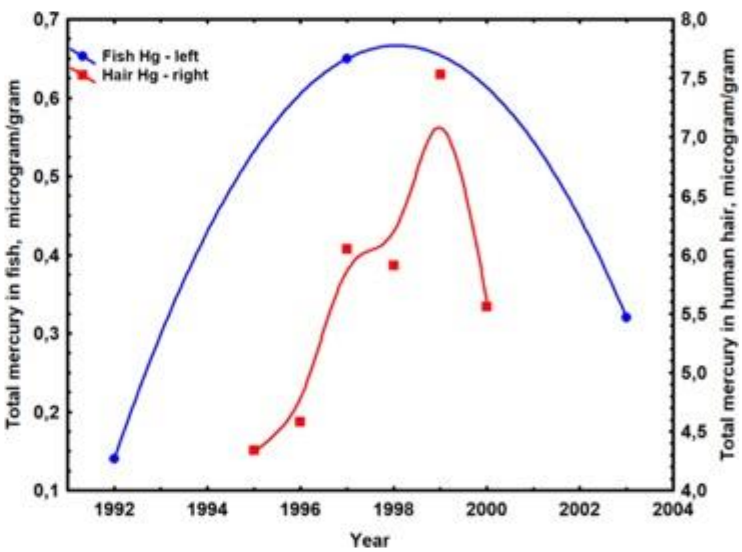
Methylization of mercury

An impact related to the emission of methane is the methylization of mercury. This process occurs in oxygen-free environments, such as in sediments at the bottom of a reservoir. Chemically, the "methylization" process — that is, the addition of a methyl group (CH_3), in this case binding to a mercury atom (Hg) — is almost identical to the process of "methanogenesis" — that is, the formation of methane (CH_4). The methyl form of mercury is highly toxic to animals, including humans.

Elemental (non-poisonous) mercury is present in Amazonian soils even without additions due to the gold-mining activity. Because Amazonian soils are millions of years old, they have accumulated mercury received in the rain over this time. Whenever there is a volcanic eruption in the world, mercury is released into the atmosphere, where it spreads throughout the planet and is deposited by rain.

The critical step is to provide environments for methylization. Even in reservoirs without any gold-mining activity, such as Balbina, the mercury content is high. After methylization, the mercury passes through plankton and fish, concentrating by a factor of approximately ten at each link in the food chain. The mercury content is high in predatory fish, as in the tucunarés that usually dominate the catches in Amazonian reservoirs. When these fish are consumed by humans, the content goes up even more. Animals, including humans, have no means of removing mercury, which then accumulates in their bodies throughout life.

Residents on the banks of the Tucuruí reservoir have high levels of mercury in their hair. This is also the case at the Balbina Dam (see here, here, and here), and is a concern at the Samuel Dam. Mercury causes very serious impacts on human health, although it can take decades of accumulation to reach critical levels. When the accumulated mercury reaches this level, the result is tragic and irreversible, as shown by tragedies like the one at Minamata in Japan (see here, here, here, and here).



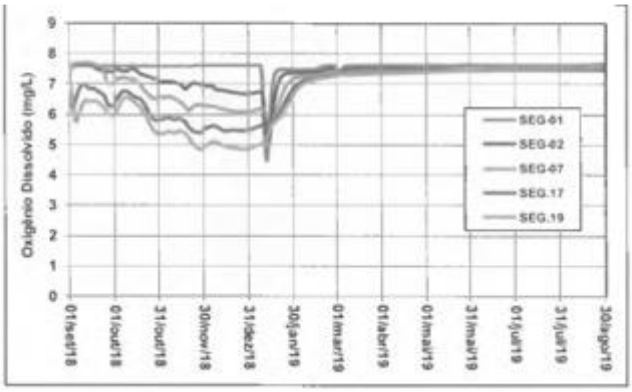
Historical variation of the mercury levels at the Balbina reservoir after damming. The blue line indicates the concentration in fish (tucunaré: Cichla spp.) And the red line indicates the concentration in the hair of residents who eat fish. The abrupt drop in the level in human hair after 1999 is explained by the closure of the reservoir to commercial fishing in 1997. Source: Forsberg et al. (2017), based on data from Weisser (2001) for the years 1992-2000 and B.R. Forsberg (unpublished) for 2003.

The role of consultants

On January 24, 2019, the Mato Grosso State Secretariat of the Environment (SEMA) authorized filling the Sinop reservoir on the basis of consultant reports submitted by the power company. The very next day the world's attention was captured by a major disaster elsewhere in Brazil: a mine-tailings dam ruptured in Brumadinho, Minas Gerais, killing over 300 people, in addition to causing dramatic environmental destruction. The Brumadinho disaster has raised the long-untouched issue of the responsibility of third-party consultants. The consulting engineers who had attested to the dam's safety were arrested and jailed under a federal court order, and a few days later another court order resulted in their release to await legal proceedings.

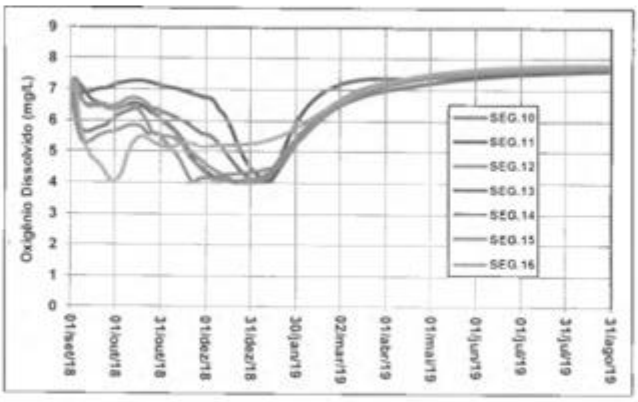
In the case of the Sinop Dam, as is common practice in hydropower development and in other industries (including mining), the hydropower company contracted consulting firms, which in turn contracted technical experts who, coincidentally, arrived at conclusions that the project proponents presumably wanted to hear. Fisheries consultants concluded (see here, pp. 129-197) that leaving the dead trees in the reservoir was needed in order to provide hiding places for fish to escape from predators. Modeling consultants concluded that only 30 percent (rather than 100 percent) of the vegetation in the reservoir area needed to be removed in order to guarantee that oxygen levels in the water would always be above 4 milligrams of dissolved oxygen per liter, including during the reservoir-filling period, and that after the first five months the oxygen levels would be above the minimum standard of 5-milligrams-per-liter set by Resolution n° 357/2005 of the National Council on the Environment (CONAMA) (see here (pp. 130-197) and here).

The modeling results for the main body of the Sinop reservoir, which is the part from which water is drawn by the turbines and spillways and passed downstream of the dam, indicate oxygen levels above 5 milligrams/liter throughout the length of the reservoir during the filling process, with the exception of a momentary drop to 4.5 milligrams/liter in one segment of the river. The fact that on February 6 the water released from the reservoir contained less than 2 milligrams of dissolved oxygen per liter indicates that this prediction was wrong.



Modeled results for oxygen concentrations in the main body of the Sinop reservoir from a consultant report presented in the hydropower company's request for authorization to clear only 30% of the reservoir. Source: CES (2016), p. 90, Graph 9.1.2-1).

In the most problematic tributary entering the reservoir, the Rio Roquete, oxygen levels were predicted to be above 4 milligrams/liter in all stretches of this flooded branch, and declines in some of the stretches stopped sharply at the 4-milligram/liter limit. The consultant report contains the caveat that the modeled results are averages and that concentrations could vary below these means "in specific locations in the reservoir;" however, these specific locations are described as being in the flooded tributaries (see here, p. 89) — that is, not in the main body of the reservoir from which the water was being drawn that killed the fish downstream.



Modeled results for oxygen concentrations in the flooded Rio Roquete (the most problematic tributary entering the Sinop reservoir) from a consultant report presented in the hydropower company's request for authorization to clear only 30% of the reservoir. Source: CES (2016), p. 90, Graph 9.1.2-1)

Shining light on the industry of paid consulting that underpins a vast array of environmentally and socially damaging developments is only a first needed step. Changes are necessary in the decision-making and licensing systems in order to eliminate inherent conflicts of interest.

Leaving trees in a reservoir such as that of the Sinop Dam contributes to various environmental impacts, such as the emission of greenhouse gases, especially methane, and the transformation of mercury into its poisonous form (methyl mercury). The benefits of providing shelter and food for fish, alleged as reasons for leaving the dead trees, are exaggerated. Legislation is clear in requiring total removal of vegetation, and standards regarding the minimum water quality (in terms of oxygen content) are additional to the requirement to remove vegetation, not providing a substitute for this removal.

Although there is a history of ignoring the legislation in question, the ongoing process in Brazil to return to legality in the environmental area is very important for the future of the country. It would be a sad setback if disregarding Law 3.824/60 were to be allowed in this emblematic case.

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