IMPACTS OF LATERITE MINING OF NICKEL AND IRON ORES ON WATERSHEDS

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The Philippine Mining Law of 1995 allows a maximum area for mining of 1,600 hectares in any one province. This implies that anywhere in the Philippines where laterite mining is conducted that may cover 1,600 hectares or more, this will be inside or traversing one or more watersheds. This paper discusses the impacts of laterite mining (either open pit, contour mining or strip mining) on the hydrologic, hydraulic and ecologic processes of watershed and river systems. These include: overland flow processes; watershed landform and river network; bays, estuaries or coastal areas, transport of metals on laterite particles transported by wind into the watershed, rivers, bays and estuaries; and effects of wind and flood regimes on the geochemistry of nickel. Mining such areas will significantly or drastically modify the watershed, which can adversely affect the watershed's ecosystem functions and services. These impacts are especially experienced and realized during the active mining period since beyond that, there may be some possible recovery, self-organization, and rehabilitation that the physical system undergoes. Further, these have long term implications on people's livelihood and health and the country's sustainable development, in general. Thus, there is a need to review the present policies and craft more responsible mining policies, which should involve all stakeholders.

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PREMISE

Open pit, contour or strip mining of laterites involves removing 1 to 2 meters of topsoil to be able to extract the laterite, limonite and saprolite deposits which occupy the soil strata from 3 to 25 meters below the ground. The laterite zone (about 2 to 4 meters thick) contains less than 1 percent nickel, while the limonite and saprolite zones (each about 8 to 11 meters thick) contain iron and as much as 1.8 percent nickel. The limonites may have 20 percent or more iron compared to the saprolites. Most of the nickel and iron ores are exported to countries like China to extract and refine nickel, iron, chromium, cobalt and even some high valued metals such as platinum, vanadium, and titanium. There are 18 nickel mines in the Philippines but only one nickel processing plant located in Palawan. Although the high valued minerals like platinum and titanium are found in minute quantities, we do not include their price when we export the ores. In fact, mining companies are taxed only on the primary metal that they declare, in the case of laterites, it is nickel.

In the 1995 Philippine Mining Law, the maximum allowable areas for exploration permits referred to as MPSA (Mining Production Sharing Agreement) onshore or inland is 1,600 hectares (in any one province) or 3,200 hectares (in the entire Philippines) for individuals and 16,000 hectares (in any one province) and 32,000 hectares (in the entire Philippines) for partnerships, corporations, cooperatives, or associations. For actual mining operations, the maximum allowable areas for mineral agreement onshore are as follows: 800 hectares (in any one province) and 1,600 hectares (in the entire Philippines) for individuals, and 8,000 hectares (in any one province) and 16,000 hectares (in the entire Philippines) for partnerships, cooperatives, associations, or corporations.

The implication here is that anywhere in the Philippines where laterite mining is conducted that may cover 1,600 hectares or more, it is going to be inside or traversing one or more watersheds. For instance, a watershed with a drainage area of 1,000 hectares or 10 km^2, once stripped to about 15 to 25 meters of top soil including the nickel and iron ore deposits, will have entirely transformed fluvial geomorphologic properties with modified overland flow properties, slope characteristics, land use cover, river network configuration, and subsequently different space-time water and sediment flow dynamics as well as river ecological functions.

A watershed, once stripped to about 20 to 25 meters (about 6 to 8 stories high building) of soil including its nickel and iron ore deposits, will have an entirely modified land cover and vegetation, obliterated gullies and streams with drastically transformed river flows and water quality, and increased sediment loads that will eventually reach and result in highly sediment-laden, murky coastal waters. Consequently, these affect the ecological integrity of the river and coastal systems and its ability to deliver important ecosystems services to support fish and fauna including people's livelihood. These impacts are especially experienced and realized during active mining period. The mining companies are required to rehabilitate the watershed after mining operations but the question is how realistic and how long can you restore the watershed to its natural, hydrologically, and ecologically functioning system and its ability to provide ecosystem services.

IMPACTS ON WATERSHED PROCESSES

The following discusses the impacts of laterite mining (through open pit, contour or strip mining) on the hydrologic, hydraulic, and ecologic processes of watershed and river systems. These impacts are especially experienced and realized during the active mining period since beyond that there may be some possible recovery or self-organization that the physical system undergoes.

Effects on Overland Flow

The major operation in laterite mining is stripping of upper soil which includes removal of forest cover or vegetal cover. The effects on overland flow processes after stripping the soil are as follows:

- Reduced interception capacity of forest and vegetal thus increasing direct runoff.
- Decreased infiltration rates since remaining soil is almost bedrock or hard pan resulting in increased direct surface runoff.
- Enhance soil erosion and transportation of sediments including metals attached to sediments from overland flow planes to the rivers and eventually into bays and estuaries.

Effects on Watershed Landform and River Network

- Stripping the upper 10 to 20 meters of soil definitely modifies the overland flow slopes and micro drainage landform by obliterating the natural rills, gullies and small channels of the watershed.
- Modification of this landform consequently changes the flow distribution and timing of overland flow production which could either result in lower flow velocities (due to decreasing slopes) or accelerate flow velocities (due to channel shortened channels).
- Consequently, sediment transport (erosion or deposition) could either be enhanced or reduced. For instance, in portions where the overland flow channels are shortened, there will be erosion upstream and deposition of sediments downstream. In the higher order streams (large channels) in particular, the effect is even more pronounced such that deep incised channels can ensue upstream (thus prone to bank collapse) and massive deposition downstream (creating flooding problem due to swallowing of the river bed).

Effects on Bays, Estuaries or Coastal Areas

The increased amount of sediment loads from the watersheds and rivers that eventually reaches the bays and estuaries will definitely have several and varying effects in the coastal areas (i.e., bays and estuaries).

- One is the change in littoral drift patterns (i.e., erosion and deposition cycles) in the coastal areas due to the increased sediment load distinct from the original, natural sediment regimes. Consequently, the coastal landform (especially mangrove zones) could change that can have adverse ecological impacts due to modified sediment accumulation and flow distribution patterns in the coastal area.
- The sediment mineralogy and geochemistry that reaches coastal areas can likewise be drastically different and this includes metals, since the sediment loads are no longer from the usual top soil. The new sediment properties can be a source of pollution to the marine resources.

Transport of Metals on Laterite Particles Transported by Wind into the Watershed, Rivers, Bays and Estuaries

- The mining operations expose and produce particulate matter (i.e., dust particles) light enough to be suspended in the air. These particulate metals bound to the lateritic suspended particulate matter can be carried or transported by the winds into the watersheds and to read watersheds and nearby rural and urban areas including bays and estuaries.
- During the dry season with seasonally strong winds, these laterite-suspended particulates may be present at high concentrations and certainly pose air pollution problems. When rainy season comes, these suspended particulates can precipitate into bodies of water to become suspended or wash load in the river, lakes, and estuaries.

Effects of Wind and Flood Regimes on the Geochemistry of Nickel

- During the dry season, the concentrations of metal present in the water of bays and estuaries can be principally governed by the strong *amihan* (northeast monsoon) or *habagat* (southwest monsoon) winds.
- During the wet season, the metal levels in the water of bays and estuaries are mainly due to floodwaters from watersheds into the bays and estuaries.
- The driving forces behind the resuspension of particles can be attributed to the shallow depths present in the bay, the intense mixing, and the resulting aggregation mechanisms. This resuspension phenomenon is responsible for the distribution of dissolved and particulate metals in the water column.
- During periods of intense resuspension, it is observed that the adsorption of nickel (Ni) onto the sediment particles is enhanced and

reversely, the concentration of dissolved nickel increases during the sedimentation (deposition) phase as a result of calm meteorological and hydrodynamic conditions.

- Redissolution of Ni seemed to be higher during the period of resuspension of the particles richer in carbonates.
- In terms of environmental impact, the amounts of lateritic particles that have accumulated over time can modify the geochemical equilibriums in the water column, particularly in shallow and sheltered bays.
- Reducing the concentration of suspended particulate matter injected into the bays and estuaries is essential to limit the effects of the bio-accumulation in exposed marine organisms.

POLICY QUESTIONS AND RECOMMENDATIONS

Watersheds can be considered environmentally sensitive or ecologically of interest.

- In this case, the fear here is that mining these areas will significantly or drastically modify the watershed to adversely affect the watershed's ecosystem functions or services.

When the mining company had already extracted all the iron or nickel ore in the area, the mining company is supposed to rehabilitate or restore the watershed.

- Again, the question here is how can you realistically restore the watershed to bring back to its ability to provide ecosystem services when geomorphologic, hydraulic, and flow-sediment dynamics had been significantly modified.

The 1995 Mining Law defines the areas that are not open to mining which include: watersheds with old growth forest, areas near dams, reservoirs and other infrastructure projects, proclaimed forest reserves, national parks, and especially declared environmentally sensitive or critical watersheds. As defined in the Forestry Code, a watershed can only be declared *critical* if it provides hydropower and water supply. Thus, this definition completely ignores other ecosystem services of a watershed such as being a source of biodiversity, food, and nutrients, and playing an important role in water quality and flood control, among others.

- Thus, considering the multi-faceted roles of a watershed, this legalistic definition of a critical watershed may be too limiting and needs to be reviewed.

Thus, it is high time to seriously review the mining policies and the processes for securing mining permits, keeping in mind two questions.

- First, how can the ecological integrity of the watershed be sustained and ensured during and after the mining period?
- Second, what are the present and future benefits to all sectors of society versus the costs of environmental degradation and restoration?

This review, which has long-term implications on people's livelihood and the country's sustainable development, in general, should engage all stakeholders and involve them in the crafting of more responsive mining policies.

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