

Vanillin-Based Photocurable Anticorrosion Coatings Reinforced with Nanoclays

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Extractivism and its socio-environmental impact in South America. Overview of the “lithium triangle”

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Abstract—This article aims to give an overview of the socio-environmental impacts of the extractive process in South America. Half of all lithium reserves on the planet are located between Chile, Argentina and Bolivia, the so-called “lithium triangle”. Lands where the transformation process is often opposed by local organizations that attempt a dialectic of negotiation/resistance of a territory harming communities and damaging fragile ecosystems. The exploitation of local water resources caused by the mining process has a strong impact on ancestral territories. Water resources are contaminated, diverted and consumed by the lithium mining process causing conflicts and exacerbating the long process of expropriation of local communities. The displacement of populations, forced by the intensive development of mining activities, leaves the population in a very high position of vulnerability. In these territories, the objective must be (1) to adapt local infrastructures to the new technological needs of the sector (eg. green technologies), (2) to focus on projects that benefit the local community both socially and environmentally. — *geopolitics, extractivism, lithium, socio-environmental impacts, local communities.*

Resumen—Este artículo se propone dar una visión general de los impactos socioambientales del proceso extractivo en Sudamérica. La mitad de las reservas de litio del planeta se encuentran entre Chile, Argentina y Bolivia, el llamado “triángulo del litio”. Se trata de territorios en los que el proceso de transformación suele contar con la oposición de organizaciones locales en una dialéctica de negociación/resistencia para un territorio que perjudica a las comunidades y daña los frágiles ecosistemas. La explotación de los recursos hídricos locales provocada por el proceso minero tiene un fuerte impacto en los territorios ancestrales. Los recursos hídricos son contaminados, desviados y consumidos por el proceso minero del litio provocando conflictos y agravando el largo proceso de expropiación de las comunidades locales. El desplazamiento de las poblaciones, forzado por el desarrollo intensivo de las actividades mineras, deja a la población en una posición de vulnerabilidad muy elevada. En estos territorios, el objetivo debe ser (1) adaptar las infraestructuras locales a las nuevas necesidades tecnológicas del sector (por ejemplo, tecnologías verdes), (2) centrarse en proyectos que beneficien a la comunidad local tanto social como ambientalmente. — *geopolítica, extractivismo, litio, impactos socioambientales, comunidades locales.*

For the purpose of this essay, a qualitative research approach has been used to better understand the local perspective and insights into the problem. That helped us to develop ideas on current scenario and the

socio-environmental impacts of the extraction process (also for potential future quantitative research). The qualitative research methodologies included a review of the available scientific literature, interviews and participant

observation.

The issue of energy transition in the automotive sector and battery production is not only technological. The geopolitical aspects are relevant if it is considered the relations between Europe, United States, Russia and China and the geographical division of the world, high-income countries (benefiting from the technology), and low-income countries but depositaries of the raw materials needed for that technology.

Nickel, Cobalt, Manganese, Lithium, Aluminum, Graphite and Copper are the most important elements implied for cells units battery (Huisman et al. 2020) and lithium is undoubtedly a central element in the production of electric batteries, one of the fundamental materials in the process of ecological transition, particularly in the transport sector. The careful analysis of the geopolitical dynamics around this material are crucial also for the support of ecological and sustainable urban regeneration processes, i.e. “smart cities”.

Half of all lithium reserves on the planet are located between Chile, Argentina and Bolivia, the so-called “lithium triangle”. From the salty desert in Bolivia, Salar de Uyuni, to the Chilean Atacama Desert, and continuing eastward into Argentina. What should be of greatest concern, however, is not the amount of lithium present on the Earth’s crust, but its global distribution. The social impact and the lack of information and consultation with the local population, together with a difficult industrialization on site (due to poor technological preparation), are issues directly related and consequent to the “geopolitics of extractivism” (we refer to extractivism (Svampa and Teran Mantovani 2019) as economic activity based on the use of large ‘natural resources’, most of which are destined for export on the global market).

In these territories the continuous process of privatization of resources for the benefit of large players and the construction of ad hoc regulations to deregulate resources has exacerbated the long process of expropriation of local communities, mainly indigenous. Lands where the transformation process is often opposed by local organizations that attempt a dialectic of negotiation/resistance of a territory that ends up being considered a “bargaining chip” leading either to ongoing conflicts, or to an often ambiguous adaptation process. The growth of the mining industry in northern Chile has led to the territorial dispossession of indigenous communities, which in turn has generated a process of indigenous self-identification that has generated ethno-territorial conflicts in response to these socio-environmental transformations (Romero-Toledo 2019).

This ambiguous role of the State/Government can be summarized with the concept of “political expropriation” which associates this term with the consequences of all those interventions implemented to facilitate the extractive process by counteracting the processes of community resistance, disarticulating them politically and thus losing decision-making and management power. The increase in the enclosures of human resources, is accompanied by the inherent expropriation of the capacity for political action and self-determination of the affected populations. Political expropriation can be thought of as an intentional strategy of disarticulation of social organizations and resistance movements-employed by state actors, corporations, or other social groups-but at the same time allows us to link such interventions with the disarticulation of community ties (Andreucci, Radhuber, and Chávez León 2021).

AN OVERVIEW IN LATIN AMERICA: THE LITHIUM TRIANGLE

Lithium resources are mainly placed in Bolivia, 21 million tons; Argentina, 19.3 million tons; Chile, 9.6 million tons; United States 7.9; Australia, 6.4 million tons; China, 5.1 million tons, according to USGS data (U.S. Geological Survey 2021). Here are located most of the continental brines in the world, where lithium rich solution is pumped up from groundwater to the plant where lithium increase percentage step by step through evaporation ponds till is ready to be refined into lithium carbonate (Liu, Agusdinata, and Myint 2019).

The assessment of the criticality of a raw material would depend basically on two factors:

- economic importance;
- supply risks.

The lithium market, under pressure from an ever-increasing push for a sustainable energy transition, is growing exponentially, but in Latin America logistical costs are very high due in part to inadequate reliable infrastructure, political and economic instability, lack of technical expertise and large capital investments.

To date Chile has the largest and most certified lithium reserve in South America located in the Atacama Desert, one of the driest places in the world (therefore not ideal for extraction and storage given its high flammability). This reserve has the great logistical advantage of being located near the city of Antofagasta, which is one of the most important industrial ports in the country. The logistical advantage, the low rate of corruption (different from other countries of the same content) combined with

liberalist policies, let Chile dominate the market. Chile today is trying to break away from the role of producer and, also in an attempt to respond to the growing share of the market, is pushing the production on site (example is the agreement with the company USA - Albermarle under which the company agrees to sell at a favorable price part of the lithium extracted to Chilean companies engaged in on-site production).

Lithium mining inevitably damages the soil and also causes air pollution. The salt flats where the lithium is found are located in arid territories and access to water is crucial for the mines, but also for the local communities and the local flora and fauna. Atacama Desert presents extremely arid climate and unique topography produce the saline groundwater containing 0.15% lithium that serves as the major water source for lithium extraction.

In the Atacama salt flats in Chile, extraction consumes, contaminates and diverts scarce water resources away from local communities, and lithium mining has caused water-related conflicts with several communities, such as the Toconao community in northern Chile (Garcés and Álvarez 2020).

Jujuy, Salta and Catamarca are the provinces with the largest deposits of lithium in Argentina. The take-off of the extractive sector has been limited mainly by several changes of government in the last 20 years that have alternated phases of total liberalization of the market with processes of nationalization of the major companies in crucial and strategic sectors (eg oil company YPF). The statist policies of the left-wing government which have increased taxes on exports and imposed heavy controls on access to foreign currency, also due to strong internal economic crises, has discouraged foreign investment and / or large companies often forced to disentangle between provincial and national regulations have thus opposed important liberalization processes, in some cases reducing the country's global market power. There are different large multinational companies that to date have set foot in Argentina (Fornillo and Zicari 2017):

- Japanese company Toyota partnered with the Australian mining company Orocobre Limited to exploit the Salar de Olaroz (province of Jujuy);
- Magna and Mitsubishi (also from Japan) did the same in the Salar de Cauchari (Salta province) with the Canadian mining company Lithium Americas;
- the Korean automaker Kores did so with Lithium One (Canadian-Chinese mining company) to exploit the Sal de Vida deposit in Catamarca, Argentina.

Bolivia has endless deposits of lithium in the area of the

Salar de Uyuni, not far from Potosi, and in the Salar de Coipasa. Despite the fact that its deposits are estimated to be among the largest in the world, lithium contributes only a small part to the GDP of the country. Local environmental, socio-political and geopolitical issues are effecting the development of this sector, such as: the high rate of internal corruption, the technological inadequacy of the extraction process (predominantly left in the hands of local companies due to nationalization) and the difficult relations with Chile that prevent Bolivia from using the nearby port of Antofagasta for exports.

The resign of Evo Morales in November 2019 for many was a concomitant of a geopolitical conflict for the access to the immense reserves of lithium that are in the salar of Uyuni. Nationalization of resources and push for infrastructure, small industries, social assistance programs for indigenous peoples are also the main points of MAS (*Movimiento al Socialismo*), which implicitly aims at the intensive exploitation of the subsoil for economic and social purposes and for local welfare (Andean-Amazonian capitalism). According to the (few) public data, this did not happen. The main result was the renegotiation of the shares of multinationals operating in the country and the modification of the royalty percentages that companies are obliged to pay to the State (Supreme Decree 28701 of May 2006), replacing North American capital with that of China and other European and Latin American companies.

According to the last data available (De Ambroggio 2020) after three years of Morales' government, 67% of oil reserves were in the hands of the Spanish company Repsol, while the state-owned companies Chaco and Andina owned only 28% of shares; as for natural gas reserves, 61% were controlled by the Brazilian company Petrobras, 22% by Repsol and only 13% by the nationalized companies Chaco and Andina. In addition, the country's largest debt to China was incurred (7.5 billion dollars, equal to 17% of Bolivia's GDP), aimed at an ambitious program of mega-projects in the region - including infrastructure, hydroelectric dams and mines - which, however, were totally conditional on being carried out by Chinese companies. Likewise, surpluses of raw materials were not reused in the welfare system in favor of the rural population, but mainly to improve the extractive process from a structural point of view or, in any case, focusing on the massive export of raw materials on the world market.

LITHIUM AND ITS ENVIRONMENTAL IMPACT

The ecological transition, environmentally sustainable, green and therefore environmentally friendly and able to combat global warming is a priority objective on the political agenda of all countries. Lithium plays a crucial role in this process, but at the same time, its extraction has a significant socio-environmental impact (Khobragade 2020): in this area, environmental problems are linked to resource availability. The supply of lithium can hide extraction methods often not-sustainable, which risk compromising the green revolution of which it is the protagonist. It is not only the emissions of CO₂ from the extraction of underground deposits, but also the excessive use of the soil that derives from it, with the enormous expanses of evaporation ponds that disfigure entire landscapes, in addition to significant water consumption for lithium extraction in brine.

The real consequences of mining activities have been for years hidden to the world population. The economic expansion generated by the extractive process in its early stages was accompanied by a lack of visibility and recognition of the territorial and socio-environmental conflicts by the local governments, exacerbating the situation in these territories (Svampa and Teran Mantovani 2019). This peaceful coexistence of local communities with mining activities was definitely broken with the publication of the first medical and toxicological studies (Observatorio de Conflictos Mineros de América Latina (OCMAL) 2020) on the impact of the mining process on human health and on local ecosystems.

In these contexts, a response is expected from the State and political decision-makers, as guardian of the territory, with adequate solutions and concrete responses to local problems often related to primary activities.

Despite the presence of clear regulations governing mining activities especially to protect the rights of indigenous communities in their territories (eg Convention 169 of the International Labor Organization - ILO, which recognizes the rights of indigenous peoples), many local communities denounce the absence of free, prior and informed consultation with the Government, a mechanism provided for by the aforementioned Convention 169 (eg new contract signed by the Chilean state-owned Corporación de Fomento with the company SQM to expand lithium extraction in the Atacama salt flats) (Observatorio de Conflictos Mineros de América Latina (OCMAL) 2020).

The same impacts of climate change could, in turn, disrupt the supply chains of raw materials (Manhart et

al. 2019). Flooding, caused by heavy rain or rising sea levels, may negatively affect the availability of fresh water or may introduce salt water into water containment systems in a mining site. This may also lead to an uncontrolled release of metal-contaminated effluents, creating a real toxic waste storage, or render the working areas in the mines impracticable, even if only temporarily. Climate change can potentially have few positive impacts: eg increased temperatures would save evaporation time by applying smaller evaporation ponds (Manhart et al. 2019).

In South America, lithium deposits are often located in desert areas, so the extraction process would create a severe water shortage. Mining practices, and in some cases the privatization of water resources / water supply services, lead to water shortages which can compromise lagoon structure and jeopardize the ecological value of these hypersaline lakes rising the social conflicts associated with water. Although the water in the plant tends to be recovered, the large amount needed and the difficult environmental context of the South American salt flats makes the problem almost unsolvable (Comisión Nacional del Litio 2010).

Lithium mining breaks the water cycle. The process affects the water table and the subterranean flow of water between the Cordillera and the sea. Drilling for lithium can reach depths of up to 300 meters where freshwater basins are often found, risking the mixing of fresh and salt water with devastating impacts on the ecosystem. One estimate is that it requires 1 liter of brine water to produce 0.05–1 mg of lithium. This translates into as much as half a million gallons to produce 1 ton of lithium. Dynamical modeling, such as the one that has been used to assess water carrying capacity in East Africa, could be a constructive approach (Mancini and Sala 2018).

This process is carried out using brines (liquid streams) located in the salt flats of Argentina, Bolivia, Chile and Brazil. As a result, intensive water consumption can reach up to 640 liters per second in mining concessions that can last at least 15 years (Fornillo 2018). In Salar de Atacama, approximately sixty-five percent of the region's water is diverted for mining practices (Morales Balcázar 2021) and the rural populations have been agitating for years against the exploitation of land by the extractive industries because the deposits are in desert areas and the extraction process creates a strong water imbalance often to the detriment of local populations of the "lithium triangle".

If we look at the specific example of the "Norte Grande" in Chile, the result of neoliberal policies that

have allowed the expropriation of water has generated a massive transformation of the Norte Grande with enormous pressure on water resources located in the territories where the Aymara, Quechua and Atacameño indigenous communities live. The water used by the mining sector corresponds to 44% of surface water and 42% of groundwater, with seawater coming in third with 8%. In addition, highland water is withdrawn by mining companies from aquifers, impacting the entire territory (Romero-Toledo 2019).

Again, Toledo in his study notes different types of impacts generated on the community due to water exploitation:

- Water extraction that affects communities in the highlands;
- Water scarcity affecting communities downstream of the extraction area;
- Water scarcity allegedly accelerating the migration process of some indigenous communities, predominantly the Aymara in rural areas;
- And finally, suspended dust and its impact on water, land and living beings, due to the transport of minerals and residues in communities near the deposit. The situation is the same in Argentina, where the extraction process also requires the use of large amounts of water, which causes a rupture in the water balance of the basin, generating a level of water discharge that exceeds the existing load level. This represents a risk of increased water stress in the area and salinization of freshwater reserves. In Argentina, lithium extraction projects are mainly located in the Puna, in high altitude salt flats. The impact on these reserves, in an arid region with a fragile ecosystem such as the Puna, would represent a decrease in the water available for vegetation and animal life, as well as a lower level of water available for human use. This alteration of water reserves would also have repercussions on the traditional primary economic activities of the local communities (livestock, agriculture and salt extraction). The impact not only translates into loss of water, but also in the disappearance of vulnerable species that only exist in these places, the loss of the cultural heritage of indigenous peoples, the losses of millions of years of evolution of adaptation processes of species, including the extremophilic organisms (Garcés and Álvarez 2020). To extract the mineral, drilling fields are set up where, through a pumping system, large quantities of brackish water containing lithium are extracted from the salt flats. This water is deposited in evaporation and concentration pools. There, the wa-

ter is evaporated by solar radiation and wind, and the brine is concentrated through a precipitation process. The concentrated brine then enters a plant process for the production of lithium carbonate, at which point the ore is marketed. The salt flats are wetlands that, due to their composition, represent important freshwater reserves, both for the biodiversity of the region and for the indigenous communities that live there. The salt flats are endorheic basins composed of an aquiferous area of brackish water with lithium and another area with low salinity (“fresh”) water. Although these areas are kept separate by their density, there is a mixing area between them (Marazuela et al. 2019). The natural sources of water recharge of the salt flats are rainfall and temporary rivers, while discharge is by evaporation. Salt accumulation occurs on the surface of the basin, due to the proximity of the aquifer water level to the surface. Therefore, alteration and damage to the saline interface could have repercussions on the brackish and freshwater areas, causing them to mix (Holzbecher 2005). Likewise, a water imbalance caused by a large discharge of brackish water could mobilize freshwater towards the saline area, causing its salinization (Houston et al. 2011).

CONCLUSION

Technological innovations (Calzada Olvera 2021) related to mining and new discoveries of lithium deposits represent (potentially) for South America redemption on the global scene (in terms of local economic and technological development), but mineral exploration is risky, inevitable, expensive and with negative ecological footprint especially on local communities (Svampa and Teran Mantovani 2019).

There are crucial steps that must be implemented at the local level (Fornillo 2018) for this to happen which can be summarized as follows:

- Adapt existing local infrastructure: weak infrastructure (logistics and energy infrastructure) brings increased project costs. Adequate infrastructure is needed to develop competitive local industries throughout the extractive chain and if this gap is not filled, South American countries run the risk of being cut off from the international scene and the great opportunity driven by the energy transition. The objective must therefore be to break the logic in which the foreign company extracts resources and profits from the territory without local added value.
- Understanding the value chain and the lithium in-

dustry (Ruiz Peyré and Dorn 2020): The lithium industry is growing rapidly and needs to adapt quickly to battery-related technological innovation. It is critical for producing countries to dynamically adapt to this rapidly evolving industry, while at the same time thinking about the long-term opportunities associated with the complex and integrated battery supply chain. The Bolivian case should be an example: despite the large resources of lithium, the country has not yet seen the emergence of operators in the sector but only press releases and political campaigns with short-term interests and a total lack of interest in understanding both the added value of the supply chain and the international scenario.

- Social and environmental sustainability: the goal must be to develop projects that benefit the local community to achieve the Sustainable Development Goals (Janikowska and Kulczycka 2021) set by the international community. Local communities must co-participate in the development activities of mining projects and must become the primary stakeholders. The extractive industry inexorably and permanently alters the environment, and these projects (necessary and inevitable for the global ecological transition process) must work to minimize these impacts. There is no perfect solution to the environmental consequences, but it is necessary to use environmentally sustainable technologies and processes and to focus on eco-sustainable business models regarding energy consumption, CO₂ emissions, water use, chemical reagent use and waste streams.

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