Institution: University College London

Unit of Assessment: 7 – Earth systems and Environmental Sciences

Title of case study: Building water quality and mining waste risk-reduction capabilities for indigenous communities, government and non-government bodies in Bolivia and Chile

Period when the underpinning research was undertaken: 2000-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Stephen J. Edwards	Research Associate and Senior Research Associate	2007-present
Megan French	Research Associate	2012-2015
Karen A. Hudson-Edwards	Lecturer, Senior Lecturer, Reader and Professor	1998-2017

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

UCL–Birkbeck research has improved understanding and management of the impacts of mining and natural processes on water quality in Bolivia. A novel hazard rating system is facilitating volunteer-led water monitoring programmes that enable indigenous Altiplanic and other Bolivian communities to identify contamination and better manage limited water resources accessed by 1,400,000 people. The work was also instrumental in the UK signing an agreement with the Vice-President of Bolivia to strengthen UK–Bolivia science, innovation and research collaboration. Moreover, the impact of the research in Bolivia led to a UCL partnership with the Chile Mining Ministry informing disaster scenarios for future failures of mine waste storage facilities. This has been pivotal in developing national safety regulations for the mining industry in Chile and more recently has been used by the global geoscience technology company CGG, to formally market its satellite remote sensing capabilities in mining.

2. Underpinning research (indicative maximum 500 words)

Research conducted since 2000 by Karen Hudson-Edwards (Birkbeck Department of Earth and Planetary Sciences), Stephen Edwards (UCL Hazard Centre in the Department of Earth Sciences) and Megan French (UCL Institute for Risk and Disaster Reduction), in collaboration with researchers and NGO (non-government organisation) practitioners from the UK, the USA, Bolivia, Sweden, Spain, the Czech Republic and Australia, has investigated the source, transport, distribution and fate of contaminants in Bolivian water sources, river channels, flood plains and irrigated areas. In 2001, Hudson-Edwards and co-workers demonstrated that water and sediment in the Río Pilcomayo basin are contaminated by tailings (the solid and fluid residue from mineral processing) (**R1**). Subsequently, human exposure to contaminants through soil, crop and water pathways was investigated in several riverine communities and demonstrated the need for proper risk assessment models in Bolivia that are versatile enough to handle site-specific conditions (**R2**). These studies laid the foundation for, and informed the approaches and methodologies used in, research on the Bolivian Altiplano, which was initiated through the pioneering research and knowledge exchange partnership between UCL and the Catholic Agency for Overseas Development (CAFOD), established in 2008 and led by Edwards (**R3**).

In 2012, Edwards and Natalie Alem of CENDA (el Centro de Comunicación y Desarrollo Andino, Bolivia) undertook interviews and a field survey that identified the Poopó and Antequera river basins on the eastern margin of the closed Lake Poopó basin on the eastern

Altiplano as representative of an area highly impacted by mining. Subsequently, French focused on water quality hazard and Alem on human vulnerability to water availability and contamination. French worked closely with Jorge Quintanilla, who, with his water quality team at la Universidad Mayor San Andrés (UMSA) in Bolivia, had demonstrated multiple sources of potentially harmful elements (e.g. arsenic, cadmium, manganese, lead and zinc) in the study area that render water resources (sampled during the wet season of 2009) vulnerable to contamination (**R4**). In a subsequent study of ground and surface waters in the same area, UMSA scientists and French collected samples at 45 sites during four sampling campaigns covering the wet and dry seasons between August 2013 and July 2014 (**R5**). The results from analysing the water were used by French to develop a Chemical Water Quality Hazard Rating (CWQHR) (**R5, R6**). This innovative rating is based mainly on water chemistry, but also the presence of algae, suspended particulate and organic material, and stagnation. Contrary to most water quality indices, which use percentages to indicate poor (low) to good (high) quality, the CWQHR uses a 1 (good quality) to 10 (highly contaminated) scoring range, consistent with levels of social vulnerability to water issues, which are also classified numerically on a scale of 0 (very low) to 10 (very high). The CWQHR showed that for the sites analysed over the sampled period, only one site provided water suitable for direct human consumption, whereas 70% of waters sources were unfit for consumption without significant treatment. Some 40% were highly hazardous with respect to both livestock watering and irrigation. The ratings were combined with Alem's vulnerability assessment to produce a water risk map and provide evidence-based recommendations to the Government of Bolivia for improving water quality and availability (**R7**).

3. References to the research (indicative maximum of six references)

R1. **Hudson-Edwards KA**, Macklin MG, Miller JR, Lechler PJ. (2001) Sources, distribution and storage of heavy metals in the Río Pilcomayo, Bolivia. *Journal of Geochemical Exploration,* 72, 229-250. doi: 10.1016/S0375-6742(01)00164-9
R2. Miller JR, **Hudson-Edwards KA**, Lechler PJ, Preston DA, Macklin MG. (2004) Heavy metal contamination of water, soil and produce within riverine communities of the Río Pilcomayo Basin, Bolivia. *The Science of the Total Environment,* 320, 189-209. doi: 10.1016/j.scitotenv.2003.08.011
R3. **Edwards SJ** (2012) Case study 3: a research and knowledge sharing partnership between UCL and CAFOD. Enhancing Learning and Research for Humanitarian Assistance On-line Guide to Effective Partnerships. http://www.elrha.org/ep/the-online-guide-for-effective-partnerships/
R4. Ramos Ramos OE, Rotting TS, **French M**, Sracek O, Bundschuh J, Quintanilla J, Bhattacharya P. (2014) Geochemical processes controlling mobilization of arsenic and trace elements in shallow aquifers and surface waters in the Antequera and Poopó mining regions, Bolivian Altiplano. *Journal of Hydrology*, 518 (Part C), 421-433. doi:10.1016/j.jhydrol.2014.08.019
R5. **French M**, **Edwards SJ**, **Hudson-Edwards KA**, Quintanilla JE, Alem N. (2015) Informe Resumido sobre el Estado Químico de las Aguas en Sora Sora, Poopó, Antequera, Urmiri y Pazña 2013–2014. London: UCL Hazard Centre. 44 pp.
R6. **French M**, Alem N, **Edwards SJ**, Blanco Coarit E, Cauthin H., **Hudson-Edwards KA**, Luyckx K, Quintanilla J, Sánchez Miranda O. (2017) Community exposure and vulnerability to water quality and availability: a case study in the mining-affected Pazña Municipality, Lake Poopó Basin, Bolivian Altiplano. *Environmental Management*, 60, 555–573. doi: 10.1007/s00267-017-0893-5.
R7. **French M**, Alem N, **Edwards SJ**, Cauthin H, Blanco Coariti E, **Hudson-Edwards K**, Luyckx K, Quino I, Quintanilla J, Sánchez O, Vallejos M. (2015) Disponibilidad y Calidad del Agua en las Subcuencas Poopó, Antequera y Urmiri del Altiplano Boliviano y Recomendaciones para la Mejora de la Gestión de los Recursos Hídricos. Water availability and quality in the Poopó, Antequera and Urmiri sub-basins of the Bolivian Altiplano and recommendations for improving water resource management. *Report for the Bolivia Vice-ministry of Water Resources and Irrigation.*

References (R1), (R2), (R4) and (R6) best indicate the quality of the underpinning research.

4. Details of the impact (indicative maximum 750 words)

Limited water resources of variable quality present a significant hazard to public health and wellbeing, the environment and its ecosystem services and food security. This hazard is particularly acute in arid regions of the world impacted by mining, where limited water resources may be prioritised for mineral extraction, processing and waste disposal, and then re-enter the natural environment in a highly degraded state. Unfortunately, for Bolivia, it has a large number of these hazard hotspots, exemplified by the Río Pilcomayo basin and many drainage systems on the Bolivian Altiplano, which have been negatively impacted by centuries of poorly regulated mining activity resulting in heavy metal contamination of soils and waters. UCL–Birkbeck research on the impacts of mining has resulted in improvements in water resource management in Bolivia and subsequently in tailings risk management in Chile and the UK. The work has benefitted indigenous communities, government and non-government bodies and business, and has enhanced UK international relations in science and innovation.

Building indigenous community resilience to reduce water quality risk in Bolivia and positioning the UK as a key science, innovation and research partner with Bolivia

The Catholic Agency for Overseas Development (CAFOD) operates one of the largest aid networks in the world and works with in-country partners to alleviate poverty and suffering in developing countries. CENDA is a key partner in Bolivia and has supported indigenous peasant communities for over 30 years. Of its four thematic areas, community water management was initiated in 2012, as a consequence of collaboration with UCL–Birkbeck researchers (**S1**). It became firmly established in 2014 with a community water monitoring programme in the Poopó and Antequera river basins (combined area of 335 km^2) in the Poopó and Pazña municipalities of the Department of Oruro. In these basins, unregulated tin, silver, lead and zinc mining and waste disposal has occurred since the 16th century affecting the quality and availability of water, which puts the survival of 12,000 indigenous peasant people at risk (**S2**). The underpinning research carried out by UCL–Birkbeck researchers informed CENDA that only 2% of waters sampled were suitable for direct human consumption and it provided essential evidence of the causes and extent of contamination (**S1**, **S3**). In 2015, CENDA published the findings of the UCL–Birkbeck research online, which has been viewed more than 1186 times, and also submitted the findings to the Bolivia Vice Ministry of Water Resources and Irrigation, which then identified the Poopó and Antequera river basins as priorities for monitoring, because of the contamination of water by mining (**S3**).

The underpinning research from UCL–Birkbeck led to the development of a uniquely versatile and qualitative tool for water quality hazard assessment—the CWQHR. The tool is specifically designed to be locally relevant and to be understood and used by community members and environmental and health managers on the Bolivian Altiplano and similar environments elsewhere. Unlike existing indices at the time, the CWQHR is applicable in areas affected by mining or natural contamination and encompasses all aspects of water use, including potable, agricultural, ecological and recreational uses, and broader environmental aspects. It also enables recommendations to be made about the level of treatment required for specific uses of water. Providing this tool and educating members of local communities in water monitoring and hazards, resulted in their active participation in water monitoring activities, understanding health risk and making informed decisions about water use (**S1**). Commenting on the benefits of the CWQHR tool and the underpinning water quality data, CENDA stated that most importantly these "provided the **hard evidence to enable the communities to stand up for their water rights**" (**S1**) and this had three key outcomes. Firstly, "communities now have volunteer water monitors and have been able to self-organise and find their own solutions to the water problem by **managing the uses of water according to its quality and availability, greatly aided by the CWQHR**" (**S1**). Secondly, "active coordination was achieved with the Vice Ministry of Water Resources and Irrigation, and the Autonomous Municipal Governments of Poopó and Pazña–Antequera" (**S1**). This consolidated a water monitoring and surveillance system in each of the two river

basins (**S1, S3**), delivering to the Bolivia National Watershed Plan (**S3**). Thirdly, the Integral Health Centre of Poopó, through its Community and Intercultural Family Health Programme, took responsibility for reporting the quality of the water. This **led to the Autonomous Municipal Government of Poopó installing chlorination and filtration systems to improve water quality for the communities**, thus ensuring they had access to more water of better quality (**S4**).

Towards the end of 2019, **200 families had directly benefitted from improved water management and 1,400 indirectly** in the Poopó and Pazña–Antequera municipalities (**S2**). The community water monitoring has been replicated in other locations in Bolivia: on the Altiplano at Coro Coro (projected population of about 9500) and along the Amazonian Río Rocha (**S2**) (that flows through the city of Cochabamba and has more than 1,400,000 people living in its 3700 km^2 basin, which is equivalent to 12% of the country's population). This has helped to ensure communities have greater access to potable water. This has all been possible, thanks to the UCL–Birkbeck research that "**strengthened the capacities of the researchers** at CENDA" (**S1**).

In June 2016, the British Embassy in La Paz showcased the UCL–Birkbeck research in Bolivia in a special supplement of La Razon (the leading newspaper in La Paz) and via the Embassy's Facebook page. This publication reached approximately 50,000 readers and its purpose was "to project the UK as a good commercial partner for Bolivia and a leader in different prosperity areas, including the UK's academic capabilities for innovation and collaboration in the mining sector" (**S5**); the UCL–Birkbeck research "in mined areas on the Bolivian Altiplano provided an excellent example in this regard" (**S5**). Subsequently, the British Embassy in La Paz "intensified its efforts to strengthen the science and research relationship between the UK and Bolivia and generate a greater amount of academic links between both countries. The Vice-president of Bolivia visited the UK in February 2019 and signed an agreement with the British Embassy in Bolivia to that effect. **The success and positive impact of projects such as [that undertaken by UCL–Birkbeck on the Altiplano] has been vital in positioning the UK as a key partner for Bolivia** in terms of science and innovation, leading to this agreement" (**S5**).

Enhancing capacities of government and business in Chile and the UK to monitor, model and reduce tailings disaster risk

Mining is one of the key priorities of the UK Department for International Trade (DIT), particularly in South America through the British Embassy in Chile. The DIT encourages and promotes UK research and commercial know-how in mining in order to attract foreign sources of business for the UK. Since 2015, the impact of the research in Bolivia has evolved to generate profound impacts for tailings risk understanding and management, which have benefitted the DIT and Mining Ministry of Chile, and created new business for CGG in the UK.

In Chile in December 2015, Edwards presented the UCL–Birkbeck research and community water monitoring programme in Bolivia to the Mining Minister of Chile and the British Ambassador to Chile (**S6**). This resulted in the Minister inviting Edwards and the British Embassy to collaborate with her ministry, through SERNAGEOMIN (the National Service of Geology and Mining), to explore ways to reduce the risk from mine tailings in Chile. This "**enabled the Embassy to greatly enhance its engagement with the Mining Ministry**" and resulted in the Minister requesting "tailings be **identified as a priority theme** in the 2016 UK Cross-Government Prosperity Fund call for Chile, which they were" (**S6**). Through this competitive call, the Foreign & Commonwealth Office awarded Edwards GBP114,000 for the project "Promoting Sustainable Mining in Chile: Building Capacity in Mine Tailings Hazard Management" and subsequently, in 2017, GBP23,500 from the Global Britain Fund for the project "Tailings Risk Analysis and Management in the Central Zone of Chile and Associated Research, Training and Commercial Opportunities" (**S6**). There were high impact results from these projects for SERNAGEOMIN in Chile and CGG in the UK.

Under Chile Supreme Decree No. 248 of 2007, it is a legal requirement for every mining operation in the country to report the dangerous distance, which is the distance tailings would flow should a tailings dam fail. Between 1915 and 2010 in Chile, 80% of the 38 reported tailings dam incidents were caused by earthquakes. As a consequence and at the request of SERNAGEOMIN within the agreement of the Prosperity Fund project, the UCL Hazard Centre developed a physical model to generate scenarios for earthquake-induced failures of tailings storage facilities and the subsequent run-out flow distance of tailings and the area they could inundate. For SERNAGEOMIN, the model "remains **the most comprehensive, rigorous and advanced methodology available**" (**S7**) and the "advanced knowledge of the values calculated with [the UCL model] has **prompted mining companies to make serious efforts to assess the distance by their own methods**" (**S7**). Moreover, commenting on proposed new national tailings regulations, SERNAGEOMIN stated that the "pioneering work to model the area of inundation **has been pivotal in developing the proposed new regulations regarding the safety and management of tailings storage facilities** in Chile; we have suggested to forcibly ask the mining companies to inform affected area (as your results show), in addition to the dangerous distance" (**S7**). The model also enables assessment of potential human, infrastructural and environmental damages from a tailings inundation that "provides unique critical information for SERNAGEOMIN, which must present such information to public authorities for purposes that include informing territorial polices and urban planning, and reducing potential tailings disaster risk" (**S7**).

CGG is a global geoscience technology leader employing some 4,000 people worldwide. The impact on business and development for them came from UCL Hazard Centre research and expertise on tailings dam failures in Chile being applied to one that occurred at Cadia Mine in Australia in March 2018. The Cadia study used Earth observation data to retrospectively forecast the failure and "resulted in significant exposure and business for CGG" (**S8**). The study became a catalyst "for CGG formally marketing its satellite remote sensing capabilities under a new brand called 'MineScope'. This has become a leading and renowned service in the [mining] sector and has been the **driver for significant growth** for CGG; we saw an up-tick in revenue during 2020 and have been perfectly placed during the COVID-19 pandemic to support clients with remote mine site intelligence. This significant increase in commercial demand resulted in CGG establishing a new business line in Minerals & Mining in October 2020" (**S8**).

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. Letter from CENDA, Bolivia – describes the water risk and its management in Bolivia's Altiplano project and corroborates its impact in Poopó and Pazña municipalities.
S2. E-mail from a consultant to CENDA, Bolivia – describes the beneficiaries and replication of the water risk and its management in Bolivia's Altiplano project.
S3. Letter from the Vice Ministry of Water Resources and Irrigation, Bolivia – corroborates Poopó and Antequera river basins as priority areas for water monitoring and clean-up.
S4. E-mail from CENDA, Bolivia – corroborates installation of filtration and chlorination systems by the Municipal Government of Poopó to improve water quality.
S5. Letter from the British Embassy in La Paz, Bolivia – corroborates the water risk and its management in Bolivia's Altiplano project as exemplary of UK- Bolivian collaboration and the showcasing of this work in the publication La Razon.
S6. Letter from the British Embassy in Santiago, Chile – corroborates UCL-Birkbeck's research activities and its impact on tailings risk management in Chile.
S7. Letter from SERNAGEOMIN, Chile – corroborates the use of the earthquake-induced failure of tailings storage facilities model at SERNAGEOMIN and its impact on regulatory development.
S8. Letter from CGG, UK – corroborates UCL's research with CGG and its impact.