ST01 - Resilience to Climate Change – A Tool to Assess Climate Impacts on Human Health of Aluminium Sector Workers and Communities

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Abstract

The risks to human health arising from climate change take many forms, including heat-related illnesses, changes or increases in vector-borne diseases, drought-related impacts and extreme weather events that can damage infrastructure and cause serious injuries, deaths and long-term mental health effects. Climate-mediated risks are ubiquitous across the aluminium sector and related communities, and must be properly managed to ensure a reliable and productive workforce and ongoing sustainability of the sector. Adaptation options need to be identified, to avert or mitigate climate impacts on the health of aluminium sector workers and communities. An online engagement forum has been developed, comprising climate literacy resources and a fully functional assessment tool suitable for utilisation by the entire aluminium value chain. This tool helps aluminium industry assets and local communities to identify climate-related hazards of relevance to the specific locality, characterise risk pathways for human health, and identify adaptation measures that may be used to manage risks. The tool has been piloted at diverse global locations representing a range of climate vulnerabilities.

Keywords: Climate change health impacts, Climate change adaptation, Occupational health, Local communities.

1. Introduction

Climate change is characterised by rising global temperatures, shifting weather patterns, melting ice caps and glaciers, and rising sea levels. Climate change has significant impacts on ecosystems, weather extremes, natural resources, and human societies. These effects include more frequent and severe heatwaves, droughts, floods, storms, and disruptions to agricultural productivity. Additionally, climate change poses risks to human health, biodiversity, and economic stability. Addressing climate change requires concerted global efforts to reduce greenhouse gas emissions, transition to renewable energy sources, implement sustainable practices, and critically to adapt to the changing climate to minimise its detrimental consequences.

1.1 Addressing Human Health Vulnerabilities to Climate Change

Climate change poses significant risks to human health, encompassing direct impacts such as heat-related illnesses, respiratory disease and other air pollution mediated adverse health endpoints, increased magnitude and geographical range of vector-borne diseases, and increased frequency of extreme weather events that deliver damaging impacts on habitations and infrastructure, displacement of peoples, and knock-on adverse consequences to mental health.

Rising temperatures, changing rainfall patterns, water quality and food supply impacts, and increased frequency of extreme weather events can disrupt industrial operations, compromise worker health and safety, and negatively impact the health of nearby populations. These risks are pervasive across various sectors, including the aluminium industry, and demand effective management strategies to ensure the well-being of workers, communities and the long-term sustainability of society.

To help address these climate-mediated risks, we have developed an innovative online engagement forum, comprising climate literacy resources and a comprehensive assessment tool. This platform facilitates collaboration and knowledge-sharing within the entire aluminium value chain, empowering industry assets and local communities to identify and address climate-related hazards specific to their localities. By characterising risk pathways for human health and identifying appropriate adaptation measures, our projects aim to enhance the resilience of the aluminium sector to climate change impacts on its workforce and surrounding communities.

Within this paper, we outline the key elements of our climate resilience projects, starting with a review of the existing literature on the impacts of climate change on human health and development of a catalogue of cause-effect pathways that connect climate change to diverse health outcomes. We discuss the development and functionality of our online engagement forum, which includes climate literacy materials and a tiered assessment tool designed to aid in risk identification and adaptation decision-making.

Additionally, we provide case studies of pilot projects implemented at diverse global locations representing various climate vulnerabilities within the aluminium sector. These case studies demonstrate the practical application of the assessment tool and showcase the outcomes, challenges, and potential adaptation measures identified through its utilisation.

By sharing our experiences and findings, we aim to contribute to the knowledge on climate resilience in the aluminium sector and provide valuable insights for other industries grappling with similar challenges. Ultimately, our efforts seek to promote the well-being of workers and communities, and foster sustainable practices that mitigate the health risks associated with climate change.

2. Risks to Aluminium Operations

The aluminium industry plays a critical role in supporting economic development and supplying essential materials for various sectors, such as sustainable energy, construction, transportation, and packaging. Even in the absence of climate change, the industry is regularly faced with challenging climatic conditions, such that certain adaptations are required to ensure continuing resilience and sustainability. However, as the global climate continues to change, the industry faces a multitude of challenges that can have increasingly detrimental effects on the well-being of its workforce and the communities in which it operates.

The aluminium sector is already feeling the effects of climate change and these effects are expected to increase in both scope and magnitude in the future. One of the most consequential effects will be the impact of climate change on the health of aluminium sector workers and their communities. Climate change is already affecting human health and is likely to take an especially large health-related toll in decades to come. Notably, the human health impacts of climate change will be most severe in many of the same regions, and specific locations, where the aluminium industry is most active – developing countries and equatorial regions – as well as among many of the populations most relied upon for labour – people of lower socio-economic means and people living in small and remote communities.

The public health and safety impacts of climate change – severe weather events, air pollution, changing vector ecologies, proliferation of allergens, water and food security, civil unrest and increasing conflict, environmental degradation and extreme heat – are increasingly likely to impact the sector's industrial sites, local communities, and its workforce. Such risks will be heterogeneous across the global sector (in terms of both likelihood and impact).

2.1 Cataloguing Cause-Effect Pathways from Climate Change to Effects on Humans

The impacts of climate change on human health can be described as cause-and-effect relationships, similar in nature to the pathways within a bowtie diagram. A detailed, highly-structured catalogue of these relationships has been developed. These range from the most direct, such as the impacts of heat, through to complex and indirect, such as mosquito-borne disease. They also vary from the immediately possible, such as extreme weather events, to longer-term consequences of gradual but eventually harmful impacts, such as food insecurity and civil unrest.

In addition to describing the cause-and-effect relationships, the catalogue includes specific vulnerabilities that make the associated impacts more likely or more severe. Adaptation options that address these vulnerabilities can reduce or eliminate the risk.

Some of the major potential risks and associated adaptations are as follows [1].

High temperature:

- Risk: High temperatures can lead to heat stress, heat-related illnesses, and even heat stroke among workers. Smelters and high-temperature operations pose a particularly high risk.
- Adaptation: Providing cooling centres, shade, heat-reflective clothing, water- or air-cooled clothing, and improving ventilation can help reduce exposure and heat stress. Work practice controls such as providing power tools, recovery breaks, and acclimatisation periods are also recommended.

Vector-borne disease:

- Risk: High temperatures contribute to increased populations of disease vectors and the incidence of vector-borne diseases like West Nile virus, malaria, dengue, and Zika.
- Adaptation: Controlling mosquito breeding sites, using insecticides, using permethrin-treated clothing, and promoting education and awareness about vector-borne diseases can help reduce exposure.

Airborne hazards:

- Risk: High temperatures can worsen air quality, leading to respiratory illnesses. Heat and sunlight increase ground-level ozone formation, while high temperatures promote the growth of allergenic pollen and mould spores.
- Adaptation: Implementing measures to reduce air pollution, controlling weed growth, and using ventilation systems and air purification can help mitigate the risks. Personal protective equipment (PPE) such as face masks or respirators can reduce exposure for workers.

Sea level rise and coastal flooding:

- Risk: Sea level rise can lead to coastal flooding, saltwater intrusion, and displacement of coastal populations. Coastal industries, including aluminium operations, are at risk.
- Adaptation: Implementing measures to protect infrastructure, relocating vulnerable facilities, improving water management systems, and enhancing early detection and warning systems can help manage the risks.

High precipitation and flooding:

- Risk: Increased precipitation can result in flash flooding, causing injuries, drownings, and waterborne diseases. Flooding can also lead to chemical contamination and scarcity of potable water.
- Adaptation: Monitoring weather forecasts, issuing timely warnings, improving infrastructure resilience, providing shelter-in-place guidance, and promoting community education and preparedness can help mitigate the risks.

Waterborne hazards:

- Risk: Increased water temperature can promote the growth of harmful algal blooms and contamination of water sources. Flooding can mobilise microorganisms and chemicals, increasing the risk of waterborne diseases.
- Adaptation: Monitoring and controlling algal populations, restricting recreational use of affected water bodies, ensuring safe water sources, and implementing effective water treatment systems can reduce exposure to waterborne hazards.

Low precipitation and drought:

- Risk: Drought conditions can lead to soil erosion, poor air quality, water scarcity, food supply threats, and population displacement.
- Adaptation: Implementing water conservation measures, improving water management, promoting alternative water sources, enhancing food storage and distribution systems, and providing humanitarian aid can help address the impacts of drought.

Extreme events:

- Risk: Extreme events such as storms, wildfires, and floods can disrupt power, communication, transportation, and water infrastructure, causing damage to human habitats, health, and well-being.
- Adaptation: Developing early warning systems, ensuring emergency response capabilities, strengthening infrastructure resilience, implementing effective communication strategies, and providing mental health support can help mitigate the impacts of extreme events.

2.2 Compiling Climate Data

To support assessments of the above set of risks, historical (baseline) and future-projected climate data are required. Baseline climate information is needed to define the observed climate with which climate change information from global and regional climate models are combined to create regionally- and locally-relevant future climate scenarios. Increasingly, historical and future-projected data may be accessed through a range of sources that provide global coverage in the form of spatially gridded datasets. The spatial and temporal resolution of gridded climate datasets varies across providers, as do the data sources.

Increasingly, online portals like the World Bank's Climate Change Knowledge Portal [2] provide climate information for climate indices, such as specific measures of extreme heat events, that could directly support climate risk assessments. The range of climate indices immediately relevant for risk assessment varies across portals.

For regions in which climate exhibits considerable spatial variation because of the presence of geographical features like large bodies of water or mountainous terrain, it may be important to seek out climate data and information products of higher spatial resolution. Section 4.1 reports on a pilot of the assessment tool at the Alumar facility, in São Luís, Maranhão, Brazil. This site is located directly on the coastline of the Atlantic Ocean; the climate of the region therefore varies considerably, in certain respects, between its coastal locations and areas further inland. The future projections of relevant climate indices for the assessment were therefore based on spatially downscaled projections of future climate change from the NASA Earth Exchange Global Daily Downscaled Projections [3]. Meanwhile, statistics for the climate indices used in this assessment were computed using the Climpact software, a product developed by the World Meteorological Organization's Expert Team on Sector-Specific Climate Indices, to help researchers deliver useful and relevant climate information to sector users [4].

3. Online Engagement Forum, Tool and Climate Literacy Materials

An online engagement forum has been developed as a platform for collaboration and knowledge sharing. Resources include climate literacy materials, and a fully functional tiered assessment tool developed to identify climate-related hazards, assess risks to human health, and propose adaptation measures.

3.1 Climate Literacy

Climate literacy is essential in addressing climate change and its impact on human health for several reasons:

1. **Awareness and Understanding:** Climate literacy equips individuals with knowledge and understanding of climate change, its causes, and its consequences. It helps people recognise the linkages between human activities, greenhouse gas emissions, and the resulting impacts on the environment and human health. This awareness is crucial in fostering a sense of urgency and motivating action.
2. **Informed Decision-Making:** Climate literacy empowers individuals to make informed decisions in their personal lives, communities, and workplaces. It enables them to assess the risks and opportunities associated with climate change and make choices that contribute to resilience and sustainability. With climate literacy, individuals can adopt sustainable practices, support climate-friendly policies, and advocate for effective climate action.
3. **Adaptation and Resilience:** Climate literacy enhances the capacity to adapt to climate change impacts and build resilience. It enables individuals and communities to understand the specific risks they face, such as extreme heat, vector-borne diseases, or flooding, and take appropriate measures to mitigate those risks. Climate literacy also facilitates the identification and implementation of adaptation strategies that protect human health and well-being in the face of changing climatic conditions.
4. **Communication and Collaboration:** Climate literacy fosters effective communication and collaboration among various stakeholders. It enables individuals to engage in meaningful discussions about climate change, share knowledge, and collaborate on solutions. Climate literacy also promotes dialogue between scientists, policymakers, health professionals, and the general public, facilitating the development of coordinated efforts to address climate-related health challenges.
5. **Advocacy and Policy Influence:** Climate literacy empowers individuals to advocate for climate-friendly policies and practices. It equips them with the knowledge and skills to communicate the importance of addressing climate change's impact on human health to policymakers, industry leaders, and the wider public. By raising awareness and promoting evidence-based arguments, climate-literate individuals can influence policy decisions that prioritise climate resilience and safeguard human health.

In summary, climate literacy plays a critical role in addressing climate change's impact on human health by raising awareness, enabling informed decision-making, fostering adaptation and resilience, facilitating communication and collaboration, and empowering advocacy and policy influence. It is an essential tool in building a more climate-resilient and sustainable future.

3.2 Aluminium Climate Resilience Engagement Forum

In addition to its role as a platform for the climate literacy resources and assessment tool, the Aluminium Climate Resilience Engagement Forum is conceptualised as a venue for sharing data and experiences.

While the Forum has a user system requiring registration and log-in, so that asset-based assessments can be saved online and accessed by a team of collaborators, it is envisaged that some resources will also be freely shared between assessors and organisations using the Forum. Climate data will be deposited and cross-referenced for future retrieval. Assessors will also have the ability to save their assessments and make them available for other Forum users. In this way the Forum will accumulate knowledge over time and enable assessors to access an ever-increasing pool of experience on climate risk assessment and adaptation in the aluminium sector. An example of this phenomenon would be where one company or site has specific experience in vector-borne disease control, and shares the effectiveness of their controls with colleagues in similar tropical regions where these concerns are important. The tool is designed to be “cumulative” in aggregating new and best practices across the industry and its value chains.

3.3 Tiered Assessment Tool

The tiered assessment tool aims to support the assessment and management of climate-related health, safety, and well-being risks for workers and local communities in the aluminium industry. It allows users to assess vulnerabilities, select adaptation measures, and engage in dialogue within impacted communities.

The concept envisages a tool that is structured to allow the user to employ up to five separate tiers of analytical complexity, as outlined in Table 1. This will accommodate the extremes that are anticipated between data-poor and data-rich assessment situations. The concept of data-poor and data-rich applies broadly, for example, to information available about an asset and its locality, about health conditions in a population, the likelihood and magnitude of climatological hazards and the efficacy of adaptation options.

As a result of using the tool, the user will have some cause-and-effect pathways identified as applicable but not further assessed (tier 1 analysis) while other cause and effect pathways could be extensively assessed (tier 3) or, in some cases, completely characterised for decision support purposes (tier 5). The choice of the level of analysis will be governed at the site level, allowing the user to choose a level of analysis applicable to a particular situation, knowledge level, and resource and expertise availability. In this way, assessments can become more sophisticated and detailed over time, with the addition of experience, expertise and knowledge sharing, and in proportion to the level or risk, and the level of investment being considered.

Furthermore, the tool's capabilities will be gradually expanded over time as industry experience and knowledge accumulate, ensuring ongoing refinement and updating of the tool and its documentation. The aim is to empower decision-makers with comprehensive risk assessments and support the implementation of effective climate resilience measures. The provision of an online tool means that updates to knowledge can be immediately made available across the industry with much less concern about “version-control” that is typical of desktop-based (e.g. spreadsheet, document) sharing approaches.

Table 1. Tiers of analysis available within the assessment tool.

Tier 1: Applicability of Cause-and-Effect Pathways	Users apply their own local knowledge to input relevant cause-and-effect pathways and associated vulnerability factors. The tool provides known adaptation options for mitigating identified risks.
Tier 2: Simplified, Rapid Semi-Quantitative Risk Assessment	Users estimate the likelihood and consequences of applicable pathways using a simplified risk matrix.
Tier 3: Detailed Semi-Quantitative Risk Assessment	The tool offers a more structured and detailed characterisation of impacts and likelihoods using a more granular risk matrix.
Tier 4: Quantitative "Phenomenon-Based" Risk Assessment	For specific pathways with well-characterised relationships between climate variables and impacts on humans, the tool applies climate phenomenon-based modules to allow quantitative predictions of adverse health outcomes.
Tier 5: Estimates of Risk Reduction and Return on Investment	Ideally, the tool provides a comprehensive understanding of risk levels, potential risk reduction through adaptation, associated costs, and return on investment for selected adaptation options.

4. Piloting the Tool at Aluminium Operations

As part of the development and testing of the functionality of the asset-based tool, it has been piloted at dissimilar global locations representing a range of different physical geographies, climate vulnerabilities, and socioeconomic and cultural contexts.

The first pilot was at an asset in the north-eastern province of Maranhão, Brail, in a rural area outside of São Luís. This region is very close to the coast of the Atlantic Ocean, and the relevant facilities are on an island separated from mainland Brazil by bridges of diverse age and construction.

A second pilot involved a coastal location which is in the Middle East and experiences hot desert conditions with high temperatures and limited rainfall. A key element to both case studies is the establishment, among many possible options, of the priority cause-and-effect pathways for which adaptation may be considered viable.

A third pilot vacation (to be confirmed) may involve extreme heat, wildfires, and extreme cold in the same locations, at different times of year. The diversity of regions and cause-and-effect relationships under consideration is a major strength of this initiative.

4.1 Alumar, São Luís, Maranhão, Brazil

Owing to its peri-equatorial location and island-like geography, key climate-related hazards that were addressed by the pilot assessment in this location were vector-borne diseases and flooding potential. This industrial complex encompasses an alumina refinery, aluminium smelter, and a port facility situated in a rural area that draws a workforce from several co-located villages and communities. Roadways, waterways, topography, unique flora and fauna, and – importantly – the sociology of surrounding communities were important elements in framing the climate change health risk profile of this pilot location. Dengue fever epidemiology and prevention strategies were a signature risk concern.

Facility visits consisted of asset-based considerations and, critically, conversation with local community leaders (including teenaged leaders) about the challenges faced by local communities which included climatic, socio-economic and a variety of important risk factors that may or may not be included in the scope of the tool. Additionally, town-hall meetings were conducted in several targeted communities from which the bulk of the asset's workforce derives, and perceived and validated climate change literacy gaps were noted as an important obstacle to overcome.

4.2 Emirates Global Aluminium, Al Taweelah, Abu Dhabi, UAE

This asset is affected by extreme combinations of temperature, solar radiation, humidity, windspeed and other variables such as fog, sand and dust storms. Key climate-related hazards that were addressed by the pilot assessment in this location were ambient heat and water levels.

5. Future Direction

5.1 Extension beyond Human Health

Prior and current work has delivered an online engagement forum, climate literacy resources, and a fully functional assessment tool suitable for utilisation by aluminium producing companies and related stakeholders. This tool helps aluminium industry assets and local communities to identify climate-related hazards of relevance to the specific locality, characterise risk pathways for human health, and identify adaptation measures that may be used to manage risks. The tool has been piloted at diverse global locations representing a range of climate vulnerabilities.

The core objective of future work is to expand the existing tools and materials beyond human health effects to encompass all 'receptors' that are impacted by climate-mediated pathways, so that assessments and adaptation options can holistically address the vulnerabilities of aluminium sector operations and enhance their resilience and sustainability. Anticipated efforts comprise a literature review and survey of aluminium sector companies, to identify and evaluate those additional climatic pathways and receptors that should be added to the Aluminium Climate Resilience Engagement Forum and assessment tool. The output would be an expanded catalogue of cause-effect (or correlation) pathways between climate variables and end receptors that can be acted upon by a climatic variable or other cause. In this way the climate resilience tool would encompass non-human receptors affected by climate change such as capital equipment, transport infrastructure, supply chains, etc.

The tools will also be updated by the addition of further sector-relevant phenomenon-based (e.g. flooding, mosquito-borne disease) modules for higher-tier assessment, where relationships are established in the scientific literature. Future work should also consider the separation of risks related to climate change impacts from those additional risks related to climate change mitigation (e.g. changing source of power generation from bunker fuel to natural gas or hydro generation), and how to address risks to vulnerable workers.

A parallel objective is to enhance stakeholder capacity in climate change related vulnerability assessment and adaptation decision-making, by the provision of training to aluminium sector companies and community leaders. This would be achieved by the development of training content, and design and delivery of live training modules on the use of the tools to conduct climate change risk assessments.

6. Conclusions

Climate change has wide-ranging impacts on ecosystems, weather patterns, and human societies. These effects include extreme weather events, disruptions to agriculture, and risks to human health. To address these challenges, it is crucial to promote and facilitate climate literacy, which involves understanding the causes and consequences of climate change. Climate literacy enables individuals to engage in the climate change dialogue with improved parity, make informed decisions, adapt to climate impacts, and advocate for effective climate action.

In the context of the aluminium industry, climate change poses risks to the health and well-being of workers and local communities. These risks include heat-related illnesses, respiratory disease, vector-borne diseases, air pollution, flooding, and water scarcity. To address these risks, an online engagement forum has been developed, which provides climate literacy resources and a tiered assessment tool. The forum facilitates collaboration and knowledge-sharing among industry stakeholders, enabling them to identify climate-related hazards and develop adaptation strategies specific to their assets and locations.

The tiered assessment tool allows for the identification and assessment of climate-related risks at different levels of complexity. It includes cause-and-effect pathways that link climate change to health outcomes, as well as specific vulnerabilities and adaptation options. The tool helps users evaluate risks and propose adaptation measures to protect workers and communities. It has been piloted in disparate global locations, considering various climate vulnerabilities.

In the future, the aim is to expand the tools and materials beyond human health effects to address all vulnerabilities in the aluminium sector. This includes considering non-human receptors such as infrastructure and supply chains. The tools will be updated with additional climate pathways and higher-tier assessment modules. Moreover, there is a focus on capacity building through training to enhance stakeholder understanding and decision-making in climate change vulnerability assessment and adaptation.

By developing climate literacy, utilising the assessment tool, and promoting collaboration, the aluminium industry can enhance its resilience to climate change, protect the well-being of its workforce, and contribute to sustainable practices.

7. References

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