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Article title: Economic impact of Ebola Virus Disease outbreak on an extractive firm: a case study

Authors: Hisham Tariq, Alexander Light, Logan Manikam, Zia Sadique, Mishal Khan, Alan Knight, Osman Dar
Affiliations: thinklab, the university of salford, united kingdom; centre of disaster resilience, the university of salford, united kingdom[1], department of surgery, university of cambridge, cambridge, united kingdom[2], ucl institute of epidemiology & healthcare, university college london, gower street, london, wc1e 6bt, united kingdom; chatham house, 10 st. james' square, st. james's, london, sw1y 4le, united kingdom[3], department for global health and development, london school of hygiene and tropical medicine, united kingdom[4], arcelormittal, 7th floor, berkeley square house, berkeley square, london, w1j 6da, united kingdom[5], chatham house, 10 st. james' square, st. james's, london, sw1y 4le, united kingdom[6]
Orcid ids: 0000-0001-7246-3651[2]
Contact e-mail: alexanderlight@doctors.org.uk

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UCL Open

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Dear Editorial Team,

We are pleased to submit our manuscript entitled '**Economic impact of Ebola Virus Disease outbreak on an extractive firm: a case study'** for consideration for publication in UCL Open

The West African Ebola epidemic was the most severe public health emergency in recent times. As well as major morbidity and mortality, the epidemic had significant economic implications too. The overall impact on the most Ebola-affected countries, including Liberia, Guinea, and Sierra Leone, was estimated at USD 2.2 billion. Most analysis of the economic impact of Ebola has been at the macroeconomic level. In contrast, there has been little investigation into the economic impact at the microeconomic level. Therefore, we aimed to estimate the economic costs of preventive measures of the epidemic to an extractive firm, ArcelorMittal. ArcelorMittal is the world's largest steel producer and a major extractive firm in West Africa, with a plant in Liberia. Due to the abundance of mineral deposits in countries in West Africa, the extractive industry is key to local economies.

Qualitative methods were used to investigate the sequence of events and channels of impact of the outbreak on the firm, as perceived by employees and contractors. Quantitative data regarding these costs was also collected. The largest cost impact of the epidemic was cessation of phase II expansion, a series of projects designed to increase local iron ore production. The next largest cost was preventive measures adopted by the firm to counter disease spread. The total cost incurred for adopting preventive measures was between USD 10.58 and 11.11 million. Other major costs were external donations to support the humanitarian response (11-12% total costs), and costs of lost productivity (relational costs; 7-12% total costs). We conclude that the response of ArcelorMittal during the epidemic was focused on its employees and its operations, which was then expanded to the wider community, and then in supporting the international humanitarian response.

We believe that the manuscript is appropriate for publication in UCL Open as it represents an important consideration of the economic impact of epidemics, such as Ebola, on individual firms and how these firms respond. We believe it will be of particular interest to your readership.

This manuscript has not been published, nor is it or the data involved under consideration for publication in another journal. All authors have approved the manuscript for submission.

We thank you for your consideration.

Yours faithfully,

The authors

Economic impact of Ebola Virus Disease outbreak on an extractive firm: a case study

Authors

Hisham Tariq[1,2]; h.tariq4@salford.ac.uk

Alexander Light[3*]; alexanderlight@doctors.org.uk; ORCID ID: 0000-0001-7246-3651

Logan Manikam[4,5]; logan.manikam.10@ucl.ac.uk

Zia Sadique[6]; zia.sadique@lshtm.ac.uk

Mishal Khan[6]; mishal.khan@lshtm.ac.uk

Alan Knight[7]; alan.knight@arcelormittal.com

Osman Dar[5]; osman.dar@phe.gov.uk

*Corresponding author

[1]THINKLab, The University of Salford, United Kingdom

[2]Centre of Disaster Resilience, The University of Salford, United Kingdom

[3]Department of Surgery, Addenbrooke's Hospital, University of Cambridge, Cambridge, United Kingdom

[4]UCL Institute of Epidemiology & Healthcare, University College London, Gower Street, London, WC1E 6BT, United Kingdom

[5]Chatham House, 10 St. James' Square, St. James's, London, SW1Y 4LE, United Kingdom

[6]Department for Global Health and Development, London School of Hygiene and Tropical Medicine, United Kingdom

[7]ArcelorMittal, 7th Floor, Berkeley Square House, Berkeley Square, London, W1J 6DA, United Kingdom

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Abstract

Purpose: The Ebola Virus Disease (EVD) outbreak was the most severe public health emergency in modern times. The economic impact of outbreaks has mostly been analysed at the macroeconomic level. Conversely, we aimed to estimate the economic costs of preventive measures of the outbreak to an extractive firm, ArcelorMittal, using data in the outbreak region from March 2014 to December 2015. ArcelorMittal is the world's largest steel producer and particularly important in West Africa, where the extractive industry is economically crucial.

Methods: Qualitative methods, in-depth interviews and focus group discussions, were used to investigate the events and channels of impact of the outbreak on the firm, as perceived by employees and contractors. Quantitative data regarding these costs was also collected. Retrospective cost analysis estimated the actual cost of preventive methods adopted.

Results: Most respondents indicated the largest cost impact was suspension of Phase II expansion, a series of projects designed to increase iron ore production in Liberia. The next largest cost was the preventive measures adopted to counter disease spread. Total costs incurred for adopting preventive measures was USD 10.58-11.11 million. The overall direct costs of preventive measures adopted within the fence shared 30-31% of the total costs incurred. The share of external donation supporting humanitarian response was 11-12% of the total costs, followed by 7-12% of relational costs.

Conclusions: The firm's response during the EVD outbreak focused on its employees and operations, which was later expanded to the wider community and then in supporting the international humanitarian response.

Introduction

The Ebola Virus Disease (EVD) outbreak of 2014 in West Africa was unprecedented, leading to a public health emergency of new scale. The morbidity and mortality impact of the 2014 EVD outbreak was far larger than all previous EVD outbreaks combined [1], and the overall economic impact of the outbreak for the most Ebola-affected countries including Liberia, Guinea, and Sierra Leone, was estimated at USD 2.2 billion [2]. The economic impact of outbreaks has frequently been reported at the macroeconomic level, that is an impact affecting the aggregate economy of a country. However, there has been relatively little investigation into the effect outbreaks can have at the microeconomic level on individual market participants, such as those in the extractive industry [3]. This industry comprises firms that extract raw materials from the earth, and is very important to the economies of West African countries, where EVD outbreaks are most likely [4].

Extractive projects put workers at high risk of exposure to pathogens such as the Ebola virus. These projects are frequently associated with increased contact between wildlife, humans and domestic animals, a major risk factor for the emergence of infectious disease [5]. The EVD crisis therefore posed a major economic threat to mining operations and future mining investments in the region. This threat was compounded by changes in market conditions, including a decrease in the global price of iron ore.

The Ebola virus epidemic reportedly began in West Africa during late 2013. It started in Guinea and spread at an alarming rate, quickly involving Liberia, Sierra Leone, Nigeria, Senegal, and Mali [5]. This is the first EVD outbreak to reach epidemic proportions; previous outbreaks were localised and were brought under control within a few weeks using methods such as effective reporting, contact tracing, and quarantine [6]. On August 8 2014 the World

Health Organization (WHO) declared the outbreak to be a 'public health emergency of international concern' and later the most severe acute public health emergency seen in modern times [7-9]. The outbreak was eventually halted, with transmission now effectively contained within the region. Since 2015 only isolated cases have been reported in Sierra Leone, Guinea, and Liberia [10-13].

Countries in West Africa are rich in many mineral deposits including alumina, bauxite, cement, diamond, gold, mineral sands, and iron ore [14,15]. The iron ore industry in particular has played a key role in the economic growth of Liberia and Sierra Leone, contributing heavily to their economies over the last few years [2,14]. Mining, a critical sector, has been affected by the EVD outbreak directly through expansion delays, lack of new investment, absence of technical expatriate staff and perception issues that have made it difficult for mining companies to raise necessary capital [16]. This has been exacerbated by a concurrent decline in the global price of iron ore. Due to the importance of mineral deposits to the economies of these countries, the extractive sector is an important industry to consider within the larger economic impact of the EVD outbreak in affected regions. How these regions are affected by the outbreak, and how they respond to the outbreak by adopting preventive measures, has potential economic consequence on the extractive industry and overall economies in the Ebola-affected region. One major firm within the extractive industry is ArcelorMittal, a multinational company headquartered in Luxembourg. Being the world's largest steel producer [17], the firm had planned a series of projects in Liberia known as Phase II, worth USD 1.7 billion. These projects aimed to expand iron ore production for AccelorMittal from 5.2 million to 15 million tons per annum. ArcelorMittal was significantly involved in developing EVD outbreak infrastructure in the region, and was recognised by the Clinton Global Initiative for its swift and collaborative response [18].

In this context, it is important to collate the channels of impact of EVD outbreak on the operations of the extractive sector and estimate the costs of preventive measures that were put in place. This study was therefore designed to estimate the economic costs of preventive measures of the EVD outbreak to ArcelorMittal and its subsidiary ArcelorMittal Liberia, using data from a case study based in the outbreak region. This study aims to analyse the perception of staff and contractors of the firm on the channels of economic impact of the EVD outbreak on the operational cost of the firm, and estimate the actual costs incurred by the firm for preventive measures adopted during the EVD outbreak period.

Materials and Methods

Study setting and design

The case study was based on ArcelorMittal and its subsidiary ArcelorMittal Liberia. The study applied mixed methods to assess the impact of the EVD outbreak on the case study firm with particular emphasis on quantifying the total costs of the preventive measures taken by the firm during the EVD outbreak period from March 2014 till December 2015. The study used qualitative methods to investigate and map the sequence of events and channels of impact of the outbreak on the firm, as perceived by its employees and contractors. The quantitative data was extracted from interviews, financial documents and other materials provided by ArcelorMittal and its employees. This data was further validated in group sessions with relevant AM personnel.

Informed by the qualitative analysis and the quantitative data collected from the finance department of ArcelorMittal Liberia, the study estimated the actual cost of the preventive measures both 'within the fence' and 'outside the fence' that the firm had adopted during the outbreak period.

Data collection and data management

The study used in-depth interviews (IDIs) and focus group discussions (FGDs) to collect qualitative data. In order to facilitate and guide IDIs and FGDs, guidance notes were prepared in advance (Appendix A, Appendix B). IDIs were conducted in English and lasted approximately 45 to 60 minutes. FGDs were conducted in English and lasted almost an hour, consisting of 5 to 7 participants. Participants in IDIs and FGDs were asked for consent before digitally recording their responses. All paper and soft copies of field notes, audio files, contact summary form, enrolment forms, consent forms and any other notes were kept securely. The

digital formats of IDIs and FGDs were anonymised, password protected and saved in a secured location.

Through the IDIs, respondents were asked to list what they believed were the most critical systems impacted within the firm by the EVD outbreak and, if applicable to them, were asked to provide information on how the cost structure within the firm may have been affected accordingly. Questions were asked about the preventive measures taken by the firm, their knowledge and opinion about the implementation of those measures and their understanding of how it may or may not have impacted their particular work. If known to them, the costs of those measures were also asked about. Detailed data on the costs components identified in the qualitative study were sought from relevant departments of the firm.

Analysis

Qualitative analysis

The study used interview data to identify major sources through which the outbreak impacted the different aspects of the firm's operation and consequent operational costs. Respondents were asked to list and rank what, in their opinion, were the three major cost impacts of the EVD outbreak on firm's operations. It was assumed that there were opportunity costs of staff time devoted to deal with the outbreak. Relational costs of the EVD outbreak, the costs indirectly arising from the impact of the EVD on operations of the firm, was investigated using data from qualitative interviews. The interviews were transcribed individually into Microsoft Word documents using ScribePro and analysed thematically using content analysis to derive the main concepts about the perceptions of the employees as well as key information about the decision making within the firm.

Analysis of Quantitative data released by the firm

A retrospective cost analysis was performed from the firm's perspective using the financial information extracted from the interviews, focus group discussion and the financial documentation provided by AM. This entailed a detailed look at the cost and expenditures data shared by the various departments of the firm – tabulating them chronologically and cross checking between sources to ensure consistency and accuracy. The policies, their costs and impacts were validated in further group sessions with participants, who had knowledge about financial expenditures, at the end of the study. Similarly, the opportunity costs of the relational items were quantified using wage data of the firm obtained from both qualitative interviews and quantitative data.

Results

Table 1 shows the number and composition of the sample of respondents interviewed across different locations and occupational categories within the firm. Although a cross section of employees was taken in the study, more interviews were taken of those in management and finance than other departments due to their role in decision-making within the firm, their knowledge about costing information, and their access to financial data. Most respondents were from senior management and had considerable industry experience.

Qualitative data

Cost impacts

Fig.1 shows the major cost impacts of the EVD outbreak as perceived by respondents. The majority of the respondents (*n*=16/94, 17.0%) indicated that the suspension of Phase II expansion was the largest cost impact on the firm. The next largest perceived cost impact (*n*=15/94, 16.0%) was the preventive measures adopted by the firm to counter the spread of Ebola followed by external donations mentioned as the third largest cost impact (*n*=11/94, 11.7%). Respondents also indicated a number of other sources of impacts which include impact associated with administrative issues, loss of efficiency due to temporary redundancies, and hazard pay.

Phase II expansion

Though not a preventive measure, the suspension of Phase II expansion was cited the most times (*n*=16/94, 17.0%) by respondents. The project is placed on hold till further notice by the firm, more due to the international market price of iron ore than the after effects of the Ebola outbreak. The resultant loss in overall production and revenue has significantly im-

pacted both the firm and Liberia itself. The assessment of what the total costs of this suspension is beyond the scope of the study. Respondents mentioned that one reason for the suspension of Phase II in 2014 may have been due to airlines ceasing services to Monrovia, the capital city of Liberia:

"The [Phase II] construction was impacted because our contractors had to leave…some of them…because of Ebola fear…they did not leave because of Ebola but because of the restrictions put on travel…and they did not want to be hemmed in."

Force Majeure, when unforeseeable circumstances prevent a contract from being fulfilled, was declared, with contractors pulling out of Liberia in August and September of 2014. Although the EVD outbreak may have been responsible for the series of events that led up to this declaration, the situation was different in 2015. The mining firm decided to delay and eventually to temporarily suspend the expansion which may have been due to the tough international market conditions for iron ore in that year (2015).

"The 2014 dates [of Force Majeure] were more driven by the contractors themselves saying…you know we are pulling out…this [risk] is not acceptable to us - 2015 was more I suppose driven by the firm in the sense that we were actually calling the suspension to the project…but one kind of fell after the other…it was a bit of a domino…but certainly you know if Ebola had not come in theory we would have…you know those months we lost we would have had contractors on the ground and they would have been constructing and we would have been further down the road then we are now."

Preventive measures

A quick response, consultant costs and training

A number of the major cost impacts that were pointed out by the respondents were part of the package of preventive measures that the firm adopted over the outbreak period. A number of respondents had the opinion that one of the factors that separated the firm from other extractive industry members was the proactive nature of the firm in seeking information from a world renowned health expert in the field. The health expert spent three crucial weeks of April 2014 in Liberia and advised the firm on preventive measures while collaborating with International SOS, a medical and travel security services firm, in developing their medical response to the outbreak. This intervention was important for ArcelorMittal both as a tool for the internal communication of risks within the organization and for providing insight into strategies to safeguard their employees, the concession and the communities around it.

Social awareness campaign and programs

Risk communication materials developed during this initial phase helped the firm in Liberia to distribute large numbers of printed material across their concessions initially targeting employees, their families and then the wider community at large. The respondents indicated that there were additional roles they had to conduct during the outbreak period. These roles included conducting a social awareness campaign on Ebola, delivering hand washing buckets and sanitizers and other activities within these communities. This was particularly for those communities inside or in close proximity to the concessions.

Screening and fencing, and Ebola treatment unit

Temperature screening and access control were some of the first steps recommended by experts and was quickly employed by the firm in Liberia throughout the concessions. The health and safety culture already prevalent in the firm, in addition multinational extractive

firms in general having to follow international standards, may have contributed to the swift implementation of temperature screening and fencing protocol. This, as reported by several respondents, was tested on several occasions when incidents of suspected Ebola persons, later on confirmed as Ebola cases, almost entered into the concessions. During the outbreak, the firm in Liberia built and maintained Ebola Treatment Units (ETUs) at significant cost, as perceived by its employees. This entailed construction of two new buildings specially designed and equipped to handle three confirmed Ebola patients each.

Human resource policies – hazard pay and evacuation of non-essential staff

A number of human resource policies were enacted during the outbreak that had significant cost implications for the firm. Two specific policies were indicated in the interviews, hazard pay policy and the non-essential staff (NES) policy. The hazard pay policy was costly because of the number of employees that qualified for it. In effect, all those who were classified as essential would receive it. In addition to this extra cost of production, those employees who were sent home were also paid a salary, but at a reduced rate, incurring additional costs for the firm. Another significant cost impact was the NES evacuation flights arranged for expatriates and NES, which was triggered after most international airlines cancelled their flights to and from Monrovia. A number of respondents indicated that the largest cost impacts on the firm's operations must have been the NES policy that the firm enacted in August to September 2014.

Relational costs and the emergency management team

Some respondents indicated that there was an administrative productivity loss (relational costs) due to the preoccupation with EVD management and as a direct result of some preven-

tive measures taken. In early 2014, the firm began reviewing and updating emergency management plans in Liberia in case of major security incidents or natural disasters. The firm had decided at that stage to develop emergency management teams (EMTs) in Liberia as part of a crisis management infrastructure within the firm. These team consisted of senior management and other concerned staff, as dictated by the needs of the crisis, and would be enacted on an emergency by emergency basis. These EMTs played a crucial role in responding to the EVD outbreak as there was a crisis management structure which the firm in Liberia could build then on and link to a central EMT located in London.

"Even before the outbreak… in Liberia…so for example if we had a major security incident or natural disaster…anything…we could manage it effectively from the company side. So we put in place what was called an Emergency Management Team… really all they consisted of was a lot of the head of departments from the CEO on to Health & Safety, Security, Communications and Medical."

The EMTs connected daily for several hours a day for the duration of the outbreak and played a key role in the decision-making process, with regards to what preventive measures were to be taken and when. These meetings of senior management and staff for several hours a day for the peak months of the outbreak had significant cost implications.

The qualitative interviews suggest that on average senior management spent 1.5 hours per day during the peak Ebola period (August to November 2014), followed by 1 hour daily during the off-peak outbreak period (December 2014 to June 2015) and 0.2 hour daily during the super off-peak outbreak period (July to December 2015). In the base case, only staff time of

senior management is costed to value relational costs. The daily hours spent by senior management on Ebola related activities during peak and off-peak period varied between upper (1 hour during peak, 0.5 hour during off peak) and lower limit (2 hours during peak, 1 hour during off peak) as indicated in the qualitative interviews. We have also evaluated time costs of all other employment categories to predict possible relational costs when outbreak affects staff time and productivity across the board. It was assumed that all other workers spent on average 0.2 hour per day on Ebola related activities over the outbreak period (August 2014 to December 2015).

Supply chain

One of the crucial impacts of any disruption is on the supply chain of the firm. However, this could not be documented through quantitative means. The outbreak caused considerable issues with logistics and this is confirmed in interviews with members across several departments within the firm. The respondents indicated that some of the extra costs and bottlenecks in operations were a direct result of issues in supply chain and logistics. This is especially true for a firm in the extractive industry working in conditions like Liberia where most supply items, if not all, are imported from other countries.

Ebola-related construction costs

During the EVD outbreak, the firm also incurred additional construction costs for mining activities while maintaining the security and safety of its workforce in light of risks related to Ebola transmission. These costs were incurred from constructing gates, installing washing stations, and building fencing as safety measures adopted to fight Ebola.

Other costs items

Qualitative interviews investigated whether there were additional costs of the outbreak from shut-down, transport costs, insurance payment, and supply chain items attributable to the EVD outbreak. The responses of key staff of the firm suggested no additional costs were incurred from any other items in addition to those already included in this analysis.

Quantitative data

Cost impacts

The main sources of actual costs impact were (a) preventive measures adopted in the firm's concession areas and raising awareness in the adjacent community, (b) in-kind donations of priority materials and direct support to national and international engagement in the health and humanitarian crisis, (c) Ebola-related construction costs, (d) additional salary paid to workers as hazard pay during the outbreak period, and evacuation of NES. There were other costs, including the lost productivity from workers' engagement with safety and health measures during the outbreak period. The total preventive costs of the outbreak incurred by the mining firm were mainly driven by direct costs and relational or productivity costs as reported in Table 2. The total preventive costs of outbreak were in the range of 10.58 million USD to 11.11 million US.

The overall direct costs of preventive measures adopted within the fence shared 30-31% of the total costs incurred (Table 2). The share of external donation supporting humanitarian response was 11-12% of the total costs, followed by 7-12% of relational costs. Construction-related costs comprised 14-15%, salary comprised 23%, and evacuation of non-essential staff comprised 11-12% of total costs.

Preventive measures

57% of preventive costs were incurred from payment to consultants (International SOS) and training for laying the security and safety measures in place (Fig.2). Costs of building an ETU for treating suspected or infected cases were 31% of the total preventive costs. Costs related to screening of everyone entering the site and building social awareness in the adjacent community was 12% of total preventive costs.

Donations and direct support to health and humanitarian crisis

The mining firm made donations to the international public health and humanitarian response communities for supporting prevention and treatment of Ebola. The costs related to donations and support to external Ebola response was approximately USD 1.27 million. The major share of external support was for supporting response towards eradication of EVD, followed by building an isolation centre, donations towards ambulance services, contract tracing, machinery and capacity to construct external ETUs, as well as other essential medical supplies (Fig.3). Donations also included supplying fuel, preparing burial grounds, and other preventive actions (screening, quarantine support and installing a scanner at the airport).

The firm provided external support to many Ebola initiatives around community. The largest share of external support was provided to support Red Cross activities (56%), followed by providing funds for the regional county task forces formed at the local government level to deal with the epidemic (28%), hospitals (11%), county/township services not covered under the taskforce roles (4%) and other beneficiaries including airport, police and other government departments (1.2%).

Human resource policies – hazard pay and evacuation of non-essential staff

The firm paid hazard and incentive payment to the workforce to help maintain a stable supply of workers during the outbreak period. The costs of additional salary payment during the outbreak totalled USD 2.41 million. The cost of evacuation of expat and NES was USD 1.27 million.

Relational costs

Based on the distribution of workforce and hourly wage rate across employment category (Table 3), the costs of lost productivity was in the range of USD 0.78 to 1.30 million.

Ebola-related construction costs

These additional construction-related costs totalled USD 1.56 million.

Discussion

Cost impacts

The magnitude of actual costs incurred by the firm largely conformed to the perceived costs identified by the respondents in the qualitative study. The actual cost of preventive measures and reduced productivity incurred by the firm was in the range of USD 10.58 to 11.11 million (Table 2). This range is attributable to partial data availability, as well as different perspectives within the form on lost productivity and, also the expenditures on addressing productivity over the period. Estimates on productivity loss are difficult to obtain accurately especially during a complex event like the EVD outbreak and it must be noted that the team had difficulty in obtaining the financial data in its entirety. The largest cost was generated from preventive health outlays and other containment measures implemented on the mining concession and the community. The second largest costs were incurred from additional salary payments and evacuation of NES, followed by Ebola-related direct construction costs, external support towards Liberia's efforts to contain, treat and eradicate Ebola, and reduced productivity due to the EVD outbreak.

The respondents in the qualitative interviews identified Phase II expansion as the largest costs impact of the EVD outbreak on the firm, followed by preventive measures, external donations, consultant fees, ETU construction, and hazard pay. In the quantitative costing, the researchers were unable to estimate the costs associated with Phase II expansion. However, for the other items listed, the actual costs incurred largely conformed to the perceived costs. It also needs to be highlighted that the low iron ore prices over the period likely added to the uncertainties stemming from the EVD outbreak on business continuity and expansion of iron ore mining.

Minimising disruption privately and publicly

The study shows that there was a system in place in ArcelorMittal Liberia for early monitoring of threats such as disease outbreaks. Despite this, Ebola was identified as a potential emerging infectious disease (EID) risk only when it was confirmed in Guinea in March 2014. By this time, Ebola had already spread to Liberia. For organisations to be resilient they need as much lead time as possible before a disruption, in order to develop and implement measures that can help prevent or mitigate the impacts of a disruption on its business activities. This is especially true for EIDs that can spread unnoticed in a human or animal population for a significant period of time before being detected.

Interviewees felt that one of the factors for continued operations of the firm in Liberia during the EVD outbreak was the role attributed to communications in its corporate culture [19]. Effective communications plays a role throughout the risk management process especially when there is uncertainty in outcomes [20]. In accordance, our qualitative data indicates that ArcelorMittal Liberia effectively used risk communication in the implementation of preventive measures at different levels ranging from community social awareness programs to industry collaboration in the form of the EPSMG and its campaign for a coordinated international response to the EVD outbreak. We recommend that firms develop training programmes in crisis coordination for communication departments at both local and international levels that will improve the ability of firms in the extractive industry to respond to a disruption. Inclusion of ArcelorMittal communication staff in EMTs at the earliest stage is an example of what role effective communication can play in reducing fears of employees in the initial stages of an outbreak.

Private firms in the extractive industry also typically have operations in remote locations, like the border areas of Nimba County in Liberia, and can therefore play a vital role in the early detection of EIDs if connected to local health systems. This is in the interest of both the public and private sectors to increase preparation time for mitigation strategies that can limit the extent of impact of the disruption [21]. The implementation of a EID early warning system would ensure that disruptions to business continuity from EIDs could be minimised. This could only be done if these extractive firms are integrated into local health systems. This requires active public-private collaboration on sharing information towards developing an effective warning system and consequent control measures.

Supporting the community

The timeline of the ArcelorMittal's response demonstrates that the firm was engaged in prevention, building and strengthening EVD outbreak control infrastructure, for example Ebola screening mechanism and ETUs (Fig.4). These developments were within the concessions and, to a certain extent, in the wider community. These developments also occurred at a time when the firm's contribution to the outbreak response was extremely important, well before the international community's response. The Ebola Private Sector Mobilisation Group (EPSMG), initiated by ArcelorMittal, had also participated in international advocacy for a global response to the Ebola outbreak at the UN and other forums, and contributed to the mobilisation of in-country private sector resources to support the humanitarian and healthcare efforts [22].

To put these expenditures on preventive measures and external donations in context to the outbreak, Fig.4 describes the chronology of when and where these expenditures were made as indicated in the interviews and quantitative data. The quick response by the firm in question

in bringing in expertise within a week to help increase disease understanding is seen here as the first step towards developing and adopting a medical approach to the EVD outbreak. Many respondents of the qualitative study indicated that by early adoption of recommended measures, like social awareness campaigns and temperature screening, the firm was reacting proactively regardless of the mortality and morbidity rates prevalent in Liberia at the time. The timeline of the firm's response also shows that when the number of cases per week increased in June and July 2014, the firm in Liberia already had systems in place to continue its production. This commitment to be operational allowed it to be in a position to help the communities it was based in to combat the outbreak by contributing to the building of critical EVD outbreak control infrastructures when they were needed most at the peak of the outbreak well before the international community's response.

The timeline of response shows that the firm started by adopting timely preventive measures to protect its employees and operations. The success of the firm's response in maintaining the site Ebola-free led it to expand its support to humanitarian response in partnership with government and non-government organisations.

Recommendations

There are several recommendations that can be made following this case study. Firstly, Due to the importance of effective communication in the risk management process, we recommend that firms train their communications department to manage crisis coordination.

Private firms like ArcelorMittal should also adopt early warning systems to monitor for critical events such as disease outbreak, with particular emphasis on being able to identify the potential impact EIDs before it is too late. Integration of such a system into the local community

and health system would also minimise the public impact of an outbreak. This requires significant collaboration and information sharing between public and private sectors in order to create this system. Being able to act early and proactively allows firms not only to protect their own operations but also allows firms to commence and support their humanitarian response earlier and more productively.

Strengths and limitations

This study's strengths are largely related to its practical applicability in the industry. The study was set in the real-world mining firm context. The views of the experienced mining staff have strengthened the study by providing a balanced and representative view of how an outbreak can affect mining operations, and how a future crisis could be handled. The study was able to report on direct costs on preventive and mitigation measures incurred by the firm over the course of the outbreak.

This study also has several limitations. First, the study was conducted while the outbreak was continuing and ArcelorMittal was experiencing economic downturn, not only because of the outbreak but also due to falling commodity prices in the international market. Second, this study was designed to capture the effect of outbreak on both direct and indirect costs, especially the effect on supply chain items and future expansion projects, but it was not possible to obtain sufficiently detailed data to estimate such costs. Third, the qualitative and system analysis was limited by the availability of the key respondents during the study's timeframe. These limitations stemmed largely from a high turnover of finance office and senior management staff over the course of the study, as well as a large number of redundancies, particularly in the finance division, which the company had to incur at the end of 2015.

Conclusions

The cost incurred by the mining firm for adopting preventive measures during the 2014-15 EVD outbreak was in the range of USD 10.58 million to USD 11.11 million. The response of the mining firm during the EVD outbreak was focused on its employees and its operations, which was then expanded to the wider community and then in supporting the international humanitarian response. This was important to building and strengthening the Ebola response infrastructure of Liberia to make a concerted effort to fight the epidemic. There are several recommendations that can be made to private firms following this case study. This includes introducing crisis communication training and creation of an early warning system for events such as EID outbreaks. Importantly, such a system should be integrated into local community and health regimes in order to minimise the public impact of an outbreak. Due to a paucity of studies examining the macroeconomic and especially microeconomic impact of Ebola, further research would help strengthen understanding of the economic impact of endemics and how firms and economies can best manage outbreaks.

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Legend

Fig.1: Major cost impacts as perceived by respondents.

Fig.2: Percentage distribution of costs related to preventive actions adopted on site and adjacent community.

Fig.3: Costs of external support by activities.

Fig.4: Ebola cases per week and the chronology of preventive measures and external support.

Table 1: Sample size and composition.

Table 2: Costs of preventive measures.

Table 3: Distribution of workforce and wage rate.

Fig. 1: Major cost impacts as perceived by respondents

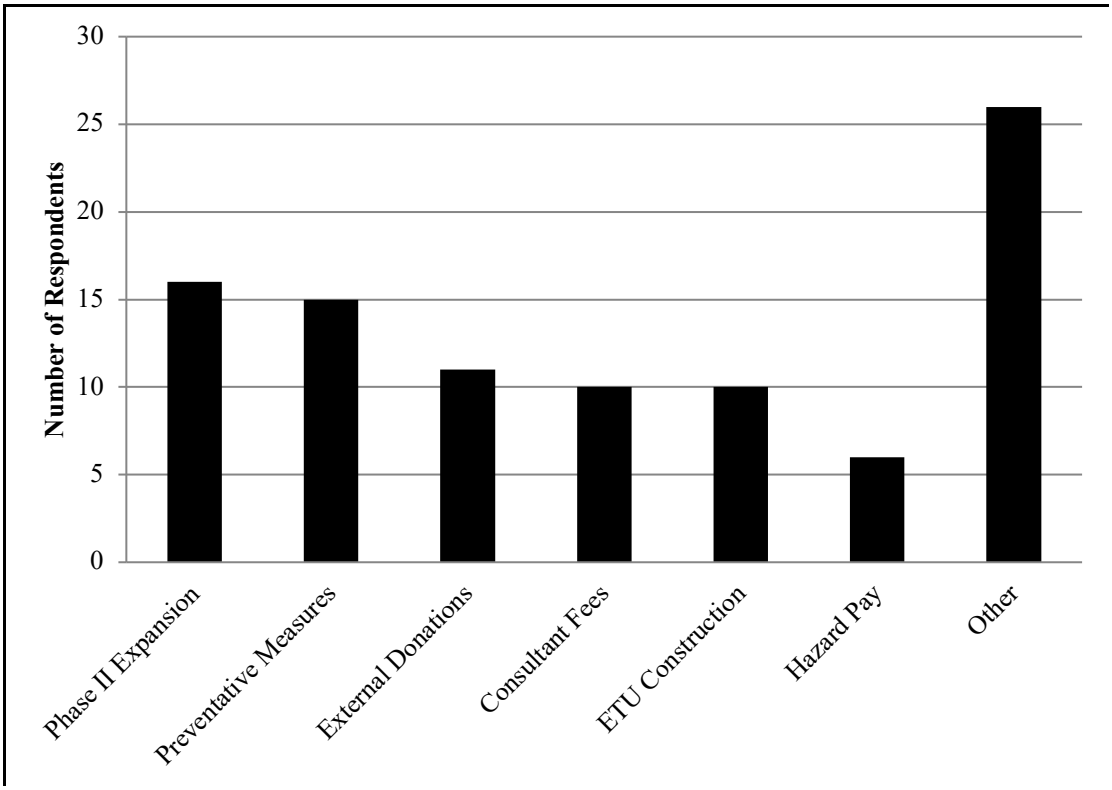

Fig. 2: Percentage distribution of costs related to preventive actions adopted on site and adjacent community

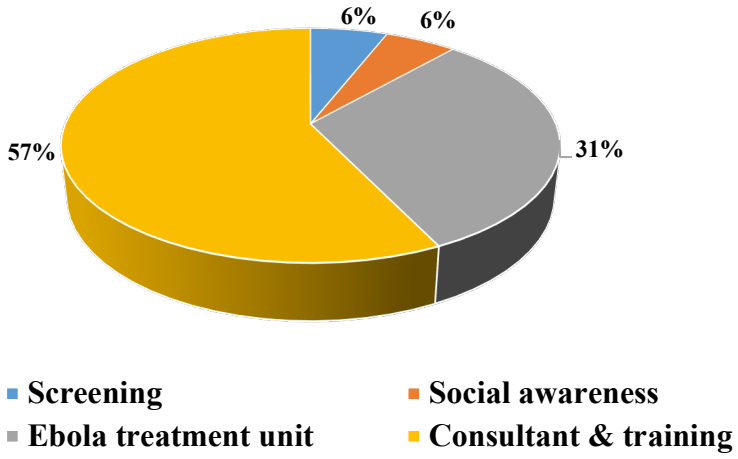

Fig. 3: Costs of external support by activities

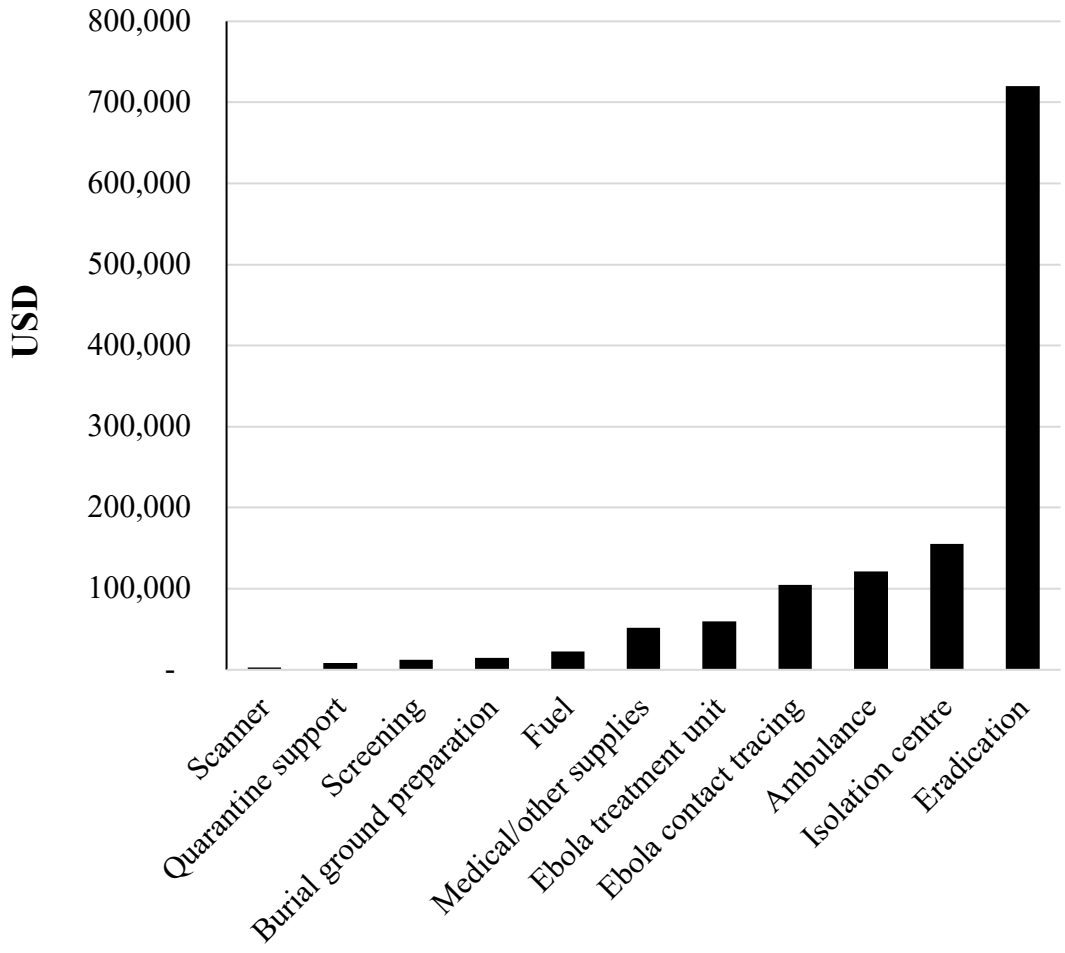

Fig. 4: Ebola cases per week and the chronology of preventive measures and external support

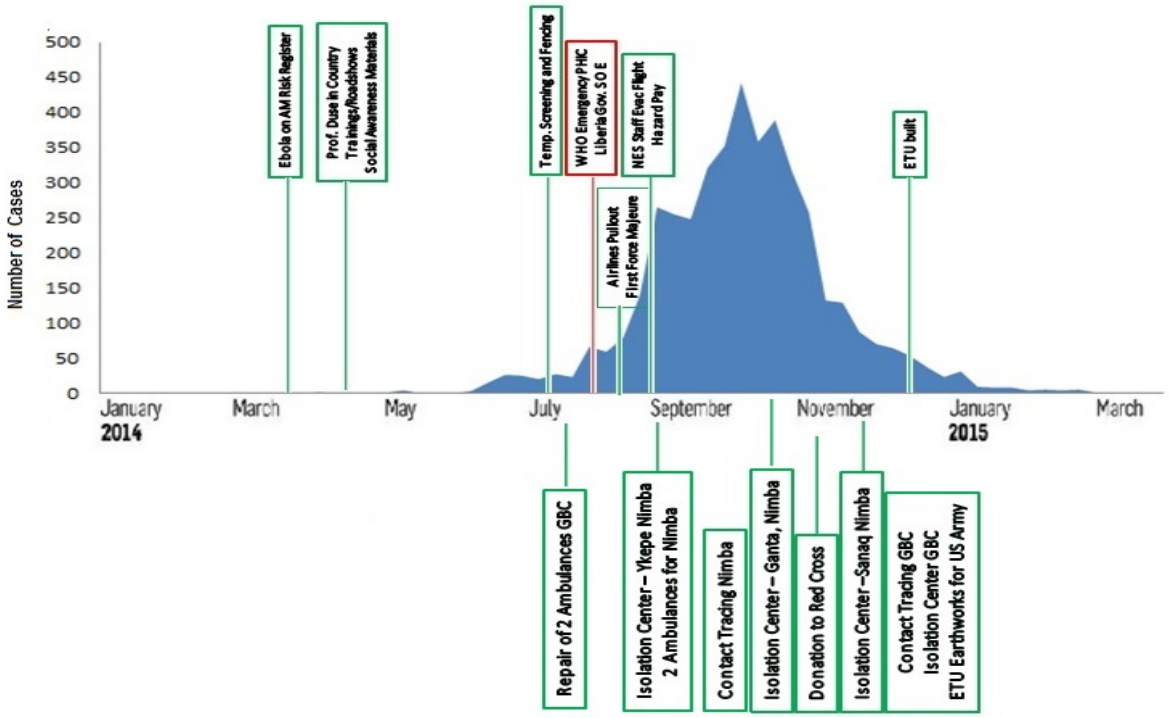

Table 1: Sample size and composition

Occupational Category	London	Liberia	Total	Remarks
Senior Management[a]	7	7	14	Workshop conducted with 6 executives from London
Professional, Administrative and Technical Management (PATM)[b]	1	5	6	In Liberia: IDIs with 7 expatriates and 9 locals 1 FGD with expat contractors
Skilled[c]		4	4	1 FGD with Liberian employees
Total	8	16	24	Skilled and unskilled

[a]Recruited from the following departments: communications, corporate responsibility, finance, human resources, supply chain/logistics, health & security and government relations.
[b] Recruited from the following departments: administration, risk management, environment, health & safety, supply chain, security, and transport.
[c]Recruited from the following departments: estate, maintenance, port, mine, rail, security, and transport.

Table 2: Costs of preventive measures

Costs	**Estimated USD (in million)**
Within the fence preventive measures	3.29
External donations	1.27
Construction related	1.56
Salary	2.41
Evacuation of non-essential staff	1.27
Relational	0.78 to 1.30
Total costs	**10.58 to 11.11**

Table 3: Distribution of workforce and wage rate

Employment category	% of total work-force [a]	Hourly wages
Senior management	1.2	150.0[a]
PATM	14.6	6.0[b]
Skilled	72.4	4.7[c]
Unskilled	11.8	3.7[d]

[a] Obtained from qualitative interview.
[b] Calculated from average monthly salary of employees working in following departments: communications, corporate responsibility, finance, human resources, information technology, legal, school, and technical services.
[c] Calculated from average monthly salary of employees working in following departments: administration, environment, health & safety, and supply chain.
[b] Calculated from average monthly salary of employees working in following departments: estate, maintenance, port, mine, rail, security, and transport.

Appendix A: Interview guide for in-depth interviews

Specific dimensions/topics	Questions	Suggested probes
Introduction/background	1. Please indicate what is your designation /department that you belong to and describe the nature of your role in the company as well as your main responsibilities and duties. 2. How long have you worked in this company? How long have you worked in the mining industry? 3. Did you work in the industry during the current outbreak period? Where exactly and for how long?	- How many countries or sites do you manage? - Is the company centralised or is decision making devolved to the sites? - Did your roles and responsibilities change in any way during the outbreak?
Risk and vulnerability	4. Can you describe any past experiences of disease outbreaks or illnesses in your mines in Liberia or other mining sites where you have worked? 5. How serious are these diseases for the company and local communities? Please give examples of their impacts.	- What happened? - What kinds of situations make these diseases more or less likely?
Systems Affected by Outbreak	6. Can you please list, to the best of your knowledge, which aspects of the mining operations were most affected during the Outbreak? (List and rank)	- Production - Mining Capacity - Human Resources - Health & Safety - Why do you think this was the most affected?
Production	1. Can you please describe how production was affected during the outbreak? (List and rank if more than one way) 2. What were the added challenges of operating	- Compare to normal operations previous to the outbreak - How was the Production Rate affected? Production Goals? Daily/Weekly/ Monthly data?

	in an outbreak environment	- How were inventory levels affected? - Did this significantly affect order rates/order fulfilments?
Factors of Production (INPUTS)	3. How were the costs of Production affected? 4. How were supply chains of inputs affected?	- Of local inputs - Of inputs being brought in from abroad - Rental/repairs - Any Critical blockages that were affected for key inputs - Petroleum/chemical products etc.
Transportation and Shipping (Logistics)	5. How was transportation of iron ore affected during the outbreak? 6. How was the shipping rate affected, if at all? 7. Other aspects of logistics that affected mining operations during the outbreak	- Freight costs - From sites to inventory/ warehousing site - Trade restrictions/border crossings etc.
Mining Capacity	1. Can you please describe how in your understanding the mining capacity, or expansion, was affected by the outbreak? (List and rank if more than one way) 2. In your opinion, what effect would the outbreak have on the ability of ArcelorMittal to attract future investment for mining capacity expansion? 3. Capital Expenditures 4. What role do foreign subcontractors play in mining capacity expansion?	- How were expansion goals/ planned capacity additions affected? - How was exploration affected, if at all? - In Liberia - In West Africa - In areas more susceptible to EIDs - i.e. any up gradation of plant machinery, equipment and/or other capital

		intensive expenditures affected
Human Resources	1. What effect did the outbreak have on the human resources available to ArcelorMittal and its mining operations? 2. How did you/your firm mitigate it/cope? 3. Was productivity compromised? If so then at what levels and how? 4. Were there any changes in the decision making structure of your firm during the outbreak – creation of new roles/departments etc.? 5. Change in Standard Operating Procedures?	- Number of workers/ level of absenteeism - What major reasons for absenteeism? transport, fear, taking care of relatives - Hiring additional workers - Training - Increasing workloads/ more overtime - financial incentives - productivity - skilled vs unskilled - domestic vs foreign - Senior management productivity/ outbreak response/workloads - Time allocation being affected vs normal - Changing roles/shortages of key personnel - For special areas/locations - For special types of activities
Health and Safety Systems	1. Can you please describe how Health and Safety has been affected, if at all, by the current outbreak? (List and rank if more than one way) 2. How has this affected your personal commitment to safety? 3. How might have both these factors affected the incident rate of Ebola infections?	- Compared to pre-outbreak period - Management commitment to safety/Time taken to respond - Living under outbreak conditions - Risky behaviour - Rate of other Incidents
	4. Can you describe any ways you have heard of	- Are there any measures that can be taken at the

	(or been personally involved in) for preventing diseases that come from animals. 5. Are any of these preventive approaches currently being used in your mining areas, in Liberia and elsewhere? a. Why or why not? 6. What health services or facilities does ArcelorMittal provide on-site for its employees? 7. What additional health services or facilities has ArcelorMittal been able to provide during this outbreak? 8. During the ongoing outbreak has this preventive been scaled up? if so then by how much 9. How effective do you feel are the preventive measures taken by ArcelorMittal? 10. How have these measures affected your morale and of the employees working in outbreak areas?	mine itself to avoid outbreaks? - Training activities - Screening - Temp checking Are there any issues around: - Costs - Logistics - Skills - Manpower - Equipment

Appendix B: Guide for focus group discussions

Specific dimensions/topics	Questions	Suggested probes
Introduction/background	1. Please indicate what are your designations /departments that you belong to and describe the nature of your role in the company as well as your main responsibilities and duties. 2. How long have you worked in this company? How long have you worked in the mining industry? 3. Did you work in the industry during the current outbreak period? Where exactly and for how long?	- How many countries or sites do you manage? - Is the company centralised or is decision making devolved to the sites? - Did your roles and responsibilities change in any way during the outbreak?
Risk and vulnerability	4. Can you describe any past experiences of disease outbreaks or illnesses in your mines in Liberia or other mining sites where you have worked? 5. How serious are these diseases for the company and local communities? Please give examples of their impacts.	- What happened? - What kinds of situations make these diseases more or less likely?
Risk Perception	6. How likely is it that there might be an incident of a worker infected with Ebola in the next year 7. How serious would it be for an employee or a worker to get infected by Ebola in the next year 8. How likely do you think it is that an employee or worker will get infected by Ebola in the next year compared to other firms working in the same area	- In general (London) - Local site (Liberia) - Magnitude question try to get answer in a scale out of 100 - Elaborate as much as possible by using "why" when getting a response from the respondent

	9. Do you think that people in general are informed and can take actions to prevent getting Ebola?	- Locals - Families of employees
Current outbreak risk	10. How many incidents have there been of workers from your firm getting infected during this current outbreak? 11. How severe is this outbreak (compared to any previous ones you may have experienced)? 12. What was/is the probability of an employee being infected in this outbreak? A close family member? 13. How confident are you that workers in your firm can prevent getting infected by Ebola? 14. How effective has the government been in addressing the current outbreak?	- General outbreak - Locality (if in Liberia) - Locals - Families of employees - Subcontractors/foreign workers - Employees in other sectors - Government commitment to safety of citizens - Time taken for response - Response/actions taken
Knowledge and Sources of Information	15. How much do you know about the Ebola virus? 16. What are the main sources of information about Ebola and what source to you trust the most? (list and rank if more than one)	
Systems Affected by Outbreak	17. Can you please list, to the best of your knowledge, which aspects of the mining operations were most affected during the Outbreak? (List and rank)	- Production - Mining Capacity - Human Resources - Health & Safety - Why do you think this was the most affected?
Causal Loop Diagrams	18. Please comment on the CLD diagram(s) that the research team have developed.	Discussion

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

The datasets generated during and/or analysed during the current study are not publicly available due, but are available from the corresponding author on reasonable request.

Competing interests

Alan Knight is the general manager of ArcelorMittal. All other authors declare no competing interests.

Funding

None

Authors' contributions

HT and AK performed data collection and analysis. HT, AL, and LG drafted the manuscript. LM, ZS, MK, AK, and OD supervised the project. All authors read, critically analysed, revised, and approved the final paper for publication

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