A Journal Of Perspectives

for young student researchers

Volume 1

Issue 2

September 2023

The Lens Journal
A journal of perspectives for young researchers

Dear Readers,

As we unveil the second issue of The Lens, we remain steadfast in our commitment to fostering interdisciplinary dialogue and championing groundbreaking research. Building on the foundation laid by our inaugural issue, this edition delves deeper into pressing global challenges, offering fresh perspectives and rigorous analyses that we hope will stimulate thought and inspire action. In this issue, we are pleased to present three meticulously researched papers that epitomize our commitment to academic excellence:

The Impact of Historical and Ongoing Technological Advances on Economic Inequality.

In an era marked by rapid technological advancements, this research delves into the intricate relationship between automation, artificial intelligence, and economic disparities. By tracing the evolution of the digital economy and its ramifications on labor markets, the paper offers a timely reflection on the societal implications of technological progress.

Method Analysis For The Purification of Heavy Metal Ions From Water.

Addressing a critical environmental and public health challenge, this study provides a comprehensive review of techniques for removing metal ions from water. By juxtaposing physical and chemical separation methods, the paper underscores the significance of a combined approach, emphasizing its potential to revolutionize water purification processes.

The ACE Project: Creation of an Eco-Friendly Brick Best Suited for the Indonesian Environment.

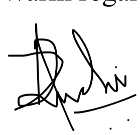
This paper embarks on an exploratory journey into the realm of sustainable construction materials, challenging traditional norms and presenting a compelling case for eco-friendly cement bricks in the Indonesian context. The nuanced analysis of cost, carbon emissions, and brick strength offers invaluable insights into the potential of alternative cement as a game-changer in the construction sector.

Complementing our research papers, we are proud to feature an in-depth article titled, 'How did venture capitalists withstand the effects of the COVID-19 Pandemic so well?'. This article provides a comprehensive analysis of the strategies and resilience of venture capitalists during the tumultuous times of the pandemic, offering insights into the financial mechanisms and decision-making processes that underpinned their success.

Looking ahead, we are excited to announce that our next issue is slated for December 2023. In this regard, we cordially invite submissions from researchers, scholars, and practitioners. This is a call for papers that resonate with our ethos of interdisciplinary research and contribute to the global academic discourse.

In closing, we extend our heartfelt gratitude to our readers for their unwavering support and engagement. It is our fervent hope that this issue of The Lens will serve as a catalyst for informed discussions, collaborative endeavors, and transformative solutions to the multifaceted challenges of our time.

Warm regards,



Ruchi Steven
Editor-in-Chief

The Lens Journal
A journal of perspectives for young researchers

How Did Venture Capitalists Thrive Amidst A Global Pandemic?

Hugo Hartono
Singapore American School

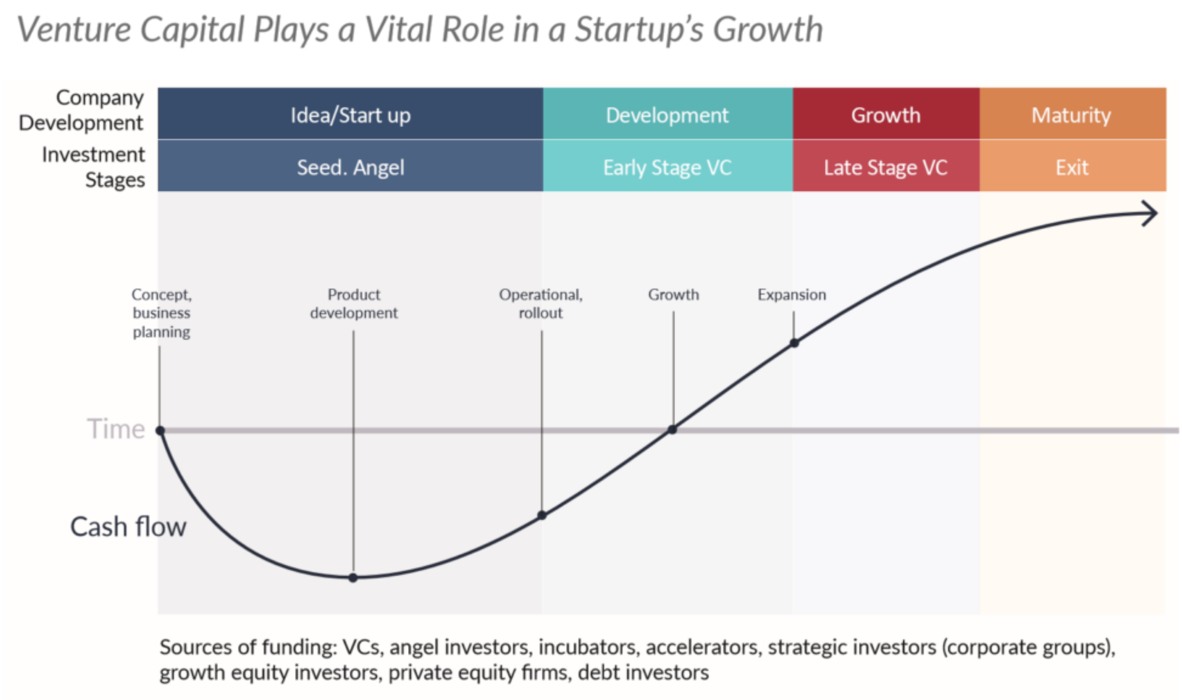
The world of business is vast and expansive, as it branches into numerous sectors, each pertaining to their specific and unique traits. However, if there is one word to describe it, it would be persistent because, time and again, businesses ranging from large to small have shown constant progression and adaptation despite major setbacks throughout history. They are undoubtedly the heart of the world's economy. However, if that's the case, then venture capitalists are the soul. After all, as Bob Zider from the Harvard Business Review astutely states, "Invention and innovation drive the U.S. economy" (Zider). And who facilitates that process more effectively than venture capitalists? A phenomenon that has garnered significant attention is how certain venture capitalists managed to thrive amidst a global pandemic.

RQ: How did venture capitalists withstand the effects of the COVID-19 Pandemic so well?

What is Venture Capital?

Venture Capital (VC) is a form of financial investment in startup companies or small and unheard-of businesses. Most commonly performed by investors from the higher end of the economic spectrum, its primary goal is to seek those early companies with a projected bright future and, in a way, nurture them through three direct tactics. The most notable method involves providing substantial capital to bolster the infrastructure. Another is giving personal insights and strategies to the entrepreneurs, and lastly, providing companies with networks, as the investors will have much larger connections and can use that to help entrepreneurs. What separates venture capitalists from other investors is their outstanding ability to strategize and follow the patient route, which is why many choose "businesses that are believed to have long-term growth potential"(Hayes). But, more importantly, it is integral to note that the word 'patient' doesn't necessarily translate to venture money being long-term money. This is expressed explicitly by Zider, as he says, "the idea is to invest in a [company…] until it reaches a sufficient size and credibility so that it can be sold to a corporation" (Zider). But, of course, that period in which the company is still growing can differ tremendously depending on the industry and the ever-changing environment surrounding each one.

VCs can be classified by the stages they decide to invest in, typically including pre-seed fundings, early stage, and late stage. It is obvious that the earlier you invest capital, the higher the risk of losing it is, which means that the startups will compensate for that by giving a higher percentage of equity. Therefore, VCs in the later growth stage face a lower risk of losing capital but receive less equity.



This is known as the Startup J Curve, which serves as a trendline that reflects a startup's "initial loss immediately followed by a dramatic gain" (Kenton). Investors expect the initial drop, but what follows isn't always the same. The "dream" scenario is for the outcome of the fall to be a steep incline, hence the name J curve.

In the next part, I will be taking a look at different studies carried out by business professors and report their findings, attempting to create a final conclusion using the data collected from the said studies.

NBER

In the first quarter of 2020, many financial institutions, more notably the International Monetary Fund, predicted that the COVID-19 virus would cause the worst economic recession the world has experienced since the Great Depression of the 1930s. This made a significant number of venture capitalists cautious, and rightfully so. VC investments, being both cyclical and unstable, often mirror the economy's trajectory. Consequently, the volume of investments tends to increase as the economy grows and decrease as it contracts. 2020 was an extremely rough and dark year for businesses worldwide, including a portion of venture capitalists. "Despite the economic uncertainty, 91 percent of venture capitalists expect their investments to outperform major equity indexes going forward"(Kost). Paul Gompers, a professor at Harvard Business School, in collaboration with "Will Gornall of the University of British Columbia, Steven N. Kaplan of the University of Chicago, and Stanford University's Ilya A. Strebulaev is to survey more than 1,000 venture capitalists at 900 firms from late June to mid-July"(Kost). Their research findings state that the pace of VCs has dropped by 29%, meaning they were spending more time and resources guiding portfolio companies they already owned through the pandemic. The VC firms the professors worked with said that "52% of their portfolio companies are positively affected or unaffected by the pandemic; 38% are negatively affected; and 10% are severely negatively affected"(Gompers et al. 1). Furthermore, many VCs report that the pandemic has only slightly impacted internal rate of return (IRR) which is a metric "used in financial analysis to estimate the profitability of potential investments" (Fernando). An IRR of 20% or above is considered good and the data provided by the study shows that it only dropped by 1.6%.

Referring back to the J-curve, the survey indicates how both late and early stage investors have a harder time evaluating deals. With the hindrance of COVID-19 preventing the majority of face-to-face team meetups, this is to be expected. In the early stage section of the curve, communication is of utmost importance because the exchange of knowledge between the VC and the portfolio company is what can really impact their future success. Owing to the continuously expanding digital realm of the internet, communication remains readily accessible, explaining why previous recessions impacted the VC world more profoundly.

It is clear that the venture capitalists were affected by the pandemic, but not nearly as badly as other industries. This is evident in a study done by a multitude of business professors from prestigious schools in the US.

Analysis

The Stanford Graduate School of Business published an article in September of 2020 regarding the current state and future predictions of the VC landscape, titled "VCs and COVID-19: We're Doing Fine Thanks". The title alone echoes sentiments similar to those found in the earlier study led by Paul Gompers. The author of this article is Lee Simmons, a senior at Hoover Institution in Stanford. In the second quarter of 2020, the National Venture Capitalist Association (NVCA) announced that "investment in the startup ecosystem is expected to drop significantly" leading to investors from around the world opting out of illiquid and slightly risky portfolio companies. In addition to that, they said "Fasten your seatbelts" as it was going to be a "Bumpy ride". Contrary to the NVCA's predictions, the ride was not, in fact, bumpy but rather smooth, at least when you look at the rest of the world. A survey of more than 1000 VCs was conducted to see not only how they were impacted, but to also reveal what the VCs themselves thought of their current situation. The survey itself was conducted in June of 2020 by a mix of alumni from Stanford and Chicago Business Schools. With numbers that resemble that of the research explained previously, the pace at which new investments were done dropped to 71% of their prior numbers. Looking at the past two recessions and how much they slowed the pace, the dot com crash of 2000 and recession of 2008, 71% is amazing. The survey, which was expected to take weeks to even months, was completed in a span of 10 days because of such extraordinary response rates. Ilya Strebulaev, a professor of finance at Stanford Graduate School of Business, had talked to a handful of venture capitalists from Silicon Valley, reporting that many of them said "this may be the best time to be around — there are so many interesting investments right now. People are sitting at home coming up with new entrepreneurial ideas." (Simmons). The article also mentions the impact of modern technology and how it can possibly cushion the effects of the pandemic.

Cristiano Bellavitis

Cristiano Bellavitis, a professor at Syracuse University, collaborated with Christian Fisch of the University of Netherlands and Rob McNaughton from the University of Auckland to publish an article reporting on the impact of the COVID-19 pandemic on venture capital (VC) investments. Using a dataset of 39,527 funding rounds occurring before and during the pandemic in 130 countries, they documented a significant decline in investments. (Bellavitis). The goal of this paper was to provide "a global and more nuanced assessment of how VC investments respond to the pandemic in terms of characteristics such as the stage of investment and syndication behavior" (Bellavitis). Through their extensive research, the authors created a claim that shared some similarities but also differences with the previous two studies.
The team's first hypothesis revolves around the central idea of how the unpredictability and uncertainty of the pandemic affect earlier stage ventures. Because the portfolio companies understand the heightened risks, they give more discount rates for the long-term prospects, therefore leading to a less justifiable reason to invest in the seed stage. Understanding that both pre-seed and seed stage ventures will most likely be impacted more than late stage ventures, the team split their first hypothesis into two.

- Hypothesis 1a (H1a): As the number of COVID-19 cases increase, VC investors are less likely to invest in seed-stage ventures.
- Hypothesis 1b (H1b): As the number of COVID-19 cases increase, VC investors are more likely to invest in late-stage ventures

It is important to understand that the pandemic affected industries unequally, meaning that some actually benefited from it. The perfect example of this is the medical and biotech industry. With companies racing to create vaccinations and treatments, "Spikes in companies' stock prices undertaking COVID-19 research or developing treatments" (Bellavitis) became more common. On the other hand, travel-related businesses were predicted to take a massive blow. Because of this, the research team's second hypothesis can be split into two different ones.

- Hypothesis 2 (H2a): As the number of COVID-19 cases increase, VC investors are less likely to invest in travel ventures.
- Hypothesis 2 (H2b): As the number of COVID-19 cases increase, VC investors are more likely to invest in biotech ventures.

Unsurprisingly, both hypotheses are spot on. As COVID-19 cases increased at an exponential rate, the sheer volume of early stage ventures dropped. Another trend found by the team was that biomedical-related ventures far exceeded companies in the travel industries. However, this was almost certain to happen, because "several studies find that investments in early-stage ventures are more heavily affected by crises than later-stage investments" (Bellavitis).

Analysis

After analyzing three research papers published by institutions and schools worldwide, it becomes apparent that there are some common themes and trends among them. The first two articles share striking similarities in their conclusions and claims. Both studies indicate that the venture capital (VC) industry is performing well overall. According to the Harvard study, the data suggests that the industry is thriving holistically. Similarly, the Stanford article reveals that not only are many VCs faring well, but they are also optimistic about the future. Paul Gompers, the lead professor on the Harvard research team, notes that the success of the VC world tends to follow the global economy, which explains why the International Monetary Fund (IMF) predicted a hit to the industry. Despite this, the world was proven wrong, and no clear reason or cause is ever stated once by any of the three studies. However, by examining specific trends in the data, particularly in the study conducted by Bellavitis, certain inferences can be drawn. These inferences are robust enough to be considered causal relationships. Notably, the venture capital industry stands out due to its exceptional adaptability, as it encompasses a vast and diverse range of investment opportunities. As such, damages to individual parts of the industry do not significantly impact the sector as a whole. Consider, for instance, Hypothesis 2a from Bellavitis' research, which states that as COVID-19 case numbers increase, investments in travel and international relations tend to decrease. However, the same investors who withdrew from these sectors subsequently redirected their funds into the biotechnology industry, which has experienced remarkable growth due to external factors such as the quest for vaccines and COVID-19 treatments. In essence, when one segment suffers, another flourishes, effectively offsetting the impact. Yet another example of this is the decrease in early seed stage investments. Yes, the amount of seed ventures decreased, but it also means the number of late game ventures increased. This is one likely cause as to why the pandemic barely slowed down the industry. Another probable factor is the integration and normalcy of technology usage in the venture capital industry. Technology was already an integral part of VCs' operations even before the pandemic, so most VCs and VC firms were able to leverage their familiarity with it to mitigate the pandemic's impact. However, this does not diminish the reality that the pandemic still created significant challenges for the industry. For instance, the number of solo ventures (also known as non-syndicate) has noticeably declined. This is because COVID-19 has made it more difficult and time-consuming to conduct thorough research and evaluate potential deals. Additionally, the surge in syndicate investments has led to a slower overall pace of VC investments. As previously mentioned, the initial impact of the virus resulted in a 30% drop in investment activity.

Works Cited

Bellavitis, Cristiano, et al. "COVID-19 and the Global Venture Capital Landscape." Small Business Economics, 4 Sept. 2021, 10.1007/s11187-021-00547-9. Accessed 13 Oct. 2021.

Fernando, Jason. "What the Internal Rate of Return (IRR) Measures." Investopedia, 24 Feb. 2022, www.investopedia.com/terms/i/irr.asp.

Gompers, Paul A., et al. "Venture Capitalists and COVID-19." SSRN Electronic Journal, 2020, www.nber.org/system/files/working_papers/w27824/w27824.pdf, 10.2139/ssrn.3698128. Accessed 3 Mar. 2021.

Hayes, Adam. "Venture Capital Definition." Investopedia, 25 Feb. 2020, www.investopedia.com/terms/v/venturecapital.asp.

Kenton, Will. "J-Curve Effect." Investopedia, 2019, www.investopedia.com/terms/j/j-curve-effect.asp.

Kost, Danielle. "COVID Not Slowing vc Investment." HBS Working Knowledge, 30 Nov. 2020, hbswk.hbs.edu/item/covid-not-slowing-vc-investment.

Simmons, Lee. "VCs and COVID-19: We're Doing Fine, Thanks." Stanford Graduate School of Business, 22 Sept. 2020, www.gsb.stanford.edu/insights/vcs-covid-19-were-doing-fine-thanks.

Zider, Bob. "How Venture Capital Works." Harvard Business Review, 1998, hbr.org/1998/11/how-venture-capital-works.

The Lens Journal
A journal of perspectives for young researchers

The Impact of Historical and Ongoing Technological Advances on Economic Inequality

Veeraj Jhaveri
British School of Brussels

Abstract
This research paper delves into the complex interplay between technological advancements and economic inequality. Tracing the evolution of the digital economy, the study highlights how emerging technologies like automation and artificial intelligence have reshaped and are still reshaping labour markets and exacerbating existing disparities. While acknowledging the efficiency gains that such technologies can bring, the paper explores how these benefits are not uniformly distributed across different strata of society, contributing to widening inequality both within countries and internationally. The paper serves as an exploratory look into how technological change impacts economic structures, inviting further discussion and research into this pressing issue.

Keywords: Economic Inequality, Technological Advancements, Digital Economy, Labor Markets, Disparities

I. Introduction

The 21st century has ushered in a period of rapid technological advancement, transforming the ways in which we understand and interact with the world around us. Devices like smartphones are no longer luxury items but everyday necessities, and artificial intelligence is not an abstract concept but an increasingly integral part of various industries and businesses. These advancements, while propelling unprecedented growth, innovation, and productivity also bring to the forefront complex challenges related to economic disparity. The rise of automation, and more recently, AI, in numerous sectors throughout history has introduced notable changes in employment patterns and distributional effects in the labour market.

Alan Turing's famous test in 1950 proposed a seemingly simple question whether a machine is intelligent: can it imitate a person so well that you can't tell it is one? Ever since, many researchers have been chasing this goal. In recent times, AI researchers and businesses especially have begun focusing on building machines to replicate human intelligence. However, while doing so, this obsession with mimicking human intelligence has led to AI and automation that often simply replace workers, rather than extending human capabilities and allowing people to do new tasks.[1] If such an approach is true, could this potentially pave a pathway to further economic inequalities?

As we tread deeper into the 21st century, it becomes increasingly clear that technological change is an evolving continuum rooted in history. Rewind to the advent of the first industrial revolution, where the introduction of machinery began a shift in production methods and labour. Moving into the 20th century, the advent of the computer age simplified tasks that once seemed insurmountable or time-consuming. This trajectory of innovation has only accelerated. Fast forward a few decades, and now artificial intelligence is not only streamlining processes but also predicting, learning, and, in many ways, thinking.

However, as with all transformative shifts, there's a deeper narrative beneath the surface. Industries, once robust and teeming with workers, are able to automate processes, potentially leading to major shifts in labour demand. For example, e-commerce platforms powered by AI-driven recommendations have severely impacted employment. In an extreme case, Suumit Shah, founder of e-commerce platform Dukaan laid off 90% of its support staff due to chatbots, claiming it was in fact, 'necessary.'[2] Such shifts aren't just restructuring businesses but are possibly reshaping socio-economic constructs.

This research will assert that technological advancement is key to our evolving economy. It is a critical element influencing substantial changes, both positive and challenging. It introduces efficiencies, innovations, and novel opportunities but potentially exacerbate vulnerabilities as well, particularly for economies not prepared for rapid technological uptake or individuals with diverse skillsets and backgrounds. By delving deep into these dynamics, this thesis aims to explore the central question: "How have historical and ongoing advancements in technology, including artificial intelligence and automation, impacted economic inequality?"

II. Methodology

This research paper adopts a multi-method approach to explore the complex relationship between technological advancements and economic inequality. The methodology employed combines literature review, historical analysis, data analysis, and comparative analysis to provide a comprehensive understanding of how technology influences economic disparities.

Study Design

The paper follows a descriptive and analytical design that serves two main purposes: first, to document the historical relationship between technological advancements and economic inequality, and second, to analyze the impact of these advancements on various segments of society. The choice of this design was influenced by the need to not only present factual information but also to offer an interpretation that allows for a nuanced understanding of the complexities involved. Tracing the evolution of the digital economy from the First Industrial Revolution through the 20th century allows for a longitudinal perspective, facilitating a more complete understanding of the mechanisms driving economic inequality in the face of technological change.

[1] Rotman, David. 2022. "How to Solve AI's Inequality Problem." *MIT Technology Review.* April 19, 2022. https://www.technologyreview.com/2022/04/19/1049378/ai-inequality-problem/.

[2] Elimian, Godfrey. 2023. "As ECommerce CEO Replaces 90% of Staff with Bots, Are Fears of AI Taking over Jobs Coming True?" *Technext.* July 12, 2023. https://technext24.com/2023/07/12/ceo-cuts-90-staff-replace-with-ai-bots/

Data Collection

The primary method for data collection is an extensive literature review. This paper references a variety of sources, including academic articles, news pieces, historical records, existing debates, and external research papers. These diverse sources offer both qualitative insights and quantitative data. Additionally, specific statistical figures from reputable databases and reports have been incorporated to lend empirical weight to the arguments presented.

Data Analysis

Historical Analysis: A meticulous review of historical events and trends helps in understanding how technological advancements have shaped labour markets and contributed to economic inequality over various time periods.

Quantitative Data Analysis

The paper uses specific data points such as “Efficiency Levels in England (1700–1880)” and “Output per Worker and Real Wage in Britain” to analyze the impact of technology on economic outcomes. This adds an empirical layer to the research, complementing the qualitative analyses to offer a balanced presentation of research.

Comparative Analysis

The study compares different time periods and corresponding technological changes to understand their evolving impacts on labour markets and broader economic structures.

By synergizing these various methods of analysis, the research offers a multi-faceted view of the impact of technological advancements on economic inequality. This methodology aims to provide a balanced and comprehensive analysis, making the paper a substantive contribution to the existing body of knowledge on this topic.

III. Literature Review and Discussion

Historical Context and Background

A. The First Industrial Revolution: A New Mechanised Labour Force

Background

The evolution of labour markets has always been intricately tied to technological disruptions. Throughout history, the introduction of new technologies and methods has consistently reshaped how work is done, leading to both the obsolescence of certain jobs and the creation of new ones. The First Industrial Revolution was a significant turning point in this regard, spanning from approximately 1750 to 1830. Originating in England before spreading to continental Europe and America, this transformative era saw a decisive move away from the predominant Agricultural Revolutions which involved mainly handcraft.[3] Instead, the world began gravitating towards more efficient and stable manufacturing processes, from traditional manual production methods to the introduction and widespread adoption of machinery, bringing forward a new age of mechanised industry and change in skills.

The onset of the 19th century introduced significant advancements in the realm of mechanisation, with water and steam emerging as major sources of power. Central to this era, particularly in Britain, was the textile industry, which experienced a series of revolutionary changes. John Kay’s invention of the flying shuttle in 1733, the spinning jenny in 1764 and the

[3] Academic Accelerator. n.d. “Industrial Revolution Encyclopedia, Science News & Research Reviews.” https://academic-accelerator.com/encyclopedia/industrial-revolution.

water frame in 1769 just to name a few. Further, Thomas Newcomen's design, seen in the coal mines of regions like Lancashire and Yorkshire, was integral in extracting water from mines. This increased coal yield, which in turn fuelled more steam engines, epitomised the synergistic relationship between technological advancements and industrial productivity and expansion.[4]

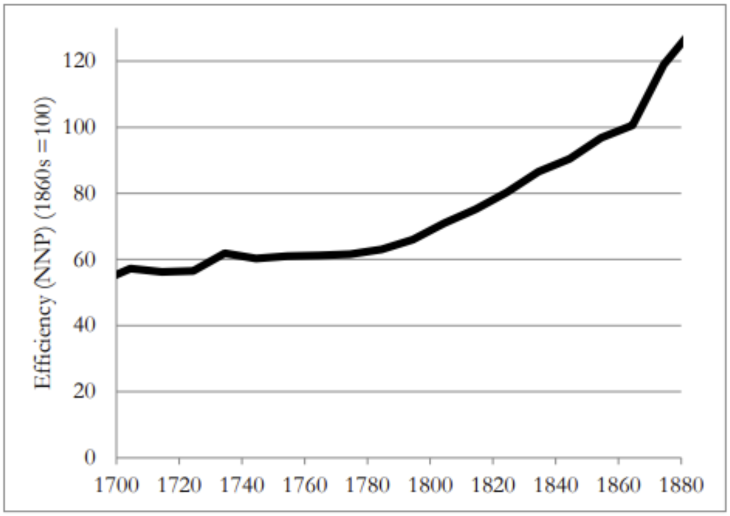


Figure 1: *Efficiency Levels in England (1700 – 1880)*[5]

Efficiency Gains through Mechanisation

While such innovations in machinery transformed industrial processes, substantial efficiency gains emerged. Specifically, during the period from 1780 to 1869, the textile sector emerged as the most prominent beneficiary, contributing a staggering 43% to the overall productivity growth. Meanwhile, the introduction of railways propelled the transport sector to account for 20% of the efficiency gains. Surprisingly, agriculture mirrored these advancements, also claiming nearly 20% of the productivity rise.[5]

So, while mechanisation enhanced efficiency, what did it mean for labour markets, wages, workers, and jobs?

[4] Engineering, Society for Industrial Management and. 2021. "Industrial Revolution 1.0 — Era of Mechanization." *Medium.* September 29, 2021. https://medium.com/spark-by-sime/industrial-revolution-1-0-9e6dc9c62c8c.

[5] Clark, Gregory. n.d. "The Industrial Revolution." *University of California, Davis.* https://faculty.econ.ucdavis.edu/faculty/gclark/papers/HEG%20-%20final%20draft.pdf.

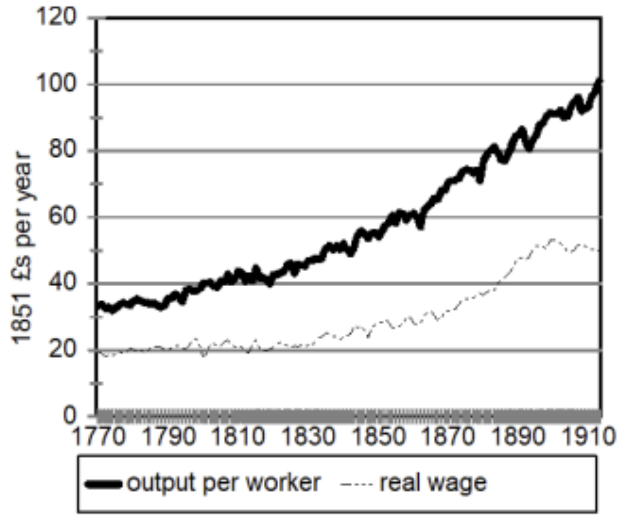


Figure 2. *Output per Worker and Real Wage in Britain*[6]

Productivity vs Wages Growth

The average worker, now equipped with the latest innovations (at the time), could produce a significantly higher amount of goods in a given timeframe. Consequently, the marked surge in "output per worker," reflects the newfound efficiencies brought about by mechanisation. Yet, as the productivity curve rose, the trajectory of real wages did not mirror this ascend between 1770 and 1830. Average real wages, in fact, remained relatively stagnant for a significant period.

Distributional Effects in the Labour Market

The rapid urbanisation that marked the era ensured a plentiful supply of workers. As towns grew into bustling cities, they attracted a vast number of individuals looking for work in new factories. Employers, bolstered by this abundance of willing labour, were able to keep wages relatively low. Factories became increasingly specialised and new roles emerged that demanded a specialised set of skills. Those with the capability to adapt, such as engineers and mechanics, found their wages and job prospects significantly improved.[7]

But what of those less adaptable? The plight of the handloom weavers serves as a cautionary tale. Once regarded as skilled artisans, they found their skills losing market value in the face of industrial-scale looms and spinning machines.[6] This nuanced shift in the job market was not without its critics. The Luddites, a group of textile artisans in the United Kingdom, embodied this resistance starting protests in around 1811. Workers sent threatening letters to employers and broke into factories to destroy the new machines, such as the new wide weaving frames. They also attacked employers, magistrates, and food merchants and fights often occurred between them and government soldiers.[8] For the Luddites, these new machines weren't just disruptive; they were seen as a direct assault on their way of life.

[6] Allen, Bob. n.d. "The Interplay among Wages, Technology and Globalisation: The Labour Market and Inequality, 1620–2020." *British Library.* Accessed June 23, 2023. https://www.bl.uk/britishlibrary/~/media/bl/global/social-welfare/pdfs/non-secure/i/f/s/ifs-the%20interplay-among-wages-technology-and-globalisation-21.pdf.

[7] Rafferty, John. 2019. "The Rise of the Machines: Pros and Cons of the Industrial Revolution." *In Encyclopedia Britannica.* https://www.britannica.com/story/the-rise-of-the-machines-pros-and-cons-of-the-industrial-revolution.

[8] Archives, The National. n.d. "The National Archives - Homepage." *The National Archives.* https://www.nationalarchives.gov.uk/education/resources/why-did-the-luddites-protest/.

Concluding Remarks

The First Industrial Revolution serves as an early example of how technological advancements can impact economic inequality: while overall productivity and economic growth may soar with technological advancements, the benefits are not evenly distributed. Some workers, particularly those with adaptable or specialised skills, may find new opportunities and higher wages. Others, however, may find themselves marginalised, their skills devalued, and their economic prospects dimmed. Further, the disconnect between rising output per worker and stagnant real wages serves as a significant indicator of how the benefits of increased productivity were distributed as well. While factories and owners saw enormous gains, the average worker did not proportionally benefit. As we consider the role of technological advancements in contemporary labour markets, we should remember that increased efficiency and output do not always automatically translate to improved benefits for all stakeholders.

B. 20th Century Tech Advancements

Background

Fast-forward to the 20th century, advancements in materials and technologies marked a departure from the First Industrial Revolution to the new "Technological Revolution." Steel supplanted iron, becoming the go-to material for infrastructure, enabling the railroad network to expand to 254,000 miles by 1916. Electricity replaced steam and waterpower, opening doors to a host of new inventions from household appliances to industrial machinery. The internal combustion engine, invented during this period, changed the face of transportation, paving the way for automobiles and airplanes. Further, Henry Ford's assembly line, introduced around 1913, transformed manufacturing, scaling up production and reducing costs. These technological shifts both evolved the labour market and changed the way society operated, setting the stage for further examination into the impact of technology on labour.[9]

Advancements in technology accelerated dramatically as the 20th century progressed, giving way to the "Digital Revolution". The transistor, introduced in 1947, was a pivotal invention that laid the foundation for advanced digital computers. By the 1980s, computers had moved from being specialised tools for government and industry to becoming a household staple. Around the same time, the first cell phones were introduced, signalling a shift in personal communication. By the 1990s, the World Wide Web had arrived, becoming an integral part of business operations by 1996. The decade saw a convergence between websites and mobile technologies. changing how we consume media and use business applications.[10]

Globalisation and Interconnectivity

The technologies that emerged during the Technological Revolution were intricately linked, creating a network of interconnected systems that transformed society. The expansion of railroads both moved people and goods and facilitated the rapid deployment of telegraph lines. Television also transitioned from analogue to digital signals. In the 2010s, the internet was accessible to over 25% of the global population, and almost 70% owned a mobile phone. Cultural historian Stephen Kern described this transformative period as the "annihilation of distance," as these innovations extended the scope of human interaction from local to national and even international scales.[9] The result was a new tempo of life and work, as well as a sense of global interconnectedness. These systems allowed for a new dynamic in labour and capital allocation across regions, affecting economies in different ways.

[9] Engineering, Society for Industrial Management and. 2021. "Industrial Revolution 2.0 — Era of Mass Production." *Medium.* July 16, 2021. https://medium.com/spark-by-sime/industrial-revolution-2-0-era-of-mass-production-594acfa228c6.

[10] Techopedia. 2019. "What Is the Digital Revolution? - Definition from Techopedia." *Techopedia.* 2019. https://www.techopedia.com/definition/23371/digital-revolution.

Social and Economic Impacts

After discussing the technological milestones and their effects on the world, the socio-economic impacts of these advancements must be considered as well. Specifically, this section will focus on how technology influences economic inequality and employment in the 20th century.

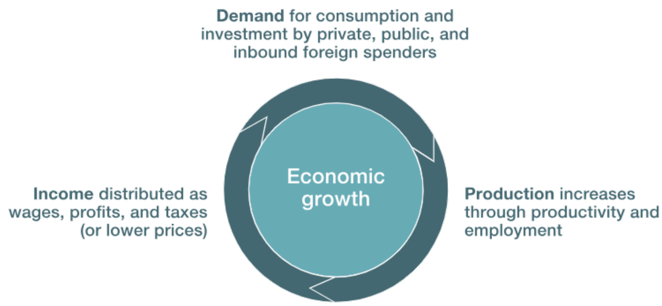


Figure 3: *Virtuous cycle of increases in demand, production, and income*[11]

Productivity and employment

Building on the productivity patterns established during the first industrial revolution, recent technological advancements have had varying but significant effects on job displacement. A virtuous cycle unfolds: technological innovations boost productivity, which lowers the cost of goods, which in turn, increases demand, ramping up production and eventually creating more jobs. According to data since 1960, in the United States, productivity and employment have grown in tandem 79% of the time within individual years. On a longer time frame, such as over five or ten years, there are virtually no instances where productivity increases while employment falls. Importantly, due to globalisation this correlation between productivity and employment growth was observed not just in the United States but also in countries like China, Germany, and Sweden.[11]

Skilled vs Unskilled Workers Debate

As was evident during the initial industrial revolution, heightened productivity did not necessarily result in equitable gains for everyone. Likewise, skill level remained a critical determinant in shaping workers' earnings and career prospects throughout the 20th century.

[11] "What Can History Teach Us about Technology and Jobs?" 2018. *McKinsey & Company.* 2018. https://www.mckinsey.com/featured-insights/future-of-work/what-can-history-teach-us-about-technology-and-jobs.

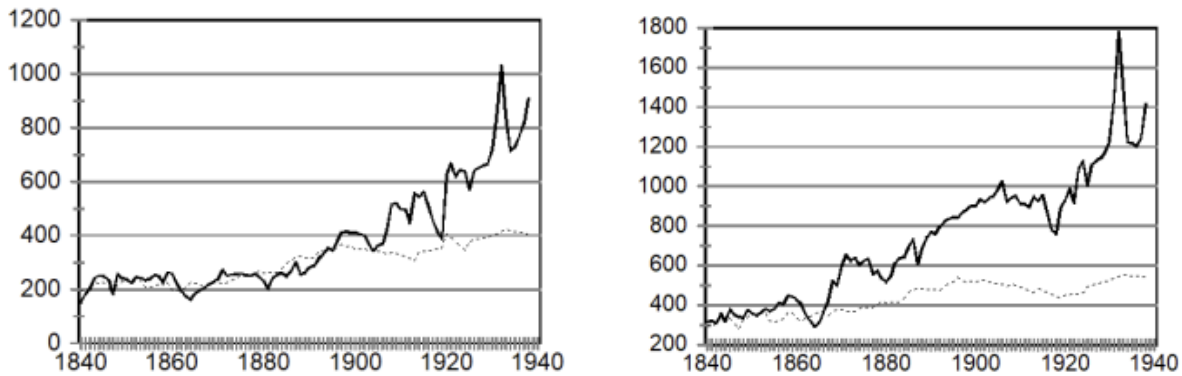


Figure 4: *Unskilled Real Wages (Left) vs Skilled Real wages (Right) in 1905 British Pence*[6]

While it may seem that the shift from skilled to semi-skilled jobs would suppress wage growth, the booming expansion of the manufacturing sector more than compensated by driving up the demand for skilled labour. Concurrently, mechanisation of material transport led to the elimination of low-skill labouring jobs, elevating the average skill level across the board. This mechanisation and the resultant rise in labour productivity intensified competition among firms for workers, which translated into an increase in real wages. Furthermore, up until World War I, unskilled wages were strikingly similar between the UK and the US.[6] However, the period following the Civil War and especially after World War I saw wages in the U.S. pull dramatically ahead, establishing a considerable gap by the end of the nineteenth century. By 1940, U.S. factory workers and unskilled labourers were earning 25-50% more than their skilled counterparts in Britain.[6] This disparity can be attributed, in part, to the U.S.'s quicker adoption of technological innovations and mass production techniques, which gave American firms a competitive edge in labour productivity and consequently wage levels. Yet, the early U.S. economy was not uniformly advantageous for all workers; unskilled labourers often earned just half of what skilled craftsmen and mechanics made, with nearly 40 percent of urban workers comprising low-wage labourers and seamstresses who lived in less-than-ideal conditions.[12]

Skilled vs Unskilled Workers Debate: Role of Technology

Henry Ford's perspective on technology's influence on labour serves as a meaningful counterpoint to popular discourse. The general concern is that technology would devalue or make obsolete unskilled labour; however, Ford argued that it's not about elimination but transformation. Technology doesn't devalue skill; it redistributes it, especially toward management and planning roles. In essence, as technology advances, the skill sets required for labour shift. While certain manual jobs may diminish or be altered by automation, new types of skilled roles emerge, even in the early 20th century. For instance, there's a growing need for personnel who can manage complex systems, understand data analytics, and implement strategic planning. These roles may not require the same skills as traditional factory work, but they are skills, nonetheless. This shift has complex implications for both skilled and unskilled labour markets. On one hand, unskilled labourers may find fewer job opportunities in traditional sectors, requiring them to acquire new skill sets for employment. On the other hand, those with skills in management, planning, and data analysis may find more lucrative opportunities, potentially exacerbating income inequality.

[12] U.S. Department of State. 2019. "Outline of the U.S. Economy." Usembassy.de. 2019. https://usa.usembassy.de/etexts/oecon/chap9.htm.

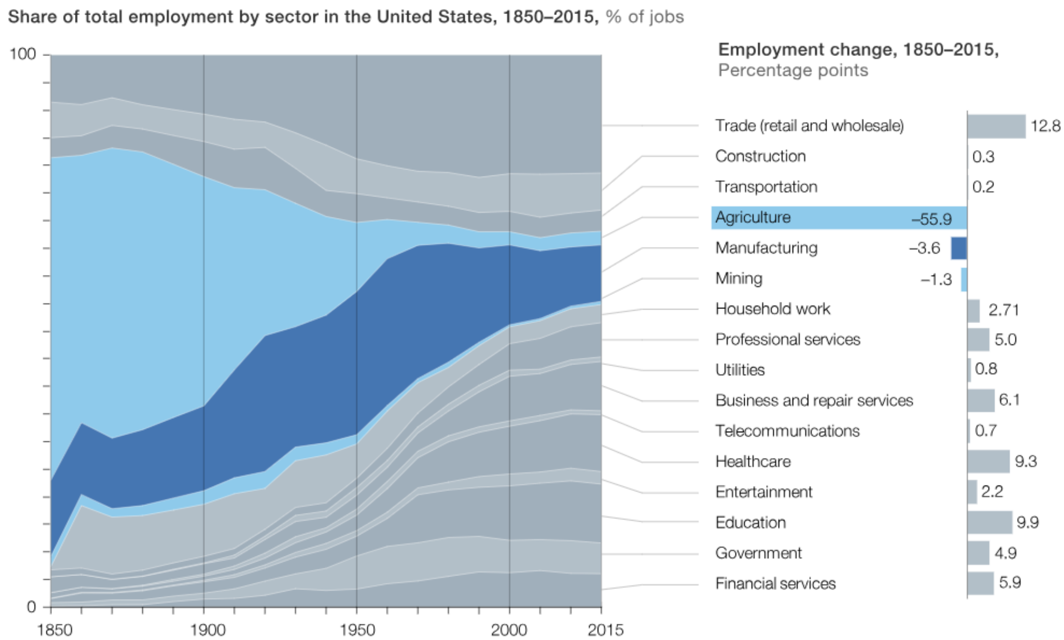


Figure 5: *Historical Employment and Sector Shifts*[11]

In examining the historical shifts in labour sectors from 1850 to 2015, a clear transition from agrarian to service-oriented economies is evident. This transformation is reminiscent of earlier industrialisation periods, where new forms of labour-saving technologies led to a decline in traditional roles but also gave birth to entirely new sectors. The decline of 55.9% in agriculture and 3.6% in manufacturing highlight the adaptability of labour markets and the potential for skill shifts over time. Interestingly, the data reveals growth in trade, healthcare, and financial services, indicating that as some sectors decline, others rise to fill the void.

This echoes earlier observations about how technological advancements not only displace existing jobs but also create new types of employment, often requiring different skill sets. Yet, the speed and equity of these transitions is under debate. While some argue that the rate of change is consistent with historical patterns, this assertion is laden with uncertainty.

C. Comparative Analysis of the Revolutions

The different historic revolutions significantly shaped labour markets, exhibiting recurring patterns in productivity, wages, skill shifts, and employment opportunities that offer insights for understanding future technological impacts on work and inequality.

Firstly, both revolutions led to significant increases in productivity. The First Industrial Revolution was focused more narrowly on the textile industry and mechanisation, revolutionising the way goods were produced. However, the gains in productivity didn't correspond with a significant rise in real wages for the average worker. During the Second Industrial Revolution, the improvements in manufacturing and transportation resulted in a much broader and quicker economic expansion. Unlike its predecessor, this period saw productivity and average wages grow more or less in tandem, particularly in industrialised nations.

Secondly, the skill sets required for work underwent transformational shifts during both eras. The First Industrial Revolution necessitated basic literacy and numeracy, as workers had to read and follow basic machine operations. On the other hand, the Second Industrial Revolution called for specialized skill. This trend indicates a progressive increase in the complexity of skills demanded by labour markets.

Thirdly, both industrial revolutions shared the paradoxical role of being both a disruptor and a creator in the labour market. The First Industrial Revolution led to job losses in artisanal and agricultural sectors but created new roles in factories. The Second had similar disruptive effects, particularly in manual and low-skilled jobs, but it also introduced new sectors and roles that had not existed before.

Overall, while the First and Second Industrial Revolutions differed in many aspects, their impacts on labour markets reveal recurring themes: increases in productivity, evolving skill requirements, sectoral shifts in employment, and the dual role of technology. These recurring patterns provide a nuanced framework for evaluating how current technological advancements, such as AI and automation, may shape the future of labour.

IV. The Modern Age: A Focus on AI, Algorithms, and Automation

A. The AI Revolution

Modern Advancements

Artificial Intelligence (AI), a concept initially inspired by Alan Turing and formally conceptualised in the late 1950s, had the goal of mimicking human-level intelligence, commonly referred to as "human-imitative AI."[13] Initially, the focus was on higher-level cognitive capabilities like reasoning and thought, distinct from other fields like operations research and control theory that were inspired by animal behaviour or low-level signals. Despite the initial focus, AI evolved to specialise more in low-level pattern recognition and movement control, disciplines closely tied to fields like statistics and engineering.[13]

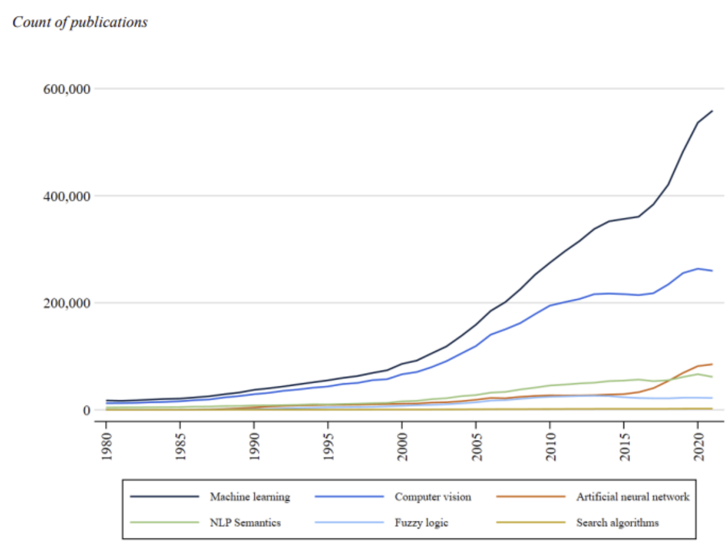


Figure 6: *AI research publications by topic, 1980-2021*[14]

AI's strength primarily lies in machine learning, a subset focusing on designing algorithms that iteratively build analytical models from new data and making predictive analyses. Machine learning has been the leading area of AI research since

[13] Jordan, Michael I. 2019. "Artificial Intelligence—the Revolution Hasn't Happened Yet." Issue 1 1 (June). https://doi.org/10.1162/99608f92.f06c6e61.
[14] The White House. 2022. "THE IMPACT of ARTIFICIAL INTELLIGENCE on the FUTURE of WORKFORCES in the EUROPEAN UNION and the UNITED STATES of AMERICA." https://www.whitehouse.gov/wp-content/uploads/2022/12/TTC-EC-CEA-AI-Report-12052022-1.pdf.

the 1980s and its applications have substantially grown over the last decade. Technologies ranging from music recommendation systems to automated language translation and targeted advertising rely on machine learning algorithms for their functionality. These developments have been critical in the success of major tech companies like Google, Netflix, and Amazon, and their applications extend to areas such as document retrieval, text classification, and social network analysis.[13]

B. Existing Debates, Arguments, and Insights

The Case for Technological Unemployment

Technology has been historically known to put workers' jobs in fear, and in the case of AI and automation, it could be even scarier. Goldman Sachs' research suggests that two-thirds of American occupations are exposed to some level of automation, with a potential impact on 300 million jobs globally.[15] A Challenger job report revealed that as recently as May 2023, 3,900 jobs were eliminated due to AI. Similarly, companies like IBM and British Telecom have announced significant job cuts attributable to automation, with the latter planning to replace more than 10% of its workforce with AI by 2030.[16] However, the work of Acemoglu and Restrepo adds nuance to these alarming figures. According to their research, introducing one additional robot per 1,000 workers might decrease the U.S. employment-to-population ratio by just 0.37% and lower wages by a range of 0.25% to 0.5%.[16] This suggests that while automation does pose some risks to employment and wages, the impact may be more complex and less catastrophic than initially thought.

Despite the concerning headlines, other analyses argue that the fears may be overblown. The World Economic Forum predicts that AI could actually result in a net increase in jobs by 2025.[17] Lawrence and Arntz support this more optimistic view, emphasising AI's potential for "creative destruction" in the labour market.[17] They argue that automation is likely to transform rather than eliminate jobs. Arntz for example, estimates that only 9% of jobs in the UK are highly susceptible to automation in the next decade, proposing that job transformation rather than job elimination is the more probable scenario.[17] Moreover, OECD findings suggest that the "AI revolution" has yet to make a significant dent in overall employment. Despite identifying that 27% of jobs could be at high risk of automation, the OECD notes that there's little current evidence of AI substantially impacting jobs.[18] Additionally, a survey from the same organisation found that among workers already using AI, two-thirds reported that automation made their jobs less dangerous or tedious.[18]

This growing body of research highlights the complexity of AI's impact on employment. While there is a possibility towards automation replacing certain types of jobs, the overall impact is far from settled. The real challenge is to understand how AI and automation affect wages and productivity, and how these changes intersect with existing disparities in skill demand and educational levels to influence economic inequality.

Income Inequality: The Disconnect Between Wages and Tech Productivity

In recent years, the relationship between productivity and wages has garnered significant attention, especially in the context of technological advancements and automation. Historically, increased productivity was synonymous with rising wages. However, this correlation has weakened considerably in the past few decades, and the implications are profound

[15] Gow, Glenn. 2023. "ChatGPT and Generative AI: What to Do with All the Productivity?" *Forbes.* July 2, 2023. https://www.forbes.com/sites/glenngow/2023/07/02/chatgpt-and-generative-ai-what-to-do-with-all-the-productivity/?sh=38b735913edc.

[16] Gries, Thomas, and Wim Naudé. 2018. "Artificial Intelligence, Jobs, Inequality and Productivity: Does Aggregate Demand Matter?" *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3301777.

[17] Ilzetzki, Ethan, and Suryaansh Jain. 2023. "The Impact of Artificial Intelligence on Growth and Employment." *CEPR.* June 20, 2023. https://cepr.org/voxeu/columns/impact-artificial-intelligence-growth-and-employment#:~:text=The%20World%20Economic%20Forum%20concluded.

[18] Reuters. 2023. "27% of Jobs at High Risk from AI Revolution, Says OECD." *Reuters,* July 11, 2023, sec. Technology. https://www.reuters.com/technology/27-jobs-high-risk-ai-revolution-says-oecd-2023-07-11/.

for income distribution and economic equality. Since the 1970s, a chasm has grown between productivity and wages, culminating in what economists call the “decoupling” phenomenon (this refers to the gap between productivity growth and wage growth for the typical worker, not the average wage, which could include high earners and skew the results). Between 1973 and 2011, worker productivity grew by an astounding 80%, yet median hourly compensation after adjusting for inflation only grew by a tenth of that amount.[19] A study from the Economic Policy Institute reports that from 2000 to 2011, while the American economy expanded by over 18%, the median income for working-age households declined by 12.4%.[19]

Technology plays a dual role in this trend once again. While it contributes significantly to productivity, it also allows companies to cut labour costs, contributing to income inequality. A study co-authored by MIT economist Daron Acemoglu estimates that technological replacement of workers “explains 50 to 70%” of the rise in inequality from 1980 to 2016. Self-checkout machines in retail settings are a prime example.[20] They may not bag groceries more effectively than human clerks, but they do allow companies to spend less on labour.[20]

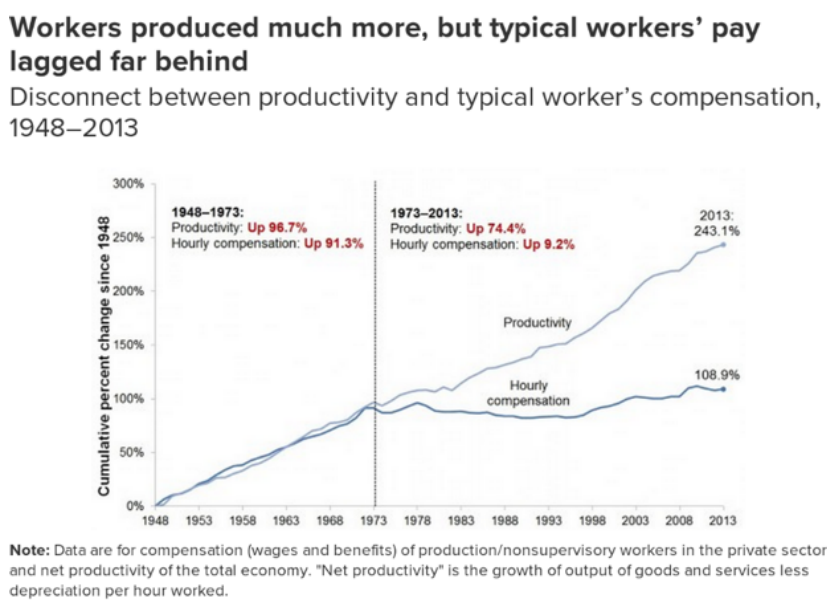


Figure 7: *Disconnect between Typical Worker's Compensation, 1948 - 2013*[21]

Wage stagnation is another concern. Corporations like Caterpillar, once icons of American industry, have reported record profits but insist on wage freezes for blue-collar workers.[21] Part of this trend can be attributed to outsourcing, where jobs are shifted overseas to cut costs, benefiting corporate bottom lines at the expense of domestic wages.[21] Not everyone has been equally affected by these changes. Data indicates that the share of wages going to the top 1% increased to 12.9% in 2010, up from 7.3% in 1979.[19] Overall, during the period 1979–2013 the top 1% of the population enjoyed a wage growth of 138%, while the bottom 90% of people only experienced a wage growth of 15% which should have grown 32% if wages grew evenly across all circles. Erik Brynjolfsson, an economics professor at MIT, notes, “There is no economic law

---

[19] Greenhouse, Steven. 2013. “Our Economic Pickle.” The New York Times, January 12, 2013, sec. *Sunday Review.* https://www.nytimes.com/2013/01/13/sunday-review/americas-productivity-climbs-but-wages-stagnate.html.
[20] “Automation Drives Income Inequality.” 2023. MIT Technology Review. February 21, 2023. https://www.technologyreview.com/2023/02/21/1067563/automation-drives-income-inequality/.
[21] Progresa. 2020. “Technology Won't Help Labourers: The Real Cause behind Wage Stagnation.” Medium. November 22, 2020. https://progresaid.medium.com/technology-wont-help-labourers-the-real-cause-behind-wage-stagnation-f6811f9be89d.

that says technological progress has to benefit everybody or even most people."[21] This unequal distribution is problematic because it undermines the assumed societal contract where productivity gains lead to widespread economic improvement.

Skill and Educational Disparities

The labour market's increasing polarisation into low-skilled and high-skilled jobs has been a subject of much concern, particularly as middle-skilled roles continue to decline. This polarisation has been significantly influenced by technological advancements, especially computing and AI.[17] Autor's findings suggest a nuanced picture where not all low-and-medium-skilled jobs are at risk. For example, roles in healthcare and human services that require emotional intelligence and nuanced decision-making are less susceptible to automation. On the bright side, certain high-skilled but routine tasks, like data analysis, might easily be automated, adding another layer of complexity to the job market.[17]

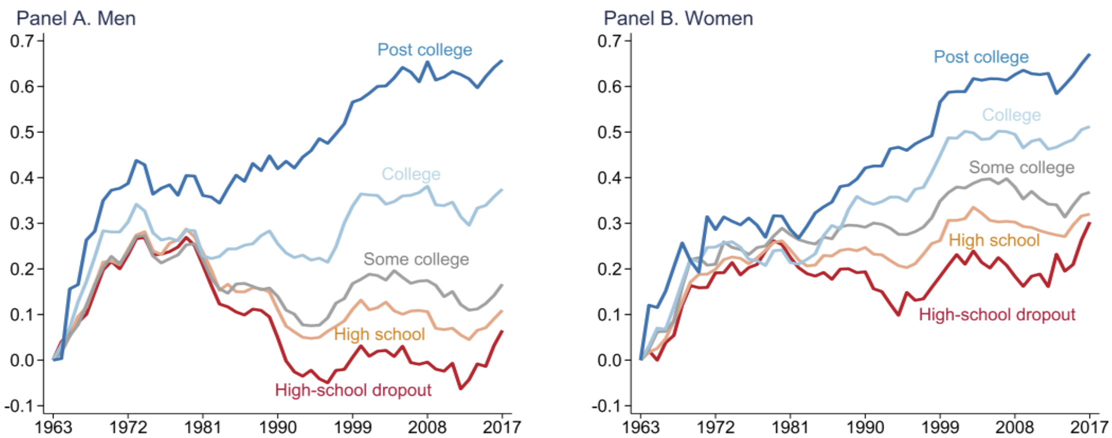


Figure 8: *Cumulative growth of real hourly wages by gender and education*[22]

The impact of automation is particularly striking when examining real wages in relation to educational attainment. In the United States, men without a high-school degree have experienced a significant decline in real wages, which are now 15% lower than they were in 1980. This trend contrasts with the wage gains seen among individuals with post-graduate degrees.[22] In this scenario, educational attainment serves not just as a marker of skill but as a predictor of financial stability and, more broadly, economic inequality.

Skillset Demands in a Changing Labour Market

Technological advancements have not only led to job displacement but also changed the types of skills that are in demand. The falling costs of carrying out routine tasks with computers have created an increasing demand for more abstract and creative services. This shift is observable in multiple sectors, from law to business management.[23] For example, the advent of text and data mining technologies has revolutionised legal research, significantly boosting the productivity and consequently the wages of legal professionals. Similarly, real-time market information has made managerial decision-making more efficient.[23]

[22] Acemoglu, Daron, and Jonas Loebbing. 2022. "Automation and Polarization." SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4238255.

[23] Benedikt, Carl, and Michael Osborne. 2013. "The Future of Employment Published by the Oxford Martin Programme on Technology and Employment." https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf.

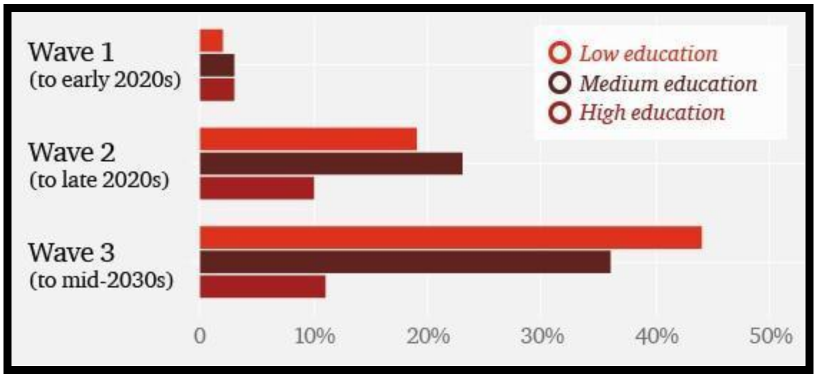


Figure 9: *Job Automation Risk Based on Education Level*[24]

The Role of Education and Retraining Programs

To navigate these complex shifts in labour market demands, retraining and educational programs will be vital. Current evidence suggests that while the short-term impact of automation is relatively low across all education levels, the long-term picture is much more concerning for those with lower educational backgrounds.[24] This makes a strong case for proactive collaboration between governments and businesses to create retraining programs. A culture of adaptability and lifelong learning, emphasising both STEM and soft skills, will be critical in preparing the workforce for the volatile demands of a technologically driven economy.[24]

Overall, the evolving landscape of automation and technology is reshaping labour market dynamics, placing a premium on high-skilled labour while marginalising low-skilled roles. This transformation emphasises the link between educational attainment and economic stability, making it imperative to address skill-set demands through targeted retraining and educational programs. These programs will need to foster both specialised skills and adaptability to prepare the workforce for a future defined by technological fluidity.

Potential Efficiency and Economic Gains

Despite fears over job displacement, sluggish growth and socio-economic disparities, the potential for AI is promising in terms of efficiency and economic growth. Generative AI technologies in particular such as ChatGPT, have shown remarkable potential in this way. A study by the National Bureau of Economic Research reveals that the introduction of generative AI can lift workforce productivity by an average of 14%, with some companies even reporting spikes of up to 400%.[15] In the customer care sector, McKinsey estimates that the application of generative AI could elevate productivity rates by as much as 45%. This dramatic improvement is largely attributed to AI's capacity to grasp customer intent and sentiment, streamlining problem-solving processes for customer service personnel.[15] In the software development sector, 88% of software coders experienced an uptick in productivity when utilising generative AI tools.[15] These systems are adept at automating mundane tasks such as inserting boilerplate code snippets and scrutinising human-generated code for bugs or security vulnerabilities. The technology also takes over the time-consuming task of software documentation, which allows human coders to focus on more high-level, creative aspects of programming. Further with its ability to process and analyse enormous volumes of data, it has the potential to boost the efficiency of business operations too. The McKinsey Global Institute predicts that around 70% of companies will adopt at least one type of AI technology by 2030, and less than half of large companies may use the full range of AI technologies. Price Waterhouse Coopers predicts that AI could increase global GDP by 14% in 2030.[17]

[24] PwC. 2018. "How Will Automation Impact Jobs?" PwC. 2018. https://www.pwc.co.uk/services/economics/insights/the-impact-of-automation-on-jobs.html.

AI and Geopolitical Inequality

However, another glaring divide lies in the existing technological capabilities and the capacity for future investment. For instance, the United Kingdom's planned $130 million investment in AI chips is not just a national endeavour but a strategic move to secure the country's position in the global tech hierarchy.[25] Contrast this with Germany, which is allocating nearly a billion euros over the next two years to catch up with AI leaders like China and the United States.[26] These investments are made in the context of already mature tech ecosystems, with firms and educational institutions that can rapidly adapt to and integrate new technologies. On the other side of the spectrum, developing countries face a daunting reality. In fact, only 0.4% of total employment in low-income countries is at risk of automation, compared to 5.5% in high-income countries.[27] This may seem like a saving grace for developing nations, but it could be seen as an indicator of how far behind they are in technological adoption. The opportunities for growth and development through technology that were available to the United States and China in their formative years are not the same for countries like Cambodia and Tanzania today.[28]

Moreover, the dynamics of global capital investment are also shifting due to AI. High-income countries, which are already using AI more intensively due to their higher labour costs, are likely to see a surge in investment aimed at further automation and AI integration.[28] This draws capital away from developing nations, where it might otherwise have been invested in labour-intensive industries. Over time, this divergence in investment exacerbates existing inequalities, as the rich countries get richer, and the poor one's struggle to even maintain their economic position. Furthermore, in developed countries, where there's a higher percentage of skilled labour, AI acts as a tool that augments human capabilities. It makes jobs more efficient without necessarily eliminating them. On the other hand, in developing nations, AI threatens to replace unskilled labour, overturning one of the few competitive advantages these economies have.[27]

AI has the potential to exacerbate existing inequalities between nations. The differing capacities for AI investment, the divergence in technological adoption, and shifts in investment and production have created an environment where advanced economies are likely to benefit more than developing ones. The onus is on policymakers globally to ensure that the technology serves as an equaliser rather than a divider.[27]

C. Future Concerns: Can Economic Inequality Be Mitigated in a Technological Age?

The question of economic inequality in the technological age is a pressing issue that defies simplistic solutions. The gap between the rich and poor is widening, and there is an increasingly urgent need to examine the role that technology plays in this divide. Specifically, how can we ensure that the benefits of technological advancements, often enjoyed by a privileged few, can be more evenly distributed? This is not just a policy question but also a moral and ethical dilemma that intersects with society.

[25] COGHLAN, JESSE. 2023. "UK to Spend $130M on AI Chips amid Scramble to Buy up Computing Power." Cointelegraph. August 21, 2023. https://cointelegraph.com/news/rishi-sunak-buy-ai-chips-in-race-for-computing-power.

[26] Escritt, Thomas. 2023. "Germany Plans to Double AI Funding in Race with China, U.S." Reuters, August 23, 2023, sec. Technology. https://www.reuters.com/technology/germany-plans-double-ai-funding-race-with-china-us-2023-08-23/?utm_source=www.neatprompts.com&utm_medium=referral&utm_campaign=germany-invests-1b.

[27] "Generative AI Likely to Augment rather than Destroy Jobs." 2023. ILO. August 21, 2023. https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_890740/lang--en/index.htm.

[28] Alonso, Cristian, Siddharth Kothari, and Sidra Rehman. 2020. "How Artificial Intelligence Could Widen the Gap between Rich and Poor Nations." IMF. December 2, 2020. https://www.imf.org/en/Blogs/Articles/2020/12/02/blog-how-artificial-intelligence-could-widen-the-gap-between-rich-and-poor-nations.

Addressing economic inequality in the age of technology requires a multi-pronged approach that involves governments, businesses, educational institutions, and society at large. Governmental solutions like progressive taxation and universal basic income may help redistribute wealth but raise questions about their impact on work ethic and innovation. Businesses, especially in tech, hold significant wealth and could collaborate with governments on retraining programs, but the effectiveness and fairness of such partnerships remain contentious. Education can adapt to future skill demands, but the slow pace of curriculum reform and the uncertainty of future needs present challenges. Finally, societal values must evolve to emphasise collective well-being over individual success, a change that would require deep cultural shifts. Each of these elements presents its own sets of opportunities and challenges, making the issue complex and ongoing.

V. Conclusion

The exploration conducted in this research reveals a complex landscape where technology acts as both an enabler and a divider. On one hand, it holds the potential to revolutionise productivity and economic prospects. On the other, it stands to widen the chasms of inequality, be it in terms of skill, education, or geographic location. The key takeaway is that while technology serves as a catalyst for economic activity, it does not inherently assure equitable distribution of its benefits but certainly has the potential to do both with appropriate use and management.

As we contemplate the evolving role of technology in shaping economic inequality, it's crucial to consider the factors that could steer this trajectory toward more equitable outcomes. While technology's promise for economic expansion is undeniable, as demonstrated by potential leaps in workforce productivity and global GDP, it also reveals an urgent need for adaptive public policy that is both global and granular in its approach. Retraining programs and educational reforms are essential but perhaps insufficient; they must be thoughtfully paired with policies that address wage stagnation and wealth concentration. Geopolitically, the disparate impacts of AI investment and adoption raise questions of equitable technological diffusion, requiring international collaboration to prevent the widening of global economic divides. The topic of economic inequality in the technological age is nuanced and multi-faceted. Nonetheless, the debate needs to be ongoing and adaptive, given the relentless pace of technological change.

VI. Acknowledgements

The author extends sincere gratitude to Dr. Fuad Hasanov for his invaluable advice, guidance, and direction in shaping this research paper.

References

Academic Accelerator. "Industrial Revolution Encyclopedia, Science News & Research Reviews," n.d. https://academic-accelerator.com/encyclopedia/industrial-revolution.

Acemoglu, Daron, and Jonas Loebbing. "Automation and Polarization." SSRN Electronic Journal, 2022. https://doi.org/10.2139/ssrn.4238255.

Allen, Bob. "The Interplay among Wages, Technology and Globalisation: The Labour Market and Inequality, 1620–2020." Accessed June 23, 2023. https://www.bl.uk/britishlibrary/~/media/bl/global/social-welfare/pdfs/non-secure/i/f/s/ifs-the%20interplay-among-wages-technology-and-globalisation-21.pdf.

Alonso, Cristian, Siddharth Kothari, and Sidra Rehman. "How Artificial Intelligence Could Widen the Gap between Rich and Poor Nations." IMF, December 2, 2020. https://www.imf.org/en/Blogs/Articles/2020/12/02/blog-how-artificial-intelligence-could-widen-the-gap-between-rich-and-poor-nations.

Archives, The National. "The National Archives - Homepage." The National Archives, n.d. https://www.nationalarchives.gov.uk/education/resources/why-did-the-luddites-protest/.

Benedikt, Carl, and Michael Osborne. "The Future of Employment Published by the Oxford Martin Programme on Technology and Employment," 2013. https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf.

Clark, Gregory. "The Industrial Revolution." University of California, Davis, n.d. https://faculty.econ.ucdavis.edu/faculty/gclark/papers/HEG%20-%20final%20draft.pdf.

COGHLAN, JESSE. "UK to Spend $130M on AI Chips amid Scramble to Buy up Computing Power." Cointelegraph, August 21, 2023. https://cointelegraph.com/news/rishi-sunak-buy-ai-chips-in-race-for-computing-power.

Elimian, Godfrey. "As ECommerce CEO Replaces 90% of Staff with Bots, Are Fears of AI Taking over Jobs Coming True?" https://technext24.com/2023/07/12/ceo-cuts-90-staff-replace-with-ai-bots/, July 12, 2023. https://technext24.com/2023/07/12/ceo-cuts-90-staff-replace-with-ai-bots/.

Engineering, Society for Industrial Management and. "Industrial Revolution 1.0 — Era of Mechanization." Medium, September 29, 2021. https://medium.com/spark-by-sime/industrial-revolution-1-0-9e6dc9c62c8c.

———. "Industrial Revolution 2.0 — Era of Mass Production." Medium, July 16, 2021. https://medium.com/spark-by-sime/industrial-revolution-2-0-era-of-mass-production-594acfa228c6.

Escritt, Thomas. "Germany Plans to Double AI Funding in Race with China, U.S." Reuters, August 23, 2023, sec. Technology. https://www.reuters.com/technology/germany-plans-double-ai-funding-race-with-china-us-2023-08-23/?utm_source=www.neatprompts.com&utm_medium=referral&utm_campaign=germany-invests-1b.

Gow, Glenn. "ChatGPT and Generative AI: What to Do with All the Productivity?" Forbes, July 2, 2023. https://www.forbes.com/sites/glenngow/2023/07/02/chatgpt-and-generative-ai-what-to-do-with-all-the-productivity/?sh=38b735913edc.

Greenhouse, Steven. "Our Economic Pickle." The New York Times, January 12, 2013, sec. Sunday Review. https://www.nytimes.com/2013/01/13/sunday-review/americas-productivity-climbs-but-wages-stagnate.html.

Gries, Thomas, and Wim Naudé. "Artificial Intelligence, Jobs, Inequality and Productivity: Does Aggregate Demand Matter?" SSRN Electronic Journal, 2018. https://doi.org/10.2139/ssrn.3301777.

ILO. "Generative AI Likely to Augment rather than Destroy Jobs," August 21, 2023. https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_890740/lang--en/index.htm.

Ilzetzki, Ethan, and Suryaansh Jain. "The Impact of Artificial Intelligence on Growth and Employment." CEPR, June 20, 2023. https://cepr.org/voxeu/columns/impact-artificial-intelligence-growth-and-employment#:~:text=The%20World%20Economic%20Forum%20concluded.

Jordan, Michael I. "Artificial Intelligence—the Revolution Hasn't Happened Yet." Issue 1 1 (June 23, 2019). https://doi.org/10.1162/99608f92.f06c6e61.

Kothari, Jash. "Artificial Intelligence: Cause of Unemployment." GeeksforGeeks, August 16, 2019. https://www.geeksforgeeks.org/artificial-intelligence-cause-of-unemployment/.

McKinsey & Company. "What Can History Teach Us about Technology and Jobs?," 2018. https://www.mckinsey.com/featured-insights/future-of-work/what-can-history-teach-us-about-technology-and-jobs.

MIT Technology Review. "Automation Drives Income Inequality," February 21, 2023. https://www.technologyreview.com/2023/02/21/1067563/automation-drives-income-inequality/.

Progresa. "Technology Won't Help Labourers: The Real Cause behind Wage Stagnation." Medium, November 22, 2020. https://progresaid.medium.com/technology-wont-help-labourers-the-real-cause-behind-wage-stagnation-f6811f9be89d.

PwC. "How Will Automation Impact Jobs?" PwC, 2018. https://www.pwc.co.uk/services/economics/insights/the-impact-of-automation-on-jobs.html.

Rafferty, John. "The Rise of the Machines: Pros and Cons of the Industrial Revolution." In Encyclopedia Britannica, 2019. https://www.britannica.com/story/the-rise-of-the-machines-pros-and-cons-of-the-industrial-revolution.

Reuters. "27% of Jobs at High Risk from AI Revolution, Says OECD." Reuters, July 11, 2023, sec. Technology. https://www.reuters.com/technology/27-jobs-high-risk-ai-revolution-says-oecd-2023-07-11/.

Rotman, David. “How to Solve AI’s Inequality Problem.” MIT Technology Review, April 19, 2022. https://www.technologyreview.com/2022/04/19/1049378/ai-inequality-problem/.

Stanford, Steven C. “Henry Ford - an Impact Felt.” Henry Ford Heritage Association, n.d. https://hfha.org/the-ford-story/henry-ford-an-impact-felt/.

Techopedia. “What Is the Digital Revolution? - Definition from Techopedia.” Techopedia, 2019. https://www.techopedia.com/definition/23371/digital-revolution.

The White House. “THE IMPACT of ARTIFICIAL INTELLIGENCE on the FUTURE of WORKFORCES in the EUROPEAN UNION and the UNITED STATES of AMERICA,” December 5, 2022. https://www.whitehouse.gov/wp-content/uploads/2022/12/TTC-EC-CEA-AI-Report-12052022-1.pdf.

U.S. Department of State. “Outline of the U.S. Economy.” Usembassy.de, 2019. https://usa.usembassy.de/etexts/oecon/chap9.htm.

The Lens Journal
A journal of perspectives for young researchers

Method Analysis For The Purification of Heavy Metal Ions From Water

Kate Winarta
Jakarta Intercultural School

Abstract
This study investigates a review of the analysis of methods for removing metal ions from water to make the water fulfill drinking standards. The paper assesses physical and chemical separation methods and includes an overview, advantages, and limitations. The comparative analysis concludes that a combination of sedimentation and chemical precipitation can provide the best result due to its effectiveness and applicability for public use.

Keywords: Metal ions, water purification, physical and chemical separation, sedimentation, chemical precipitation

I. Introduction and Background Information

Water purification and its study has been pressing in today's society. As highlighted in the UN's Sustainable Development Goal No. 6, "Clean Water and Sanitation," removing harmful agents from water sources remains one of the world's most vital issues. As the research for water purification has advanced, most research has focused on a more popular harmful agent in water: bacteria; however, it overlooks another – metal. Metal ions are commonly found in household water, with the most common ones being arsenic, cadmium, nickel, mercury, chromium, and zinc. The safe limits for these metals are 10 µg/L, 3 µg/L, 70 µg/L, 6µg/L, 50 µg/L, and 5000 µg/L respectively (World Health Organization, 2017). The existence of such metals in water is typically a result of industrial-generated waste that is discharged into the environment, which, thus, goes into the water people use for household activities, causing further harm. When consumed, these metal ions can cause repercussions and are a detriment to one's health. It can cause life-threatening diseases, such as "damage to the central nervous system, hearing speech and visual disorders, hypertension, anemia, dementia, hematemesis, bladder, lung, nose, larynx, prostate cancer, and bone diseases" (Bansal). As noted previously, studying metal ions in water is vital, specifically the component of removing the metal ions from the waters people drink and use in their day-to-day activities. With this, a new question arises: what is the best method for removing this harmful agent? Several methods, each with its own advantages and disadvantages, have been previously researched; these methods can be separated into physical and chemical separation. Because determining the importance of one method's effectiveness over another can be subjective, this paper will also assess its applicability in its use to the public.

II. Physical Treatment

2.1 Ultrafiltration

2.1.1 Overview and Applications

Ultrafiltration is a method that uses a membrane to filter out contaminants based on their size and charge. The membrane has tiny pores, which allow the water molecules to pass through while retaining larger contaminants. The size and charge of the contaminants determine their ability to pass through the membrane. For example, negatively charged ions such as heavy metal ions are typically retained by the membrane, while neutral molecules such as organic contaminants can pass through more easily. Subsequently, the filter system needed for this method has a role in creating a large surface area for the particles to adhere to, which blocks and separates the heavy metal ions from water. The filter media can be made of various materials, including granular activated carbon, which is particularly effective at removing heavy metal ions due to its high surface area and chemical affinity for these ions. Granular activated carbon is a type of carbon that has been treated with oxygen to increase its surface area and porosity. Its high surface area allows activated carbon to adsorb contaminants, including heavy metal ions– thus, making it easier for the heavy metal ions to separate and be collected. Furthermore, according to research, filtration can be further enhanced by using a pre-treatment process, such as coagulation, which involves adding chemicals to the water to cause the heavy metal ions to form larger particles that are more easily captured by the filter media (Yu, et al. 2014).

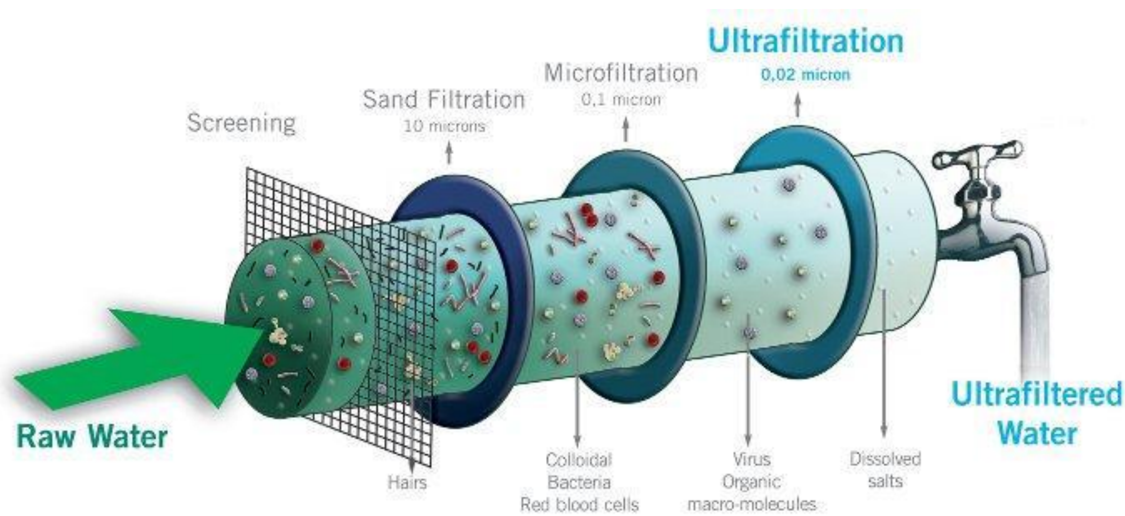


Figure 1: *Process of Ultrafiltration*

2.1.2 Limitations

However, there are some limitations to the use of ultrafiltration for removing heavy metal ions from drinking water. The efficiency of this method depends on the size and shape of the ions, as well as the size and type of the filter media. Some heavy metal ions, such as mercury and arsenic (common metals found in water), may be too small to effectively remove by filtration. Ultrafiltration and the use of the filter media, granulated activated carbon, is most effective for larger heavy metal ions Another limitation is the cost of the equipment and maintenance. It takes somewhere around 50-70 thousand US dollars to operate such machinery, and this cost would be at its most basic level (Drouiche, et al. 2001) (Yoo, 2018). Ultrafiltration systems can be expensive to purchase and operate, and the membranes must be replaced regularly to maintain their effectiveness. Similarly, the Granulated Activated Complex also requires periodical oversight as it can easily become saturated with contaminants. When saturated, it needs to be replaced or regenerated; however, the regeneration process involves using chemicals to release the contaminants of the GAC. If not done correctly, doing so can contaminate the water again, as there is a possibility that the regeneration process releases heavy metal ions back into the water. In summary, while ultrafiltration is an efficient process, it can be challenging to maintain.

2.2 Sedimentation

2.2.1 Overview and Applications

Sedimentation is another physical method that can be used to separate heavy metal ions from drinking water. This method allows the water to stand for some time, allowing heavier particles, including heavy metal ions, to settle to the bottom of the container. The clear water can then be separated from the sediment, leaving the heavy metal ions behind. To purify drinking water using sedimentation, the water is first treated with the adsorbent material. The mixture is then allowed to settle, with the heavy metal ions being adsorbed onto the surface of the adsorbent. The purified water can then be collected, while the adsorbent material can be removed and disposed of or reused.

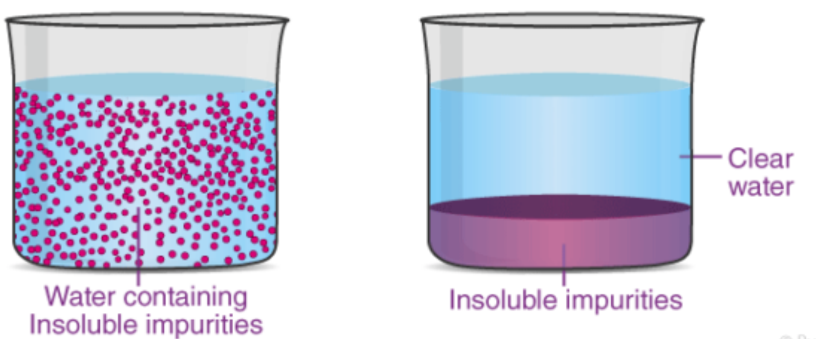


Figure 2: *Process of Sedimentation*

To enhance its effectiveness, like ultrafiltration, sedimentation can be enhanced by using a coagulant, as mentioned above, to cause the heavy metal ions to form larger particles that will settle more quickly (Abouzied et al., 2022). Although research on the combination of sedimentation with chemical coagulant has been done on algal removal from water (Abouzied et al., 2022), further research on sedimentation is needed to support that adding a chemical coagulant would advance the purification of metal ions from water.

2.2.2 Advantages

An advantage of using this method would be its simplicity, as no specialized lab equipment or skills are needed to perform this method. Similarly, this method is cost-effective and can be scaled up to treat large volumes of water. Furthermore, it does not produce any harmful by-products or requires the use of chemicals, making it environmentally friendly.

2.2.3 Limitations

There are also some limitations to using sedimentation for purifying heavy metal ions from drinking water. It can be slow, requiring several hours or even days for the sedimentation process to be completed. In addition, it is ineffective at removing all types of heavy metal ions and may not be suitable for some water sources. Because this method relies on the metal ions and water to separate itself, all metal ions, especially the smaller ones, might not be collected. This presents a limitation since smaller metal ions, such as cadmium and copper, which are common in water, might not be effectively separated and could remain in the water's residue.

III. Chemical Treatment

3.1 UV Light treatment

3.1.1 Overview and Applications

Ultraviolet light's connection to water disinfection is not a foreign field; for instance, a highly researched area would be ultraviolet light's effect on water-borne bacteria. A detailed study by Henry Ricks highlights the success of using UV light to kill bacteria such as E-Coli as well as other bacteria with similar properties in water. Several commercially sold products have been created using this research, and thus far, ultraviolet treatment continues to be a leading solution in water purification from bacteria. The multitude of research regarding this methodology can be applied to research on metal ions in water using similar methodologies. Although not ideal, this study mentions research that showcases the criteria for using accurate ultraviolet light. To name a few would be the duration of ultraviolet exposure, the intensity of ultraviolet light, a controlled temperature, and the importance of warming up the UV light before use. Since this study on bacteria uses the same methodology, research on metal ions in water can be adapted by altering the listed components. Admittedly, there has been limited research on the relationship between ultraviolet treatment and the removal of metal ions. However, although the section on metal ions was brief, the review paper titled "Advances on Water Quality Detection by UV-Vis Spectroscopy" talks about ways to separate individual metals and ways to avoid spectral overlap. According to the research, to avoid overlaps between metals, one would need to determine the concentration of multi-metal ions, as UV irradiation allows the liberation of metals connected to the organic structure, which determines the amount of content of each element. In other words, this method helps with a crucial part of the metal removal process: determining which metals are in the water. As suggested by researcher Guo, using a UV-vis wave band and colorimetry, one could "[select] a suitable color reagent to react with the component to be tested to form a colored substance or to change the color of the solution, and then the generated colored substance is compared with the standard solution, the color of the reaction solution and the standard solution is observed, or the spectrum of its UV-Vis wave band is measured to determine the substance quantitatively." Nevertheless, research conducted so far has yet to prove the effectiveness of ultraviolet treatment in filtering out metals for complete water purification.

3.2 Chemical Precipitation

3.2.1 Overview and Applications

Chemical precipitation can be deemed one of the most researched and viable methods for removing heavy metal ions from water. This method involves the addition of chemicals to the water to encourage forming solid, insoluble precipitates that can easily be removed. A study conducted on chemical precipitation and its effects on removing heavy metals was done on common metals in water: lead, copper, and chromium. In this study, the researchers added a mixture of alum and calcium oxide, as well as sodium hydroxide and sodium carbonate; both mixtures served the role of "chemicals" (Oncel et al., 2013). A similar study supports this research; its mixture of sodium carbonate and magnesium oxide acted similarly to that of Yang and yielded similar results (Mahmood et al., 2011). Both these chemicals that were added to the water proved successful as not only was a solid precipitate formed, but the removal process of this precipitate was easy to accomplish. The precipitate is formed in this method due to the reaction's formation of a complex that reduces the bioavailability of the metal ions.

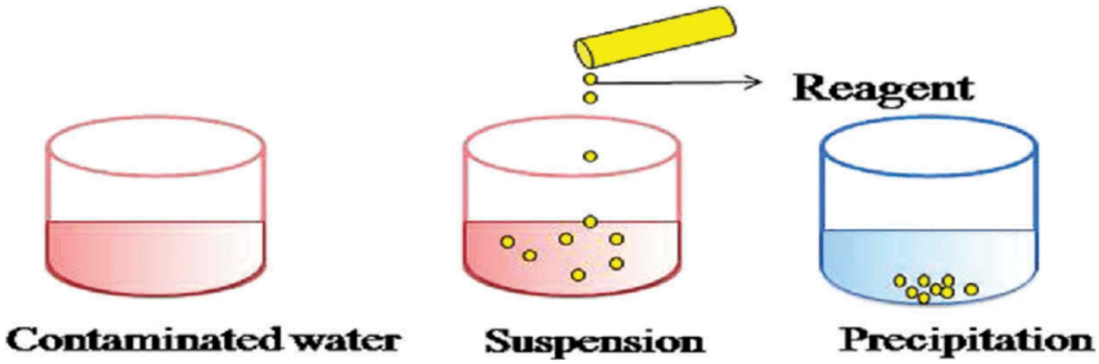


Figure 3: *Process of Chemical Precipitation*

3.2.2 Advantages

In addition to its effectiveness, chemical precipitation has several advantages as a method for removing heavy metal ions from water. Firstly, this method is inexpensive (which is one of the main reasons for extensive research on this method). The materials needed for this chemical precipitation are widely accessible, and no specific lab condition is needed to conduct this reaction. This also makes the method a viable option for treating water in both developed and developing countries. Second, this method is relatively simple to accomplish. Basic instructions are sufficient to conduct this experiment, as no expert supervision is needed. Third, it is a versatile method that can be applied to a wide range of water sources, including both surface water and groundwater; this versatility is vital as drinking water can come from a variety of sources. Lastly, this method produces minimal waste, as the solid precipitates that are formed can be easily disposed of.

3.2.3 Limitations

Despite its advantages, chemical precipitation has its limitations. The main limitation would be that the effectiveness of this method can be limited by the presence of other ions in the water, which can interfere with forming a solid precipitate. Calculations determining the type of mixture needed to form the solid precipitate rely on the existing metal in the water. Other ions that are unaccounted for would disrupt this process. Furthermore, the formed precipitate might not capture all the metals, potentially leaving traces of heavy metal ions in the water.

3.3 Ion Exchange System

3.3.1 Overview and Applications

An ion exchange system is a method that involves passing the contaminated water through a bed of ion exchange resin to remove the heavy metal ions. A study by Hubicki et al. (2012) investigated the use of an ion exchange resin specifically designed to remove heavy metal ions, such as copper and zinc, from contaminated water. To conduct the study, the author first prepared the ion exchange resin by soaking it in a solution of hydrochloric acid and sodium chloride. This process, known as “conditioning", removed the impurities from the resin and made it more usable for the ion exchange process. The resin was then placed in a column, and the researcher passed the contaminated water through it. As the water flowed, the heavy metal ions were attracted to the resin and bound to it, while the non-metal ions in the water passed through the column unchanged. The purified water can be collected at the bottom of the column, while the heavy metal ions would be collected at the top.

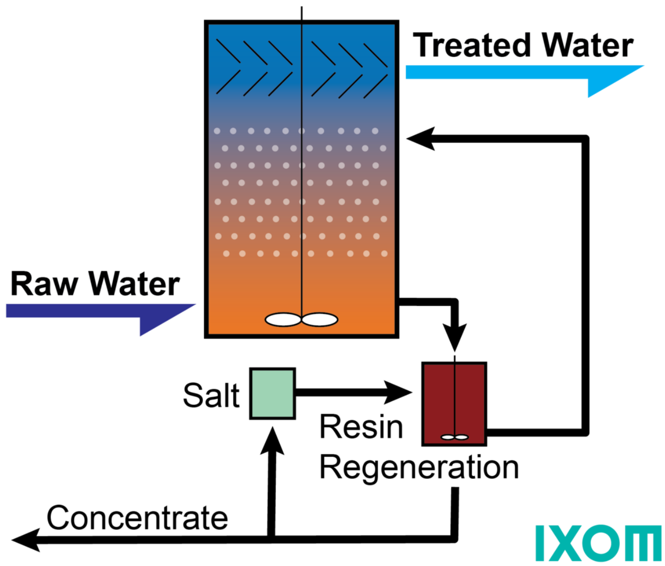


Figure 4: *Process of Ion Exchange System*

In the same research, the effectiveness of this method was also tested under different conditions, such as different flow rates and resin bed depths. The results showed that increasing the flow rate and resin bed depth improved the effectiveness of the resin in capturing metal ions. The researchers also found that these columns could be easily regenerated by soaking them in a solution of sodium hydroxide, allowing for multiple uses. Ultimately, the purified water collected at the bottom of the column effectively removed the metal ions and made the then-contaminated water able to meet the standards for drinking water.

3.3.2 Advantages

An advantage of using the ion exchange process is that this method offers high efficiency with relatively low processing requirements (Sole, 2017). The ion exchange systems are able to remove a wide range of contaminants due to its versatility and long life span. Its versatility is valuable as it can work in different settings including large treatment plans or smaller decentralized systems. In other words, this method can be easily integrated into existing water treatment systems.

3.3.3 Limitations

There are also some limitations to ion exchange for purifying heavy metal ions from drinking water. It requires using chemicals to regenerate the resin, which can produce harmful environmental impacts. Additionally, the resin has a limited lifespan, requiring periodic replacement (Wang et al., 2016).

3.4 Ligand-Attached Chelate Surfactant

3.4.1 Overview and Applications

Chelate surfactants are compounds that consist of both a surfactant and a chelating agent. A chelating agent, a compound consisting of ligands (molecules that can bind to metal ions through coordination bonds), when added to water, can separate into its constituents– properties that can form a complex with the metal ions in the water, helping separate the metal ions from the water molecules. A surfactant such as C14-ED3A3Na (Peng et al., 2020), on the other hand, can help to solubilize the metal ions.

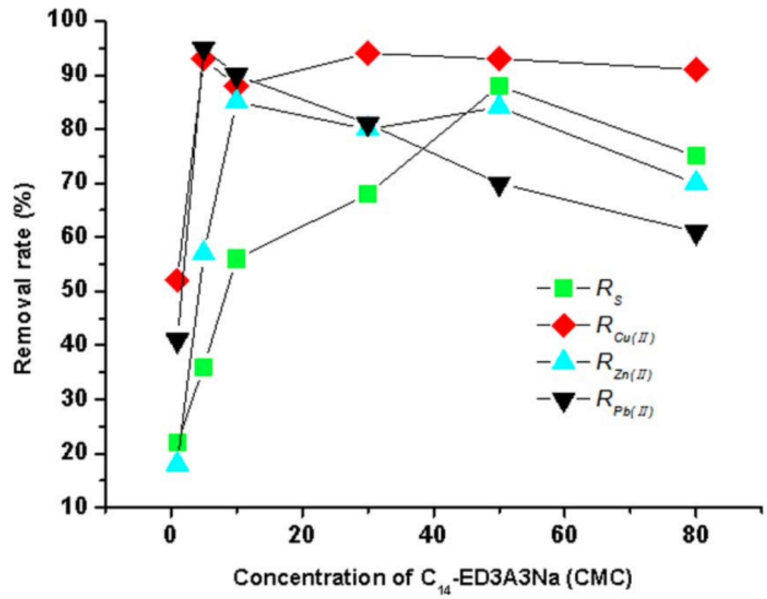


Figure 5: *Effectiveness of C14-ED3A3Na (surfactant) on metal removal rate*

Thus, both the chelates and surfactants contribute to making the ions easier to remove. A chelating surfactant can be used to increase the effectiveness of ligands further. By attaching ligands to the chelating agent, the affinity of the chelate surfactant for specific metal ions can be enhanced, leading to more efficient removal of the targeted ions from the water.

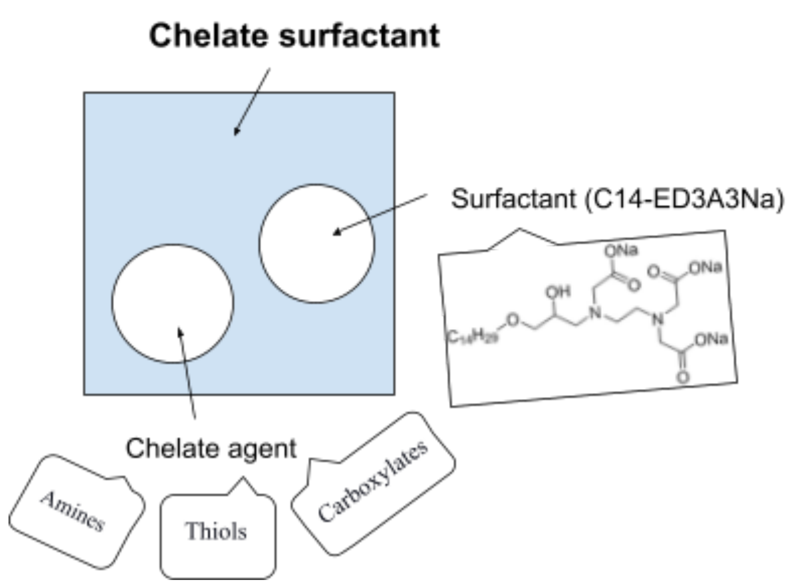


Figure 6: *Process of Creating Chelate Surfactant*

Several types of ligands can be attached to chelate surfactants, including amines, thiols, and carboxylates. Each type of ligand has its specific properties and binding strength depending on the different metal ions, as different metal ions have different individual properties. Therefore, the choice of which ligand to use depends on the specific metal ions that need to be removed. In addition to their ability to remove heavy metal ions from drinking water, chelate surfactants have several other advantages.

3.4.2 Advantages and Limitations

Ligand-attached chelate surfactants are effective at low concentrations and exhibit high removal efficiency., even at low pH values. They also have low toxicity to humans and the environment, making them a safe and effective option for purifying drinking water.

3.4.3 Limitations

However, there are some limitations to using chelate surfactants for purifying drinking water. One potential challenge is the formation of stable metal-ligand complexes that may not be easily removed from the water. Although this method separates the metals from the water, the removal process itself could be difficult to achieve and would require another method. Additionally, ligand-attached chelate surfactants might perform better in removing specific metal ions over others. For example, this method may not effectively remove certain types of heavy metal ions, such as arsenic and selenium, but work more effectively on others, such as cadmium and copper (Wang et al., 2016). This limitation presents a drawback to this method because an ideal method should effectively work on common metals, yet this method does not fulfill this requirement.

IV. Analysis and Discussion

Further research should be conducted, but in this researcher's opinion, sedimentation and chemical precipitation are the most beneficial among all the methods. Both these methods are simple to do and cost-effective. Sedimentation requires no materials, while the method of chemical precipitation only needs non-harmful chemicals– readily available and safe materials for household use. Limitations that sedimentation poses, chemical precipitation fulfills, and vice versa: sedimentation is effective at collecting heavier metal ions and not so much on smaller metal ions, while, on the other hand, chemical precipitation is effective at collecting smaller metal ions but not effective at collecting heavier metal ions. Therefore, combining these methodologies and considering their respective advantages and limitations can prove effective in purifying household drinking water from metal ions.

V. Limitations of Paper and Conclusions

This research paper, while offering a thorough analysis of methods for removing heavy metal ions from water, has certain limitations that should be acknowledged to ensure a clear understanding of the study's scope and potential implications. A notable limitation pertains to the absence of quantitative analysis within this paper. The focus of this paper was primarily directed towards qualitative aspects of the examined removal techniques. As a result, the quantitative analysis is beyond the scope of this research. Nonetheless, it is crucial to recognize the essentiality of quantitative analysis in comprehensively assessing the effectiveness and efficiency of removal methods. Future research endeavors should thus incorporate quantitative analysis to facilitate precise measurements and enable a comprehensive evaluation of the techniques for the elimination of heavy metal ions from water.

The listed methods above all serve their respective advantages and limitations. While some methods excel in certain aspects, they may fall short in others. As mentioned previously, naming one advantage more beneficial than another is subjective to what a researcher prioritizes. In the case of the purification of metal in drinking water, because the aim is more so on the public, an important aspect of the chosen method would be its affordability and cost-effectiveness and applicability to different types of metals regardless of their sizes and properties. Through thorough comparative analysis, this paper concludes that sedimentation and chemical precipitation are the best methods to do so.

References

Admin. (2016, January 18). Sedimentation & Examples | Centrifugation | Chemistry | Byju's. BYJUS; BYJU'S. https://byjus.com/chemistry/sedimentation/

Bansal, Om. "Health Risks of Potentially Toxic Metals Contaminated Water". Heavy Metal Toxicity in Public Health, edited by John Nduka, Mohamed Rashed, IntechOpen, 2020. 10.5772/intechopen.92141.

Barakat, M. (2011). New trends in removing heavy metals from industrial wastewater. Arabian Journal of Chemistry, 4(4), 361-377. https://doi.org/10.1016/j.arabjc.2010.07.019

Blue, L. Y., Van Aelstyn, M. A., Matlock, M., & Atwood, D. A. (2008). Low-level mercury removal from groundwater using a synthetic chelating ligand. Water Research, 42(8-9), 2025-2028. https://doi.org/10.1016/j.watres.2007.12.010

DąbrowskiA., Hubicki, Z., Podkościelny, P., & Robens, E. (2004). Selective removal of the heavy metal ions from waters and industrial wastewaters by ion-exchange method. Chemosphere, 56(2), 91–106. https://doi.org/10.1016/j.chemosphere.2004.03.006

De, L., & De, R. (2023). Sustainable Development Goals in Europe. Springer Nature. https://www.who.int/publications/i/item/9789241549950

Figure 3. Schematic diagram showing chemical precipitation for removal... (2020). ResearchGate; ResearchGate. https://www.researchgate.net/figure/Schematic-diagram-showing-chemical-precipitation-for-removal-of-heavy-metal-ions_fig3_341642536

Hubicki, Zbigniew, Kołodyńska, Dorota. "Selective Removal of Heavy Metal Ions from Waters and Waste Waters Using Ion Exchange Methods". Ion Exchange Technologies, edited by Ayben Kilislioğlu, IntechOpen, 2012. 10.5772/51040.

Mahmood, M & Barbooti, Mahmood & Balasim, A & Altameemi, Abid & Al-Terehi, Mona & Al-Shuwaiki, Najah. (2011). Removal of Heavy Metals Using Chemicals Precipitation. Eng. Technol. J.. 29.

M. Drouiche, Hakim Lounici, D Belhocine, & Nabil Mameri. (2001, April). Economic study of the treatment of surface water by small ultrafiltration units. ResearchGate; MDPI. https://www.researchgate.net/publication/267981788_Economic_study_of_the_treatment_of_surface_water_by_small_ultrafiltration_units

MIEX® Magnetic Ion Exchange Systems. (2020, September 11). Ixomwatercare.com. https://www.ixomwatercare.com/equipment/miex-magnetic-ion-exchange-systems

Oncel, M.S., et al. "A Comparative Study of Chemical Precipitation and Electrocoagulation for Treatment of Coal Acid Drainage Wastewater." Journal of Environmental Chemical Engineering, vol. 1, no. 4, Dec. 2013, pp. 989–995, www.sciencedirect.com/science/article/abs/pii/S2213343713001346,10.1016/j.jece.2013.08.008. Accessed 21 Dec. 2022.

Peng, Z., Chen, H., Li, Y., Feng, K., Wang, C., Liao, F., Deng, H., & Huang, Y. (2020). Chelating surfactant for the removal of heavy metals from wastewater and surfactant recovery. DESALINATION and WATER TREATMENT, 206, 229–234. https://doi.org/10.5004/dwt.2020.26302

Peng, Zhongli, et al. "Chelating Surfactant for the Removal of Heavy Metals from Wastewater and Surfactant Recovery." DESALINATION and WATER TREATMENT, vol. 206, 2020, pp. 229–234, 10.5004/dwt.2020.26302. Accessed 15 Feb. 2021.

Rehman K, Fatima F, Waheed I, Akash MSH. Prevalence of exposure to heavy metals and their impact on health consequences. J Cell Biochem. 2018 Jan;119(1):157-184. doi: 10.1002/jcb.26234. Epub 2017 Aug 2. PMID: 28643849.

Shin, Mari & Barrington, Suzelle & Marshall, William & Wang, Li. (2005). Complexation of a Ligand with a Surfactant Micelle for Soil Heavy Metal Desorption. Soil & Sediment Contamination - SOIL SEDIMENT CONTAM. 14. 357-372. 10.1080/15320380590954088.

Sole, Kathryn & Mooiman, Michael & Hardwick, Ed. (2017). Ion Exchange in Hydrometallurgical Processing: An Overview and Selected Applications. Separation & Purification Reviews. 47. 10.1080/15422119.2017.1354304.

Ultrafiltration - REKAINDO. (2018). REKAINDO. https://rekain.com/service/ultrafiltration-membrane/

Veluchamy, Chitraichamy, et al. "Recovery of Value-Added Materials from Wastewater." Current Developments in Biotechnology and Bioengineering, 2021, pp. 175–196, www.sciencedirect.com/topics/chemical-engineering/precipitation-chemical#:~:text=Chemical%20precipitation%20is%20the%20most,compounds%20and%20the%20precipitating%20reagent, 10.1016/b978-0-12-821009-3.00014-2. Accessed 21 Dec. 2022.

Wang, L., Guo, J., & Li, H. (2016). Heavy metal ions removal from aqueous solutions by ion exchange resins: a review. Environmental Progress & Sustainable Energy, 35(1), 1-13.

Yoo, S. (2018). Operating Cost Reduction of In-line Coagulation/Ultrafiltration Membrane Process Attributed to Coagulation Condition Optimization for Irreversible Fouling Control. Water, 10(8), 1076. https://doi.org/10.3390/w10081076

Yu, W., Xu, L., Graham, N., & Qu, J. (2014). Pre-treatment for ultrafiltration: effect of pre-chlorination on membrane fouling. Scientific Reports, 4(1). https://doi.org/10.1038/srep06513

The Lens Journal
A journal of perspectives for young researchers

The ACE Project: Creation of an Eco-Friendly Brick Best Suited for the Indonesian Environment

Sheina Pribadi
Jakarta Intercultural School

Abstract
This paper presents a comparative analysis to address the question: Can eco-friendly cement bricks outperform traditional Indonesian clay bricks and regular cement bricks in terms of cost, strength, and performance, thus being a viable building material in the Indonesian construction sector? Throughout this experiment, the researcher determined the validity of alternative cement through three factors: cost, carbon emissions produced, and the strength of the bricks tested. The cost and carbon emissions produced were determined by the data from scholarly sources; however, the brick strength was tested both in a lab, through a compression strength test, and in the current environment, through building a 2m by 2m prototype house.

Despite initial test and research suggesting that alternative cement offers environmental, structural, and economical benefits, further investigation is required to validate these findings, as the experiment remains in its early stages.

Keywords: fly-ash cement, eco-friendly cement bricks, clay bricks, carbon emissions, environmental sustainability

I. Introduction

8% of global emissions arise from cement production (Ellis et al., 2019), which is equivalent to 1.7 billion metric tons of global carbon dioxide emissions caused by the cement manufacturing industry alone (Tiseo, 2023). In the thriving and vibrant construction industry of Jakarta, many faults persist, including poor air quality and the need to enhance environmental sustainability. As Indonesia strives to reduce carbon emissions, alternative cement emerged as a possible solution. Thinking of implementing this solution for Indonesia, the researcher developed her own version of fly-ash cement - a form of alternative cement, proven to produce stronger, less permeable, and more cost-effective construction materials, as it utilizes the by-product of coal-burning power plants to replace some of the cement and water in bricks. This eco-friendly variant of cement intrigued this researcher during her time at an Environmental Solutions course at Stanford University. Using a polluting waste product to replace the majority of cement in bricks will reduce the carbon dioxide produced by creating cement, which allows for a sustainable and eco-friendly brick. Every kilogram of cement replaced by fly-ash saves 0.9 kilograms of carbon dioxide from being emitted into the atmosphere (Fayomi et al., 2019).

II. Literature Review

The most influential resources used to aid the information provided in this research were these two sources:

1. Evaluation of Alternative Home-Produced Concrete Strength with Economic Analysis: Muhammad Rauf Shaker, Mayurkumar Bhalala, Qayoum Kargar, and Byungik Chang.
    a. This paper compared the costs of ready-mix concrete to alternative materials used in concrete such as fly-ash, wood-ash, and recycled aggregates. This paper also investigates the percentage in which users can replace cement with the materials mentioned above without compromising the original compressive strength of regular cement. Additionally, this paper mentions the carbon dioxide emissions saved from using alternative materials.
2. Perspectives on environmental CO2 emission and energy factor in Cement Industry: Gbenga Fayomi, Simphiwe Enoch Mini, Ojo Sunday Isaac Fayomi, and Ayodeji Ayoola.
    a. This paper analyzes the carbon emissions released through the cement-making process, more specifically the additive ratio, consumption mix, and manufacturing process. The authors investigated the components of clinker used in Portland cement, the carbon dioxide emissions released through the different types of fuel and clinker ratios used for the different cement formula ratios, and historical trends of cement production in different countries. Experimental Program (Method)

III. Experimental Program (Method)

For the first experiment, the concrete mixture was poured into a 10cm 22cm 6.5cm wooden brick mold. The materials used, fly-ash, cement, and river sand, were sourced from the same location. A nearby construction shop provided the cement and river sand, while the fly-ash was sourced from the Paiton PLTU power plant factory. The cement (including fly-ash if applicable) to sand ratio was 1:2. There are two main mixtures: Control (regular Portland cement), and the fly-ash replacement.

The total number of mixtures is 8, where the cement is partially replaced by different dosages of fly-ash. The replacement fly-ash to cement ratios are 2:0.5, 3:0.5, 2:1, 4:0.5, 5:0.5, 1:1, and 1.5:1. The bricks were dried outside for at least two days to solidify. The table below reflects the following proportions and labels that will be discussed during the Tests section of this paper.

Formula (labeled on brick)	Fly-Ash to Cement Ratio
1	2:0.5
2	3:0.5
3	2:1
4	5:0.25
5	4:0.5
6	5:0.5
7	1:1
8	0:1 (control)
9	1.5:1

Table 1 *Composition (fly-ash to cement ratio) of each brick*

Figure 1. *Handmade bricks used in the testing stage*

The next phase of the testing stage was to determine whether alternative cement bricks could withstand the current Indonesian environment; therefore, after analysis of the lab results, the researcher proceeded to mass-manufacture the strongest brick formula at a local workshop. Additionally, traditional Indonesian clay and sand bricks, Portland cement bricks, and a 80% fly-ash and 20% clay brick were created for a comparative analysis of alternative cement and commonly used bricks in Indonesia. Each wall consisted of a different type of brick supported by concrete pillars. A local workshop in Malang mass-manufactured 500 of each brick. The clay bricks are 4cm 9.5cm 19cm in size, and the bricks including cement are 6cm 10.5cm 21cm. The proportions and composition of each brick is described in Table 2. To track the progression of each brick, the researcher compiled pictures of each wall every two weeks to analyze any changes in the brick appearance or degradation (refer to the Appendix A.).

Brick Code/Name	Composition Ratio
Bata 1 and Bata 2	100% (Clay)
Bata 3 and Bata 4	4:1 (Fly-ash to clay)
Parling 1 and Parling 2	100% (Cement)
Parling 3 and Parling 4	1.5:1 (Fly-ash to cement)

Table 2. *Proportions and composition of each brick(Shaker et al., 2020)*

Figure 2. *Tracking the progression of each brick*

IV. Tests

4.1 Compressive Strength Test

The test is conducted to evaluate whether the strength of different fly-ash mixtures could surpass the strength of concrete bricks. Furthermore, this test also determines whether these bricks adhere to the regular FC20 standard. The first test was performed on 10cm 22cm 6.5cm bricks. The second experiment tested the two types of 4cm 9.5cm 19cm clay bricks and the two variations of the 6cm 10.5cm 21cm cement bricks that were used in building the prototype house, which served to determine which type of the brick could withstand the current Indonesian environment the best. All compression strength tests were carried out in the construction and concrete technology lab in Universitas Tarumanagara (UNTAR). The machinery was handled by UNTAR lab personnel.

4.2 Price

Another aspect of this report was analyzing the cost-effectiveness of alternative cement compared to regular Portland cement. The price comparison was determined by the cost analysis of a research paper titled “Evaluation of Alternative Home-Produced Concrete Strength with Economic Analysis” (Shaker et al., 2020), which also analyzes the price of resources required to manufacture bricks with recycled aggregates, fly-ash, and regular cement bricks.

4.3 Carbon Emission

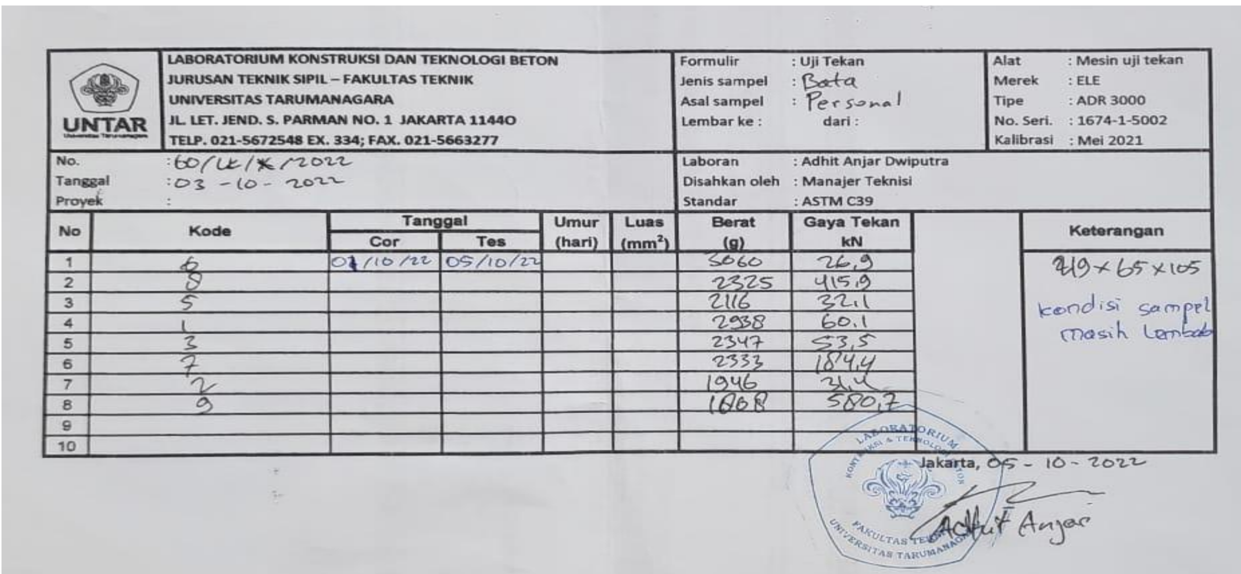
The purpose of this test was to determine the carbon emissions produced through manufacturing regular Portland cement compared to fly-ash cement. This comparison is based on the idea that fly-ash is readily available nearby the manufacturing area; therefore, the emissions of transporting the fly-ash from the source to the workshop are not accounted for. However, the transportation emissions from transporting these bricks to Jakarta is included.

V. Results and Discussion

Based on this experiment and the conclusions from other research-based papers, the results strongly suggest that fly-ash bricks are stronger, more environmentally-friendly, and cost-effective compared to traditional clay or regular Portland cement bricks.

5.1 Compressive Strength Test

Below are the lab results from the first experiment, which is the strength compression test carried out at Universitas Tarumanegara (UNTAR) for the nine bricks. Refer to Table 1 for the specific composition (fly-ash to cement ratio) of each brick.


UNTAR
LABORATORIUM KONSTRUKSI DAN TEKNOLOGI BETON
JURUSAN TEKNIK SIPIL – FAKULTAS TEKNIK
UNIVERSITAS TARUMANAGARA
JL. LET. JEND. S. PARMAN NO. 1 JAKARTA 11440
TELP. 021-5672548 EX. 334; FAX. 021-5663277

Formulir : Uji Tekan
Jenis sampel : Bata
Asal sampel : Personal
Lembar ke : dari :

Alat : Mesin uji tekan
Merek : ELE
Tipe : ADR 3000
No. Seri. : 1674-1-5002
Kalibrasi : Mei 2021

No. : 60/LK/X/2022
Tanggal : 03 - 10 - 2022
Proyek :

Laboran : Adhit Anjar Dwiputra
Disahkan oleh : Manajer Teknisi
Standar : ASTM C39

No	Kode	Tanggal Cor	Tanggal Tes	Umur (hari)	Luas (mm^2)	Berat (g)	Gaya Tekan kN	Keterangan
1	6	03/10/22	05/10/22			3060	26,9	219×65×105 kondisi sampel masih lembab
2	8					2325	415,9	
3	5					2116	32,1	
4	1					2938	60,1	
5	3					2347	53,5	
6	7					2333	184,4	
7	2					1946	21,4	
8	9					1868	580,7	
9								
10								

Jakarta, 05 - 10 - 2022
Adhit Anjar

Figure 3. Lab results from the first experiment

The second strength compression test was carried out after the building of the prototype house. Each type of brick was tested twice, and the following results are shown below.

Brick Code/Name	Composition Ratio	Average Weight (kN)
Bata 1 and Bata 2	100% (Clay)	236.25
Bata 3 and Bata 4	4:1 (Fly-ash to clay)	122.45
Parling 1 and Parling 2	100% (Cement)	214.20
Parling 3 and Parling 4	1.5:1 (Fly-ash to cement)	277.85

Table 4. *Second strength compression test results*

UNTAR Universitas Tarumanagara

LABORATORIUM KONSTRUKSI DAN TEKNOLOGI BETON
JURUSAN TEKNIK SIPIL – FAKULTAS TEKNIK
UNIVERSITAS TARUMANAGARA
JL. LET. JEND. S. PARMAN NO. 1 JAKARTA 11440
TELP. 021-5672548 EX. 334; FAX. 021-5663277

Formulir : Uji Tekan
Jenis sampel : ~~silinder~~ Bata
Asal sampel :
Lembar ke : dari :

Alat : Mesin uji tekan
Merek : ELE
Tipe : ADR 3000
No. Seri. : 1674-1-5002
Kalibrasi : Agustus 2022

No. :
Tanggal : 02 Maret 2023
Proyek : Rumah

Laboran : Adhit Anjar Dwiputra
Disahkan oleh : Manajer Teknisi
Standar : ASTM C39

No	Kode	Tanggal		Umur	Luas	Berat	Gaya Tekan		Keterangan
		Cor	Tes	(hari)	(mm^2)	(g)	kN		
1	Bata 1	08/01/23	02/03/23			940	321,4		15,6 × 7,7 × 4,4
2	Bata 2					1020	151,1		
3	Bata 3					1040	150,8		
4	Bata 4					1190	94,1		
5									
6	Paving 1	08/01/23	02/03/23			2520	254,6		
7	Paving 2					2620	173,8		
8	Paving 3					2820	313,7		
9	Paving 4					2780	242,0		
10									

Jakarta, 02 Maret 2023

Adhit Anjar

Figure 4. *Lab results from the second experiment*

<u>5.1.1 Construction Aspect</u>

According to table 2, the initial strength compression test results, brick number 9, consisting of the formula with the 60% fly-ash and 30% cement ratio (table 1), was the brick that could withstand the most weight. The compression strength of brick 9 was 580.7 kN and the strength for the regular cement was 415.9 kN (table 3), portraying how brick 9 could withstand more force compared to a regular cement brick. According to the lab professional executing the compression test, the minimum strength for a brick to pass the FC20 standard was 300 kN, which brick 9 exceeded by 280.7 kN. Therefore, the results portrayed how alternative cement bricks could potentially be a stronger building material compared to the traditional cement bricks. The second compression test, comparing the different types of house bricks, conveyed similar results (table 4). The order of bricks from weakest to strongest based on the average kN is as follows: fly-ash and clay bricks (122.45 kN), cement bricks (214.20 kN), clay bricks (236.25 kN), and fly-ash bricks (277.85 kN). Theoretically, despite cement bricks being more resistant to heat and water, clay bricks can prove to have a higher compressive strength than cement (Ayu, 2009). However, the crumbly appearance on the surface of the cement bricks could suggest the lack of cohesion of the ingredients in the cement mixture; thus, lowering the compressive strength. To increase the validity and accuracy of the data presented, the researcher strongly recommended to repeat this experiment to confirm how fly-ash bricks are the strongest building material alternative. Furthermore, according to the construction worker building the 2m by 2m house, the fly-ash-cement bricks are easier to work with because they are “lighter but do not break as easily compared to the other bricks” (translated from Indonesian to English), and the worst brick was the fly-ash and clay mixture. Fly-ash has been proven to enhance the strength of bricks in the long-term due to reduced thermal cracking, as less heat is given off when fly-ash reacts with the cement and water. The very fine, powdery substance of fly-ash creates better cohesion within the cement, creating less segregation and rock-pockets compared to regular cement (Kumar Behera, 2009). Not only is fly-ash better strength-wise; however, despite the heavy rainy season these past months, the fly-ash house bricks remain intact and undamaged.

5.2 Price

Price of Regular Bricks ($/yd3):

Material	Unit Cost ($/lb)	Quantity (lbs/yd^3)	Total Cost (lbs/yd^3)
Water	$0.0010	237.67	$0.24
Cement	$0.1380	433.33	$56.33
Coarse Aggregate	$0.0098	1755.76	$16.68
Fine Aggregate	$0.0090	1583.24	$13.46
Total Cost			$85.47

Table 6 *(Shaker et al., 2020)*

Price of Fly-Ash Bricks ($/$yd^3$):

Material	Unit Cost ($/lb)	Quantity (lbs/yd^3)	Total Cost (lbs/yd^3)
Water	$0.0010	237.67	$0.24
Cement	$0.1380	173.37	$23.93
Coarse Aggregate	$0.0098	1755.76	$16.68
Fine Aggregate	$0.0090	1583.24	$13.46
Fly-Ash	$0.0120	260.06	$3.12
Total Cost			$57.43

***Table** 7 (Shaker et al., 2020)*

5.2.1 Cost-Effective Aspect:

Referring to the price comparison section (table 6 and 7), the total price for fly ash bricks ($57.43) is $28.97 cheaper than regular cement bricks ($85.40) given that fly-ash is readily available. In the production process of power plants, fly-ash is inherently generated, rendering its cost lower than that of cement. The latter necessitates a mining and refining procedure involving machinery, notably the rotary kiln, which operates on electricity or fuel. This additional process contributes to the elevated cost of cement. In the United States, the average cost of fly-ash per pound is 1.75 cents compared to cement which costs 13.8 cents per pound (Shaker, 2020), and fly-ash bricks tend to be 10-20% cheaper than clay bricks (Narayanan, 2022). Due to the cheap price of fly-ash, fly-ash cement provides companies with both an economical and environmental incentive. Making cement accessible paves a possible pathway for rebuilding sustainable communities in rural areas who previously could not afford building materials.

5.3 Carbon Emission

Emissions for each kg of portland cement:

- Manufacturing Process: 0.9kg
- Transportation to Jakarta (around 26 km): 6.76 kg
- Total Emissions: 7.66 kg

Emissions for each kg of fly-ash cement:

- Manufacturing Process: 0.54kg (since fly-ash replaces cement by 60%)
- Transportation to Jakarta: 6.76 kg
- Total Emissions: 7.30 kg

Determining the costs and carbon emissions required extensive use of the data from research papers, as they encompass a plethora of quantitative data, which allows the researcher to use a reliable average value. These sources were written by a group of credible researchers who work in universities specialized in engineering. Due to their extensive knowledge on this matter, the detailed analysis and the multitude of scholarly citations (both papers cited more than 15 sources) provided, the information presented can be considered reliable. However, due to the research being limited to the researchers' location, such as China or South Africa, the data does not accurately represent the current carbon emissions in Indonesia. Both research papers prove to have no particular bias as the "Life Cycle Assessment and Impact Correlation Analysis of Fly Ash Geopolymer Concrete" report claims to have "no conflict of research" or "received no external funding." However, both sources acknowledged the support of their corresponding universities. Even though the "Perspectives on environmental CO2 emission and energy factor in Cement Industry" paper received publication funding from Covenant University CUCRID, this university has the core values of research, innovation, and discovery; therefore, it is unlikely that this paper has a bias towards a certain perspective.

<u>5.3.1 Environmental Aspect:</u>

According to the carbon emissions comparison section, the total amount of carbon dioxide produced in regular concrete is 60% more than the emissions produced in the fly-ash formula. Due to the lack of efficient or electric truck transportation in Indonesia, transportation emissions are inevitable; however, the carbon emissions saved from producing fly ash cement could assist in offsetting the carbon dioxide released. Reusing fly-ash, a by-product of coal-burning power plant factories, would restrict the improper disposal of this material, hence reducing waterway or soil pollution caused by the heavy metals that make-up fly-ash (U.S Environmental Protection Agency, 2014). This solution increases the efficiency of using otherwise-wasted resources produced by one of the most heavily polluting manufacturing processes on this planet. Additionally, when 20% of cement is replaced by fly-ash, the amount of water required to create cement decreases by approximately 10% (U.S Department of Transportation, 2017); therefore, fly-ash cement aids in preserving an essential and scarce natural resource. As long as coal-burning factories remain, the supply of fly-ash will be abundant; therefore, there will be a sufficient supply of fly-ash to mass-manufacture these bricks on a large-scale. The use of fly-ash in bricks assists in preserving the planet's current resources and reducing carbon emissions.

Based on this experiment and the conclusions from other research-based papers, the results strongly suggest that fly-ash bricks are stronger, more environmentally-friendly, and cost-effective compared to traditional clay or regular Portland cement bricks.

VI. Conclusion

The present study aimed at determining what type of brick would be best for the Indonesian environment uses multiple experimental approaches. Strength compression tests were utilized both in the initial prototyping and house-building stage. A 2m by 2m prototype house was built with the purpose of comparing whether the fly-ash bricks could better withstand the current Indonesian environment compared to traditional clay, regular Portland cement, or a fly-ash and clay mixture brick. Carbon emission and cost calculations were determined by the use of a transportation carbon emissions calculator and various scholarly sources, due to the lack of equipment to accurately record the emissions during the current manufacturing process. This study incorporates a wide-range of information, from interview responses from construction workers and progression photos of the house, to data from the strength compression tests paired with experimental results from credible research papers.

The findings of this study suggest that fly-ash bricks are the strongest, most cost-effective (assuming fly-ash is readily available), and eco-friendly option amongst the other types of bricks tested. The conclusion drawn from this experiment, aligned with the data found from other scientific journals and research papers. The wide variety of data-gathering techniques enhanced the reliability and validity of this experiment; however, there were some inconsistencies between the data and the opinions of professional engineers and lab reports, such as the strength of clay bricks in comparison to cement bricks. It is recommended that future research replicates this experiment to eradicate any potential flaws in the manufacturing mixing process that could have caused the decreased strength in cement bricks.

The credibility of this research is enhanced through the sources used throughout this report. Majority of sources used were research papers written by those who have a pH.D in engineering or a group of students who attend or graduated from a university with a chemical or environmental engineering degree, who do not have conflicting interests or are paid by a private company or business corporation, hence eliminating the chances of bias.

VII. Recommendations

7.1 Strengths of method:

The usage of multiple test methods allowed for the collection of quantitative and qualitative data. While lab tests supplied precise data that allowed for an accurate comparison between bricks, the prototype house tested the capability and adaptability of these bricks in the current Indonesian environment. Interviews with the house builders on the quality and workability of the bricks paired with the bi-weekly pictures of each wall, this researcher hopes to eventually see the progression of degradation of each brick type. Therefore, with a variety of data collection methods combined and supported with data from credible sources, the information provided is suitable to answer the research question.

7.2 Weaknesses of method:

Due to the nature of this experiment being in the early testing stages, the researcher only tested each prototype brick once (table 1); therefore, there might be inconsistencies in the data. To enhance the validity of this, these bricks should be tested multiple times. Furthermore, due to time constraints, creating a definitive conclusion on the progression of the house was challenging because there is an average of 50 years before bricks degrade (Ahmad, 2017); therefore, as of April 8th 2023, the prototype house had only 2 months of exposure to real-life elements, the changes or data collected from the house is not sufficient enough to create a definitive conclusion.

Amongst the limitations of this data collection process is the insufficient collection of data due to funding constraints–the costs of running multiple trials would exceed the current budget. The lack of access to a variety of testing equipment restricted the researcher from testing the strength of concrete using other methods such as the Schmidt rebound hammer or the water permeability test. Due to the lack of availability of cement manufacturers in close proximity that would satisfy the request of providing the small number of bricks required for this experiment, the researcher chose a remote workshop approximately 18 miles from Jakarta, that would meet our request at a reasonable price. However, the distance created an obstacle for the researcher to consistently observe the cement-making process and quality check the bricks. A supervisor who helped collect footage of the cement-making process was present. However, due to the difference in machinery and time spent in mixing the ingredients together, the bricks were not identical to the ones the researcher made during her initial prototyping stage.

Due to technology limitations to accurately determine the carbon emissions produced during this experiment, the total carbon emissions below were concluded based on the results from a transportation carbon emission calculator abiding to the EU Standard EN16258, validated by Swiss federal authorities and ETH University, and scholarly papers that averaged the amount of carbon dioxide produced per kilogram of cement (Fayomi et al., 2019).

Given more time and resources in the future, the researcher hopes to continue collecting data on the degradation of these bricks, run more compressive strength tests, and expand her modes of testing, such as the permeability or hammer test, to have a wider variety of data to further answer the research question.

VIII. Acknowledgements

Below are the people to whom I extend my greatest thanks and appreciation:

- Richard Wiriyanto, who has supported me since day one. He acted as my engineering and architectural advisor and guided me through the logistics of the brick manufacturing process.
- Veronika Wiyono and Ellen Wiyono had enough faith in me to invest funds during the research stage of my project and supported me through the process of mass-manufacturing my bricks.
- Marijana Brown-Djuricic, who advised me during my research-paper writing process and helped me organize the long-term logistics of my project.
- Kirolos Wagdy Guirguis, who acted as my engineering advisor and provided insight on how to improve the strength of my bricks, the specifics of bricks, and previous experiments that have been carried out.
- Jim M. Doherty taught my environmental solutions summer class and gave me detailed insights during and outside the class.

References

Ahmad, Zahra. “Why Modern Mortar Crumbles, but Roman Concrete Lasts Millennia.” Www.science.org, 3 July 2017, www.science.org/content/article/why-modern-mortar-crumbles-roman-concrete-lasts-millennia#:~:text=Modern%20 concrete%E2%80%94 used%20in%20 everything.

Andrew, Robbie M. “Global CO2 Emissions from Cement Production, 1928–2018.” Earth System Science Data, vol. 11, no. 4, 20 Nov. 2019, pp. 1675–1710, https://doi.org/10.5194/essd-11-1675-2019.

Ayu, Ida, and Made Budiwati. “Experimental Compressive Strength and Modulus of Elasticity of Masonry Kuat Tekan Dan Modulus Elastisitas Hasil Eksperimen Dari Masonry.” Jurnal Ilmiah Teknik Sipil, vol. 13, no. 1, 2009. Accessed 28 Apr. 2023.

CarbonCare. “CO2 Calculator of Greenhouse Effects for Transport and Logistics.” Www.carboncare.org, www.carboncare.org/en/co2-emissions-calculator.html.

Ellis, Leah D., et al. “Toward Electrochemical Synthesis of Cement—an Electrolyzer-Based Process for Decarbonating CaCO3 While Producing Useful Gas Streams.” Proceedings of the National Academy of Sciences, vol. 117, no. 23, 16 Sept. 2019, p. 201821673, https://doi.org/10.1073/pnas.1821673116.

Fayomi, G U, et al. “Perspectives on Environmental CO2 Emission and Energy Factor in Cement Industry.” IOP Conference Series: Earth and Environmental Science, vol. 331, no. 1, 16 Oct. 2019, p. 012035, https://doi.org/10.1088/1755-1315/331/1/012035.

Global Cement and Concrete Association. “Key Facts : GCCA.” GCCA, 2019, gccassociation.org/key-facts/.

Hawken, Paul. Drawdown : The Most Comprehensive Plan Ever Proposed to Reverse Global Warming. New York, New York, Penguin Books, 2017.

Hillhouse, Grady. “What Is Concrete?” YouTube, 27 Mar. 2018, www.youtube.com/watch?v=UOHURuAf5iY.

King Khalid University. “صناعة الاسمنت الجاف - Portland Cement Dry.” www.youtube.com, 2 Aug. 2017, www.youtube.com/watch?v=uQ2Hm6r16IM. Accessed 10 Apr. 2023.

Kumar Behera, Rakesh. Characterization of fly ash for their effective management and utilization. A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Technology in Mining Engineering. 2009.

Lehne, Johanna, and Felix Preston. Making Concrete Change: Innovation in Low-Carbon Cement and Concrete. Chatham House Report, 13 June 2018.

McGovern, Martin. “Concrete Technology Today.” Concrete Technology Today, vol. 23, no. 2, July 2002.

Narayanan, Subramanian, Ph.D. “Why Are Fly Ash Bricks Better than Clay/Red Bricks?” Www.linkedin.com, 17 Oct. 2022, www.linkedin.com/pulse/why-fly-ash-bricks-better-than-clayred-dr-subramanian-narayanan/. Accessed 28 Apr. 2023.

“Rotary Kiln - an Overview | ScienceDirect Topics.” Www.sciencedirect.com, www.sciencedirect.com/topics/engineering/rotary-kiln#:~:text=A%20rotary%20kiln%20is%20a.

Shaker, Muhammad Rauf, et al. "Evaluation of Alternative Home-Produced Concrete Strength with Economic Analysis." Sustainability, vol. 12, no. 17, 20 Aug. 2020, p. 6746, https://doi.org/10.3390/su12176746. Accessed 28 Oct. 2020.

Shi, Xiaoshuang, et al. "Life Cycle Assessment and Impact Correlation Analysis of Fly Ash Geopolymer Concrete." Materials, vol. 14, no. 23, 1 Dec. 2021, p. 7375, https://doi.org/10.3390/ma14237375. Accessed 28 July 2022.

Tiseo, Ian. "Global Cement CO2 Emissions 1960-2021." Statista, 6 Feb. 2023, www.statista.com/statistics/1299532/carbon-dioxide-emissions-worldwide-cement-manufacturing/#:~:text=Global%20emissions%20from%20the%20manufacture.

U.S Department of Transportation. "Chapter 3 - Fly Ash in Portland Cement Concrete - Fly Ash Facts for Highway Engineers - Recycling - Sustainability - Pavements - Federal Highway Administration." Www.fhwa.dot.gov, 27 June 2017, www.fhwa.dot.gov/pavement/recycling/fach03.cfm#:~:text=Decreased%20water%20demand. Accessed 24 Apr. 2023.

US EPA,OLEM. "Coal Ash Basics | US EPA." US EPA, 12 Dec. 2014, www.epa.gov/coalash/coal-ash-basics#01.

Appendix A.

Picture Progression of Prototype House Walls

Brick Type	Month 1	Month 2	Month 3
Fly-ash and cement			
Clay			
Cement			

Fly-ash and clay			

Appendix B.

Below are the interview questions the researcher asked. Answers were then summarized in the paper above.

- What is the compressive strength requirement for a brick to reach the FC20 requirement?
- What type of brick has the best workability when building the house?
- Which type of brick has the best and worst durability when building the house?
- Describe the texture and physical qualities of each brick type.

Appendix C.

The picture is the machinery used for the cement strength compression test conducted in the UNTAR lab.