

COVID-19 vaccine wastage in the midst of vaccine inequity: causes, types and practical steps

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INTRODUCTION

Vaccination is the cornerstone of current strategies to mitigate the COVID-19 pandemic, through reductions in transmission, morbidity and mortality.¹ To optimise the impact of vaccination, an approach for equitable global distribution which minimises vaccine wastage is essential. Yet, after more than a year of distributing COVID-19 vaccines, unnecessary vaccine wastage continues, with wastage rates as high as 30%.²

Globally, highly inequitable distribution of COVID-19 vaccines persists, despite the approval and mass manufacturing of COVID-19 vaccines in high-income countries (HIC), and agreements with initiatives such as COVAX—the vaccines pillar of the Access to COVID-19 Tools Accelerator—to support vaccination in low- and middle-income countries (LMIC). To date, HIC have administered over 2.3 billion doses (79% of the population) and have procured over 7 billion doses,^{3,4} some of which may go to waste as vaccination rates are stagnating, while in low-income countries only 15% of the population has been vaccinated.⁵ Of equal importance, effective supply chain management for the distribution of COVID-19 vaccines in LMIC should be improved to overcome the ineffective practice of HIC donating ‘about-to-expire’ vaccine doses to LMIC, which exacerbates the issue of overall wastage. Such ‘late-date donations’ create the false impression that HIC are ‘doing their bit’ while LMIC are incapable of effectively distributing vaccines.

OPEN VERSUS CLOSED VIAL VACCINE WASTAGE

There are two main types of vaccine wastage: open vial wastage and closed vial wastage. Open vial wastage is primarily related to the packing format. Following manufacturers’

Summary box

- ⇒ There has been open and closed vial COVID-19 vaccine wastage in low-income, middle-income and high-income countries, with wastage rates of up to 30%.
- ⇒ Plans to monitor, forecast and ultimately reduce vaccine wastage are urgently needed in every country.
- ⇒ Open vial wastage should be reduced by strategies increasing overall vaccination rates, such as over-booking appointments and appointment-free vaccination, as well as through technologies maximising the number of doses being extracted from the vial.
- ⇒ Closed vial wastage should be reduced by timely, well-organised surplus donations and reallocations, as well as supporting effective supply chain management in recipient countries.

instructions, all doses in a vial must be used within 24–48 hours after opening, leading to wastage in case of insufficient, immediate demand. On the other hand, due to concerns about vaccine wastage, there is a risk of a vaccine not being administered to someone who needs it if the entire vial cannot be used. Therefore, depending on the demand at the vaccine delivery point, fewer vaccine doses per vial could reduce vaccine wastage while ensuring access for those in need of a vaccine. This was demonstrated by a study on wastage of measles-vaccines in Zambia, where health-care workers reported to be more willing to open a 5-dose vial, compared with a 10-dose vial, leading to reduced open vial vaccine wastage.⁶ Open vial wastage is more likely to occur in rural and remote delivery points, and in later phases of a vaccination campaign. In addition, open vial wastage occurs when not all vaccine doses can be extracted from the vial due to a lack of suitable injection supplies. For example, the Pfizer-BioNTech vaccine vial contains six doses when extracted



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with specialised low dead space (LDS) syringes; however, when regular syringes with high dead space are used, only five doses can be extracted, meaning that when no LDS syringes are available, one out of every six vaccines will be wasted.⁷

Closed vial wastage occurs due to both vaccine expiry and loss of product integrity in the supply chain, often due to non-compliance to storage temperature and other distribution requirements. A key logistical challenge with COVID-19 vaccines is the short expiration date that, despite recent shelf-life extensions, remains well under 1 year.^{8 9} In addition, vaccine storage requirements, including maintaining the cold chain,¹⁰ have resulted in transportation and storage logistical issues, especially in early 2021 and in LMIC. Now, with the European Medicines Agency approval for storing the Pfizer/BioNTech vaccine at 2°C–8°C for up to 1 month after thawing,¹¹ which was already the case for the other approved COVID-19 vaccines, vaccine doses can be stored in a simple refrigerator. This has mitigated some of the initial transportation and storage issues, increasing access in rural and remote communities.

COVID-19 VACCINE WASTAGE

Ultimately, some vaccine wastage is inevitable. For all vaccines, the GAVI Alliance recommends countries to aim for a maximum wastage rate of 25% for the first year, with a gradual reduction to 15% by the third year. For vaccines in single-dose or two-dose vials, the maximum wastage allowance is 5%.¹² For calculations on COVID-19 vaccines delivery, COVAX uses a 10% vaccines wastage rate,¹³ though countries should strive for less wastage. However, accurate

reporting of vaccine wastage rates per country is currently lacking. The WHO has developed a Vaccine Wastage Rate Calculator, which aims to improve the overall accuracy of forecasting vaccine waste rates,¹⁴ but it remains underused in planning and reporting. Despite the lack of exact numbers, many striking examples of COVID-19 vaccine wastage have been reported worldwide (table 1), highlighting the urgent need to better report, identify the root cause of wastage and, ultimately, reduce vaccine wastage rates globally.

While accurate data on the difference in wastage between COVID-19 vaccines are not yet available, based on the characteristics of the various vaccines, differences in wastage are expected (table 2). Although vaccines with fewer doses per vial, such as the Pfizer/BioNTech vaccine, might have lower open vial wastage, those benefits may be offset due to higher closed vial wastage as a result of more stringent storage and distribution requirements, for example. Therefore, the optimal COVID-19 vaccine to minimise vaccine wastage rates is context dependent. Finally, public trust in vaccines plays an important role, and this trust is highly influenced by communication and the spread of misinformation.^{15 16} For example, the media's sensationalisation of possible risks related to the AstraZeneca vaccine, starting in March 2021, led several countries to temporarily stop using the vaccine, which likely led to increased levels of vaccine wastage.¹⁷ Further, although initially questioned due to adapting the practice of heterologous dosing (eg, dosing with an adenovirus-based vaccine, followed by an mRNA vaccine) with a weak evidence base, it has now shown advantageous immunogenicity outcomes and could provide additional flexibility in using vaccines that might otherwise be wasted.¹⁸

Table 1 Global examples of vaccine waste including reasons

Country/territory/region	Number of vaccines wasted	Reason	Date
Hong Kong	Up to 2 million	Vaccine hesitancy, below 20% of the population had been vaccinated and this low up-take led to a potential wastage of up to 2 million vaccines	May 2021
African countries, include Malawi, South Sudan, Liberia, Mauritania, Gambia, Sierra Leone, Guinea, Comoros, and the Democratic Republic of Congo.	450 000	Expired due to delays in shipment of vaccine doses and therefore no time to roll-out before expiration date	July 2021
The Netherlands	39 000–200 000	Since they are surplus and about to expire and the Dutch law states that medicines that have been delivered to doctors for their patient cannot be traded, even if it is for charity and free of charge	July 2021
Ireland (Republic of)	220 000	Vaccine expiration of boosters	August 2021
Catalonia, Spain	69 129	Too many vaccines defrosted due to miscalculation and declining vaccination rates	September 2021
Australia	Up to 7 million	Expiration and unwanted	October 2021
Madrid, Spain	117 977	Expired	November 2021
UK	600 000	Vaccine expiration	November 2021
South Korea	938 630	Expiration—913 817 (97.4%) Temperature excursions—21 260 (2.3%)	November 2021

Table 2 COVID-19 vaccine characteristics

Vaccine	WHO EUL holder	Doses/vial	Shelf-life	Storage
COMIRNATY COVID-19 mRNA vaccine (nucleoside modified)	BioNTech Manufacturing GmbH	6	9 months after date of manufacture for undiluted vaccine at storage temperature -90°C to -60°C	<ul style="list-style-type: none"> ▶ -80°C to -60°C in ULT freezer ▶ -90°C to -60°C in thermal shipper as temporary storage for up to 30 days from delivery (should be re-iced every 5 days if opened up to two times a day, less than 3 min at a time) ▶ Up to 1 month (31 days) prior to dilution for undiluted thawed vaccine at +2°C to +8°C up to 2 hours for undiluted thawed vaccine at temperatures up to +30°C
VAXZEVRIA COVID-19 vaccine (ChAdOx1-S (recombinant))	AstraZeneca AB/SK Bioscience Co. Ltd AstraZeneca AB	10	6 months for unopened vials stored at 2–8°C	<ul style="list-style-type: none"> ▶ 2–8°C ▶ Opened vials can be stored at 2–25°C for use within 6 hours ▶ Up to 25°C for 2 hours
COVISHIELD COVID-19 vaccine (ChAdOx1-S (recombinant))	Serum Institute of India Pvt. Ltd	10	Unopened vials can be stored at 2–8°C for 6 months or up to 25°C for 2 hours Opened vials can be stored at 2–25°C for use within 6 hours	▶ 2–8°C
COVID-19 vaccine (Ad26. COV2-S (recombinant))	Janssen–Cilag International NV	5	Unopened vials -25°C to 15°C for 2 years Unopened vials 2–8°C for 4.5 months of printed expiration date Up to 25°C for 2 hours	<ul style="list-style-type: none"> ▶ 2–8°C ▶ Or -20°C if kept unthawed in shipping conditions
SPIKEVAX COVID-19 mRNA vaccine (nucleoside modified)	Moderna Biotech ModernaTX, Inc	10, 15	9 months at storage temperature: 20°C±5°C	<ul style="list-style-type: none"> ▶ 20°C ▶ Do not store on dry ice or below -40°C
Inactivated COVID-19 Vaccine (Vero Cell)	Beijing Institute of Biological Products Co., Ltd. (BIBP)	1, 2 or 5	24 months	▶ 2–8°C
CoronaVac COVID-19 vaccine (Vero Cell), inactivated	Sinovac Life Sciences Co., Ltd	1, 2 and PFS	12 months	▶ 2–8°C
COVAXIN COVID-19 vaccine (whole virion inactivated corona virus vaccine)	Bharat Biotech International Ltd	1, 5, 10, 20	9 months	▶ 2–8°C
COVOVAX COVID-19 vaccine (SARS- CoV-2 rS protein nanoparticle (recombinant))	Serum Institute of India Pvt. Ltd	1, 10	9 months	▶ 2–8°C
NUVAXOVID COVID-19 vaccine (SARS- CoV-2 rS (recombinant, adjuvanted))	Novavax CZ a.s	10	9 months	▶ 2–8°C

EUL, Emergency use listing procedure; PFS, Prefilled syringe vaccine doses; ULT, Ultra low temperature .

PRACTICAL ACTIONS TO REDUCE VACCINE WASTAGE

One mechanism to reduce wastage is for all countries, irrespective of their income classification, to provide regular and transparent data on COVID-19 vaccine wastage. This helps identify key drivers of wastage (eg, whether the predominant cause of wastage in a specific country is closed or open vial wastage) which, in turn, helps identify effective interventions to minimise such wastage. We suggest that individual

countries include vaccine wastage data in their national COVID-19 vaccine tracking portal, which many countries and regions already have in place. Once a sufficient number of countries start reporting, this could be organised as a global repository by COVAX.

Open vial wastage can be reduced by having vaccination centres report their available supply of doses daily, such as via an online portal, while increasing demand in parallel, when

needed, via targeted outreach to unvaccinated individuals, who could be allowed to get vaccinated without an appointment. Another option is overbooking vaccine appointments to overcome no-shows. In the Canadian province of Alberta, for example, overbooking appointments to avoid wastage from no-shows led to waste on site being reported at only 0.3%. Furthermore, using artificial intelligence (AI) can allow for better matching of demand and supply through new data and analytical tools. An example is the Connected Health AI Network vaccine forecasting tool, which was able to reduce vaccine wastage in Tanzania by 96%, using real-time data sources.¹⁹ In addition, simple technology such as LDS syringes can effectively reduce open vial wastage by increasing the effective number of doses from one vial by up to 20%. Admittedly, some of these measures could lead to higher operational and programmatic costs, but if these measures are undertaken for routine immunisation, then the resulting per unit cost implications of some such one-time fixed investments will be relatively small. In addition, reducing vaccine wastage leads to cost-savings, which can offset new one-time costs. For example, the production cost of a single LDS syringe is less than 1 dollar while one additional dose extracted from a vial can save more than 20 dollars.²⁰

Closed-vial wastage can be reduced via improved tracking and more timely redistribution of surplus vaccines. First, the number of donated vaccines to LMIC should be increased drastically, as HIC have not been fully honouring their commitments of delivering vaccines to the rest of the world. Redistributed doses should have sufficiently long expiration dates to allow the receiving countries to administer them. For example, unless it is explicitly intended for mass vaccination sites or use in a very large hospital, redistributed doses should have a minimum of 90 days remaining at the time of in-country arrival to allow for storage, delivery and administration. This requires HIC to improve advanced planning and operations regarding their donations and reallocations. In addition, laws preventing redistribution of surplus vaccines should be reformed. For example, a law in the Netherlands states that medicines cannot be traded or donated once they have been delivered to physicians to be used for their patients—this has prevented physicians from reallocating vaccines.²¹ Second, countries can consider swap-deals to prevent vaccines from expiring, such as seen in the agreements made between Israel and South Korea,²² as well as those between Australia and Singapore.²³

Furthermore, manufacturers of vaccines should continue to apply for shelf-life extensions and remove any contractual barriers impeding donating to LMIC. For example, the contracts between vaccine manufacturers and the US Federal government included clauses such as ‘The Government may not use, or authorise the use of, any products or materials provided under this Project Agreement, unless such use occurs in the United States or U.S. territories’.²⁴ Further, to complement manufacturers’ printed expiry dates, the Vaccine Presentation

and Packaging Advisory Group,²⁵ UNICEF and other LMIC vaccine delivery-focused agencies should accelerate the use of electronic lookup of expiry date for new vaccines where stability has not yet been fully established. Dynamic lookup of expiry date based on batch number avoids the problem of static printed expiry dates, and allows for dynamically adjusting the expiry date when new stability information to extend shelf-life becomes available.

Finally, in addition to increasing donations and limiting vaccine wastage parallel efforts are necessary to ensure vaccine access in LMIC. Plans to produce more COVID-19 vaccines in LMIC, for example in sub-Saharan Africa,²⁶ are underway, and may contribute in the long run to increased availability and access to vaccines. To facilitate this process, governments and vaccine developers should prioritise know-how transfer, enhance the supply chain for critical input materials and help remove any patents barriers coming in the way. Vaccines such as the Corbevax vaccine, developed with no patent and transferred without payment to vaccine manufacturers in several LMIC, including Botswana and India, play a vital role in improving access and also reducing wastage.²⁷

CONCLUSION

COVID-19 has highlighted critical issues of vaccine wastage and the need for all countries to develop detailed plans to monitor and reduce vaccine wastage. Importantly, current plans should include well-organised donations to minimise closed vial wastage and the use of strategies such as overbooking or appointment-free vaccination to minimise open vial wastage. While supply constraints were initially due to the low number of vaccines being manufactured, this is no longer the case. Therefore, it is time for high-income countries to share their vaccine surpluses with low- and middle-income countries, where many vulnerable individuals, including frontline healthcare workers, are still awaiting their first dose of a COVID-19 vaccine.

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