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HOLISTIC SCENARIO AND ENVIRONMENTAL IMPACT EXPLORATION OF COVID-19 VACCINATION PROGRAM: BANGLADESH PERSPECTIVE

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ABSTRACT

COVID-19 outbreak appears to be a worldwide epidemic with increasing rate of mortality. Since the only way of dealing with this coronavirus is through vaccination, vaccination projects need to be implemented to decrease the mortality rate. Bangladesh, a developing country, is also pursuing this immunization strategy. The aim of this study is to explore holistic scenario of vaccination program against COVID-19 in Bangladesh. To meet the objectives, a literature review on holistic scenario and environmental impact against vaccination is provided. Bangladesh has planned to vaccinate nearly 80% of its population against COVID-19. In eight divisions of Bangladesh, at least one dose vaccine inoculated in the percentage of population is ≥ 16 % (Dhaka), 15-16 % (Barisal), 14-15 % (Rangpur, Khulna), 13-14 % (Chittagong), 12-13 % (Rajshahi), 11-12 % (Sylhet) & <11 % (Mymensingh) till 18 September 2021.The vaccination campaign includes manufacturing, packaging, transportation, storage and distribution phases. The unplanned disposal of medical waste associated with COVID-19 vaccination programs such as disinfectants, syringes, vials, PPE, mask etc. exposes drastically into the environment. This study estimated that the amount of waste of syringes, vials and alcohol swab by vaccination was 472 ton till September 2021. In this context, the vaccination program of Bangladesh would produce approximately 1.37×10^9 gm and 3.74×10^8 gm of syringe and vial wastes respectively. This study also identifies the environmental impact of this vaccination program and possible mitigating measures with a proper management plan. The overall assessment revealed that the proper management plan of the vaccination project would promote the sustainable development of Bangladesh.

***Keywords**: COVID-19, Environmental impact, Vaccination program, Mitigation measures, Waste management plan.*

1. 1INTRODUCTION

The world is currently suffering from the vulnerable issue of COVID-19 outbreak that significantly increases the rate of mortality. Coronavirus, the severe acute respiratory syndrome- first appeared in December 2019 and has since spread around the world (Helmy et al., 2020). The virus continues to spread unabatedly and results into widespread environmental, social, economic and health disruption. As a result, effective vaccines are urgently required to terminate this pandemic and assist society in returning to normalcy. Many COVID-19 candidate vaccines have been studied, created, tested, and reviewed at an unprecedented rate, giving us hope for a brighter future. (Li et al., 2021).

Vaccination is regarded as one of the greatest medical advances of the modern era. Smallpox eradication is one of the best examples of how immunization prevented a fatal illness and saved millions of lives. (CDC, 2021a). Despite all protective measures, the rate of COVID-19 infection is moving at a fast rate. It took around 6 months to confirm first 10 million cases, the second took 1.5 months, the third took 35 days, and the 8^{th} took only 16 days (Ritchie et al., 2020). Several vaccines were conditionally approved in February 2021 to fight against the COVID-19 that significantly dropped both of the confirmation cases and deaths. Even so there have been 226 M confirmed cases and 4.6 M deaths due to COVID-19 as reported by the World Health Organization in 17 September 2021 (WHO, 2021b).

Because the COVID-19 immunization program is a recent phenomena, there has been minimal research on this topic. Li et al., (2021) describe a comprehensive review of the global efforts on the COVID-19 vaccine development. Klemes et al., (2021) studied on energy, environmental impacts on vaccination against COVID-19 pandemic. COVID-19 vaccination mismanagement creates pressure on energy, environment, economy, and social equity(Jiang et al., 2021). Santos et al., (2021) investigated refrigeration of COVID-19 vaccines and environmental impact of various vaccine options. Ecological footprint of COVID-19 mRNA vaccines have been shown by (Kurzweil et al., 2021).

Bangladesh started administering COVID-19 vaccinations on January 27, 2021 while widespread vaccinations began on February 7, 2021(Aljazeera, 2021). Besides Vaccination campaign is a crucial challenge, there are also environmental issue to deal with as well. Potential causes of vaccine waste include expired and contaminated/damaged vials, mislabeled power failure, temperature alarm failure, unable to extract all vaccine from vials etc. that results environment pollution (WSDH, 2021a). One recent estimation indicated the low temperature-controlled supply chain (cold chain) accounts for 1% of worldwide greenhouse gas (GHG) emissions and 3–3.5% of GHG emissions in industrialized countries. (Heard & Miller, 2019). Vaccination Program can be divided into several phases as showed in Fig. 1. Each of these phases results waste disposal into environment which causes negative impact on the environment. This study also overviewed the vaccination process in terms of environmental impact perspective of Bangladesh to achieve sustainable development goals (SDGs).

Figure 1: Several phases of Vaccination Campaign

2 REVIEW METHODOLOGY

This study exploited respective channels to recognize relevant literature. Academic databases such as Science Journals, Web of Science, Scopus were used to search for academic papers and reports. Google Scholar was also utilized to look for a broader range of literature, such as environmental impact reports, books, and conference proceedings. To locate relevant material, the following search phrases were combined (COVID-19, vaccination program, environmental impact assessment, waste generation against vaccination). The search for literature was limited to the past 3 years (2019–2021) as the investigation of the impacts of vaccination against COVID-19 is relevantly recent. These pertinent studies aid in the classification of vaccination campaigns into the several phases depicted in the introduction section 1. To make a valuable evaluation, many trustworthy online websites (WHO Dashboard, Washington State Department of Health, UNICEF, Reuters, Biomedical Waste Services, Aljazeera etc) regarding COVID-19 were used. The holistic scenario of COVID-19 program in Bangladesh was summarized mainly by using COVID-19 vaccination dashboard for Bangladesh on the website of the Directorate General of Health Services.

3 VACCINATION SCENARIO IN BANGLADESH

On 30 January 2020, the World Health Organization proclaimed the coronavirus disease 2019 (COVID-19) outbreak a Public Health Emergency of International Concern, and on 11 March 2020, it was classified as a pandemic. COVID-19 vaccination production is expected to reach $1x10^{10}$ doses worldwide by the end of 2021, according to estimates from 20 manufacturers(Pagliusi et al., 2020). Bangladesh, a developing country, began to administrate COVID-19 vaccines to overcome this pandemic. In this context, the whole country is taking effective measures to ensure the maximum coverage of the vaccination program against COVID-19. Table 1 presented that Bangladesh has planned to vaccinate 80% of the population (~138,247,508) after final stage.

Table 1:**.** Phases of COVID-19 Vaccine Rollout Plan in Bangladesh and Population

Phase	**Stage**	**Population (%)**	**Population Number**	**Total Number of Doses (Considered Two Doses/Person)**	**Total Number of Doses with 10% Wastage**
1	I [a]	3	5,184,282	10,368,564	11,509,106
	I [b]	7	12,096,657	24,193,314	26,854,579
2	II	11–20	17,280,938	34,561,876	38,363,682
3	III	21–40	34,561,877	69,123,754	76,727,367
	IV	41–80	69,123,754	138,247,508	153,454,734
Total population coverage =			138,247,508	276,495,016	306,909,468

Currently, the administrative structure of Bangladesh comprises eight divisions such as Dhaka, Chittagong, Rangpur, Barisal, Khulna, Raj Shahi, Mymensingh & Sylhet. At least one dose vaccine inoculated in the percentage of population is ≥ 16%(Dhaka), 15-16% (Barisal), 14-15% (Rangpur, Khulna), 13-14%(Chittagong), 12-13%(Rajshahi), 11-12%(Sylhet) & <11%(Mymensingh) clearly identified in Fig. 2 till the date of 18 September 2021.

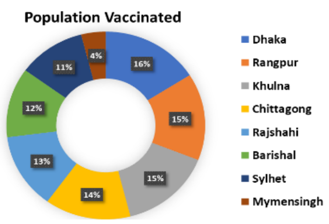

Figure 2: Percentage of the population vaccinated in the districts of Bangladesh till September, 2021.

Bangladesh ordered AstraZeneca vaccine produced by Serum Institute of India but due to technical difficulties Bangladesh received less than half of the doses as negotiated (Prothom Alo, 2021). Due to the vaccine shortage, Bangladesh has given its approval to Russia's Sputnik V (Paul, 2021) and Chinese BBIBP-CorV (DT, 2021) vaccines for emergency use in late April 2021. Bangladesh has also authorized the emergency of Pfizer–BioNTech COVID-19 vaccine and to be distributed as part of COVAX. The amount of 22,827,373 people among the target of 117,856,000 nos has received at least one dose i.e., 20% as of percentage and 15,025,970 among the target of 117,856,000 has been fully vaccinated i.e., 13% as of percentage up to the date of 20 September 2021(DGHS, 2021). AstraZeneca, developed by British-Swedish -is ChAdOx1 virus type vaccine with an efficiency rate of 79% (Astrazeneca, 2021). Table 2 presented that the AstraZeneca of 1st Dose in Bangladesh was administrated by male and female of 4,247,006 and 2,823,236 respectively and total in amount of 7,070,242 nos. The 2nd dose was administrated by male and female of 3,368,463 and 2,035,007 respectively and 5,403,470 nos in total.

Pfizer, developed by USA & Germany – is a mRNA type of vaccine with efficiency rate of ~95% (Chong, 2020). The Pfizer of 1st Dose was administrated by male and female of 54,745 and 8,419 respectively and total amount is 63,164 nos. The 2nd dose was administrated by male and female of 38,378 and 6,879 respectively and 45,257 nos in total. Sinopharm, developed by China – is an Inactivated virus type vaccine with efficiency rate of 79.3% (CNA, 2021). The Sinopharm of 1st dose was administrated by male and female of 7,560,602 and 6,508,674 respectively and the total amount is 14,069,276 nos. The 2nd dose was administrated by male and female of 4,326,031 and 3,681,146 respectively and 8,007,177 nos are in total. Moderna, developed by USA – is a mRNA type vaccine with efficiency rate of ~95.0% (Chong, 2020). The Moderna of 1st dose was administrated by male and female of 1,499,533 and 1,081,257 respectively and the total of 14,069,276 nos. The 2nd dose was administrated by male and female of 1,388,327 and 1,011,245 respectively and 2,399,572 nos are in total.

Table 1: Administrated vaccine in Bangladesh as of 26 September 2021 (DGHS, 2021).

Vaccine type	**1st Dose Administrated (Nos)**			**2nd Dose Administrated (Nos)**		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
AstraZeneca	4,247,006	2,823,236	7,070,242	3,368,463	2,035,007	5,403,470
Pfizer	54,745	8,419	63,164	38,378	6,879	45,257
Sinopharm	7,560,602	6,508,674	14,069,276	4,326,031	3,681,146	8,007,177
Moderna	1,499,533	1,081,257	2,580,790	1,388,327	1,011,245	2,399,572

4 IDENTIFICATION OF ENVIRONMENTAL IMPACTS

Mismanagement in Vaccination program has been already identified from the beginning of different phases as shown in Fig. 3. Each of these situations will increased the negative impact tremendously which causes environmental pollution Vehicle traffic from patients, staff, and visitors is expected to increase around health-care institutions, causing congestion, a risk of accident and associated noise due to the lack of crowd management. Waste mismanagement revealed impacts includes generation and inadequate management of medical waste during immunization (used needles, syringes, PPE's etc.) that require special handling and treatment, waste spreading, frowsy, aesthetics degradation, increased water volume, hygiene and releases of associated effluents in the health care facilities, hospitals, medical colleges and research institutes (McInerney-Lankford, 2019). Impact characteristics can be considered according to the following categories such as spatial dimension, temporal dimension, reversible/irreversible, beneficial/adverse, socio-political dimension which demonstrate the increasing air pollution, solid waste, liquid waste, wastewater etc. in the environment.

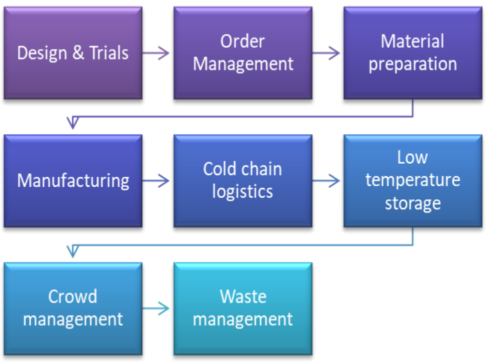

Figure 3: Mismanagement in the vaccination life cycle.

4.1 Impacts on Air

The anti-COVID vaccination campaign is exploring several kinds of impact on air, including Green House Gases (emission of CO_2, hydrofluorocarbons (HFC) gases etc) (Guillot, 2021), increase in air particulates etc. In section 4.1.1, we concentrate on the emission of CO_2 into the environment to discuss.

4.2 Emission of CO2

Vaccination campaign causes emission of CO_2 from different view point of using R-404A refrigerant (Santos et al., 2021), dry ice (Kurzweil et al., 2021) is the solid/frozen form of carbon dioxide, some of which is used as a refrigerant , telemedicine and e-healthcare (Jiang, Klemeš, Fan, Fu, & Bee, 2021), air travel (Kurzweil et al., 2021) and so on. The storage temperature of AstraZeneca, Pfizer, Sinopharm and Moderna is 2.0-8.0°C (Gov Uk, 2021), -70°C (Pfizer, 2020), 2.0-8.0°C (CNA, 2021) and -20°C (Santos et al., 2021) respectively. It is important to maintain these storage temperatures in COVID-19 cold chain which includes (1) truck transportation from industrial sites to medical trials and drug producers, (2) airplane transportation of high-volume refrigerated consignments to worldwide distribution locations, (3) supply vaccine to regional healthcare facilities by truck, and (4courier service distribution to local healthcare facilities (Kurzweil et al., 2021). So, several kinds of refrigerant are encouraged to maintain cold chain which emits CO_2 significantly, as shown in Figure 4.

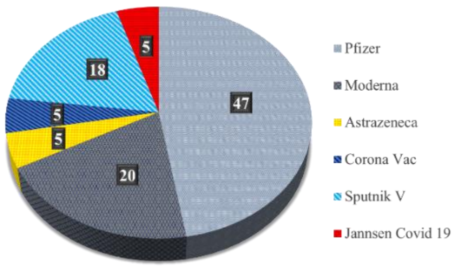

Figure 4: Relative CO_2 emission rate of different type of vaccine based on refrigerant (R-404) usage (Santos et al., 2021).

The information and communication technology (ICT) sector produces 2% of the global carbon dioxide (CO_2) emissions (Avgerinou et al., 2017). According to CO_2 emission and fuel burning transformation (i.e. about 33 t of CO_2 for 10.7 t of fuel) (Pearce, 2021), CO_2 emissions from the COVID-19 vaccine flight would amount over 2.38–2.57 Mt.. Flight CO_2 emissions are projected to account for 2% of global human-induced CO_2 emissions, with a total quantity of 915 Mt CO2 created by global flights. (IATA, 2021). So, Bangladesh is also accountable in increase of CO_2 emission into air.

4.3 Increase of Solid Waste

Solid waste produces from different categories includes (i) use of PPE, syringes, needles, vials (Guillot, 2021); (ii) spoiled, lost, damaged vials and mislabeled wastes (WSDH, 2021a); (iii) from manufacturing and packaging (BWS, 2021) etc. COVID-19 vaccine waste rates have been observed to range from 0.3 percent to 30 percent (Schiffling & Breen, 2021). The original syringe size design results in two excess doses per vial (Moutinho, 2021), resulting in 16.7% (Pfizer) to 28.6% (Moderna) wastage during the early stages of vaccination programs. According to the United Nations International Children's Emergency Fund (UNICEF), the world produces about $1.6x\ 10^{10}$ disposable syringes per year, with roughly 5% being utilized for various. Syringes have traditionally not been recycled because it is more cost effective to just make a new one. Afterwards, a number of material, energy, emissions, and waste increases may arise. (UNICEF, 2021). Bangladesh will produce at least 235,712,000 number of syringes waste (5.82 gm/syringe) (Al-Omran et al., 2021), from view of weight, it would be $1.37x10^9$ gm. The vials waste would be $1.37x10^9$ gm from 235,712,000 number of vials (1.59 gm/vial) (Al-Omran et al., 2021). The completion of vaccination campaign will generate about $3.74x10^8$ gm of solid waste to vaccinate 80% of people as mentioned in section 2.

4.4 Calculation of solid waste during vaccination

This calculation includes syringes, glass vials and alcohol swab which are used in vaccination of one`s in vaccination centers. Using the formula, the total waste weight generated by all vaccinated people was computed.(Al-Omran et al., 2021). Total waste`s weight of vaccination is the multiplication of weight of vaccine set and number of vaccinated people. Table 3 presents that the weight of wastage for 2 doses administrated is 270 ton and 202 ton for 1 dose administrated till the date of 28 September 2021. The total amount of waste generated due to vaccination campaign is 472.8 ton which looks significant in amount and it is to be managed properly to ensure safe environment in Bangladesh.

Table 2. Total calculated waste generated by vaccination till 28 September 2021.

Weight of vaccine set during one dose vaccination [a]		Number of vaccinated people [b]		Waste`s weight [c](gm)
1	2	3	4	5
Tool	Weight(gm)			
Syringes	5.82	2 doses	16,401,651	270,299,208
Glass vials	1.59	1 dose	24,575,140	202,499,154
Alcohol swab	0.83			
Total	8.24			472,798,368 (472.8 ton)

[a] (Al-Omran et al., 2021),[b] (DGHS, 2021), [c](8.24 x column 3 x column 4)

4.5 Increase of Liquid Waste

Liquid waste mainly would come from category of expired, spoiled and wasted multidose vial (MDV). If the MDV was opened or partially used it is not returnable. Vaccine will be spoiled because of several reasons that includes cold chain not maintaining during shipment, failure to store properly, natural disaster/power outage- a storm or countrywide power surge interrupts power to storage units for a length of time that caused vaccines to spoil, freezer mechanical failure, freezer too cold, freezer too warm, vaccine spoiled in transit. As vials are not viable, they would be broken, spilled or dropped (WSDH, 2021b). Each of these categories results liquid waste. In production phase such kind of chemicals, reagents also dispose in environment as a liquid waste. In the manufacturing phase, liquid waste is also formed in the form of culture liquid when the mycelium is isolated from it (Klemeš et al., 2021).

4.6 Potential Measures of Mitigating Impacts

4.6.1 Use of Refrigerant

As main concern is to reduce Green House Gases, particularly CO_2 gas emission reduction in this study and refrigerant have the significant contribution. For example, hydrofluorocarbons have the greater impact on global warming that is about 23000 times greater than CO_2 (EC, 2021) which is used to freeze vaccines, as vaccine is demanded to store at lower temperature. It is exigent demand to demonstrate alternate mode of refrigerant. Despite the fact that zero-emission vaccine refrigeration aboard aircraft is almost impossible, it is preferable to use alternate refrigerants like as dry ice to achieve a lower GHG emission strategy (Klemeš et al., 2021).

4.6.2 Cold chain logistics

Basically, the temperature-controlled supply chain that comprises all vaccine-related equipment and procedures is referred to as the cold chain. The cold chain must be maintained in all phases starting from manufacturing companies' cold storage unit, extent to transport and delivery that ends at distribution phases. Any mismanagement in cold chain logistics results extreme disposal of waste into environment. In light of WHO, as much as half of the immunizations are squandered worldwide every year, owing in huge part to an absence of temperature control and coordination to help a solid cold-chain. Recent study showed that basically 25% of vaccines may be squandered because of coordination and temperature control disappointments internationally (Zenk, 2020). It is imperative that the COVID-19 vaccine should be administered at a rate that minimizes wastage during its critical period. An effective cold chain relies on three principal components: (I) a very much prepared staff; (ii) Reliable capacity and temperature checking gear; (iii) Accurate vaccine stock administration (CDC, 2021b).

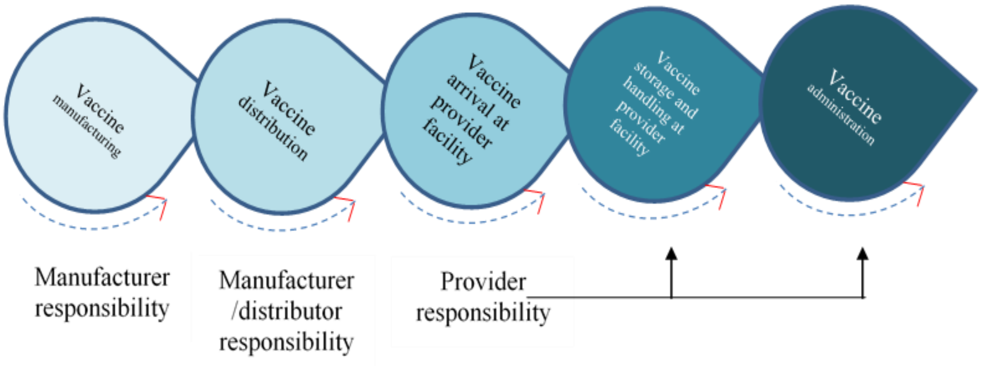

Figure 5: Flow Chart of Cold Chain (CDC, 2021)

Figure 5 shows the flow chart of cold chain where the responsibility of manufacturer and provider are clearly displayed. To ensure the appropriate utilization of cold chain, significant key exercises and upkeep undertakings have been introduced elaborately in table 4.

Table 3. Key exercises and support assignments to ensure legitimate utilization of cold chain (WHO, 2020).

Tasks Types	**Key exercises**			
	Control and Monitoring of Temperature	**Arrangement of Materials**	**General Maintenance**	**Reporting**
Daily tasks	• Temperature checking and recording twice a day. • Checking and adjusting the the flame quality.	• Ensure that vaccines, diluents and ice packs are stacked according to existing national rules.	• Cold boxes and vaccine carriers that have been used during the day should be cleaned, dried, and stored. • Check the wick's quality and trim it if necessary (kerosene)	• Report any equipment problems to the appropriate authority. • In the event of equipment failure and/or prolonged power outages, follow the emergency plan.
Weekly tasks	• Examine the temperature chart's trend. • Talk to the authorities about any unexpected pattern.	• Examine and discard expired stock • Ensure replacement of stocks.	• Check the availability of fuel (kerosene and gas). • Determine whether the refrigerator and/or freezer need to be thawed out.	
Monthly tasks	• Examine the temperature chart's trend. • Talk to the authorities about any unexpected pattern.	• Examine and discard expired stock • Ensure replacement of stocks.	• Clean and dry the inside of the refrigerator and/or the freezer. • Wipe off the outside of the refrigerator to remove dust.	• Follow the instructions on all monthly reporting forms and submit them to the next level.

Bangladesh should follow these elements to ensure effective cold chain procedure for reducing the environmental pollution.

4.6.3 Energy Use

Energy is an essential part of keeping the supply chain running smoothly. Thoroughly authorized cold chain coordination are needed for COVID-19 vaccines. For example, vaccine storage temperature at 2°-8°C or at -70° and -20°C to maintain in cold chain, it consumes more energy. Several types of energy are used includes electricity, solar, gas, kerosene. It is being recommended to use renewable sources (solar energy) for its environmentally friendly nature which would also be a substitute for traditional energy source. Another renewable energy is wind energy which can be used in here to fulfill the requirements (Sookne, 2021). These kinds of renewable energy essentially more effective in remote area in where the condition of energy is insufficient for maintaining storage temperature.

5 MANAGEMENT PLAN OF VACCINATION PROGRAM

5.1 Manufacturing Phase

Bangladesh has declared to manufacture COVID-19 vaccine (BSA, 2021). Incepta, a Bangladesh-based pharmaceutical company, would deliver Sinopharm COVID-19 vaccine very soon. Though manufacturing process consumes less energy, which make it conceivable to lessen the measure of waste significantly (Klemeš et al., 2021), Bangladesh should have proper management plan to deal of its adverse impact on environment. WHO recommended the guideline of Good Manufacturing Practice (GMP), in where proper regulations have gathered to release the pollutants into the environment.

5.2 Packaging Phase

Vaccine international shipment is the first requirements of long trip for vaccines to reach their intended recipients in a country. It must be ensured environmental sustainability and maintaining required temperature during this journey (World Health Organization, 2020). Proper packaging plays a crucial role in order to protect vaccine from both exposure high temperature and physical damage during international transport. From the starts of manufacturing to ends of distribution phase, proper packaging keeps vaccine and ancillary products safe that enhances the ability effectiveness of vaccination campaign. A typical vaccine packaging system can be categorized in different level. Ramakanth et al. demonstrates various types of materials (Ramakanth et al., 2021) are used in each level of vaccine packaging which is represented in Figure. 6.

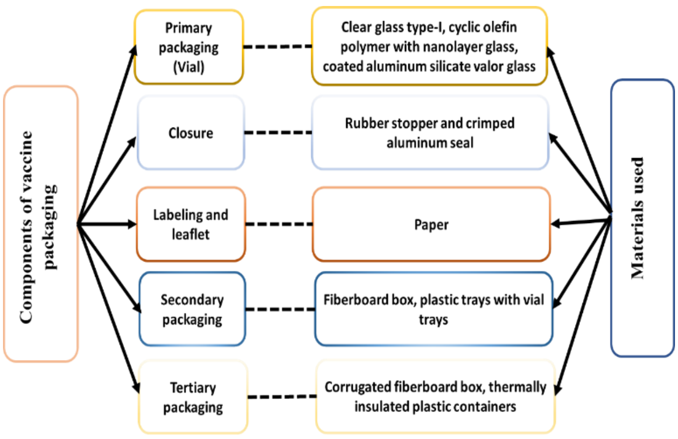

Figure 6: Type of materials used at each level of vaccine packaging.

5.3 Transportation Phase

Transportation can be categorized into two aspects such as (i) global transport; (ii) local transport. Efficient and good practice of transportation mainly depends on better packaging system which is discussed above. Most important thing is that cold chain logistics must be maintained properly. Global transport by air keeps vaccine safe by easing dry ice rules (Reuters, 2020). Last mile distribution in local transport would have significant environmental impacts due to bulk transportation and packing efforts. A few emergency clinics embraced bicycle conveyance to lessen the carbon emission byproduct of the last mile allocation in Paris (Guillot, 2021). In case the immunization quality can be ensured while utilizing the bicycle conveyance, it very well may be of a promising method for utilizing cycle for the decrease of the environmental adverse as cycling produces 16 g of CO_2/km just, yet that would be on normal 101 g of CO_2/km by transports and 271 g of CO_2/km by private vehicle (Klemeš et al., 2021).

5.4 Storage Phase

In storage phase, the main challenge is to maintain stored temperature as each vaccine has unique storage necessities. One effect that the COVID-19 vaccine products may have been on the types of vaccine storage units that will be in use and the monitoring devices in the cold chain. Direction on COVID-19 vaccine storing and temperature observing is subject to:

- supply chain of one's country framework;
- cold chain storage and equipment ability of the government;
- cold chain storage availability in the private marketplace for renting;
- the key qualities and thermostability necessities of the new immunizations.

The COVID-19 immunizations should be directed speedily once got the vaccine store. The period of vaccine storage should be for a short term. The potential COVID-19 vaccination applicants are as of now being created which can be classified by three storage prerequisites as introduced in table 5 (as of January 2021).

Table 4**:** Guideline of vaccine storage in required temperature

Required storage temperature	**Vaccines**	**Guideline**
2 - 8 °C	• AstraZeneca (Viral vector) • Janssen (Viral vector) • Sinovac (Inactivated virus)	WHO guidance for managing vaccines[a]
-20 °C	• Moderna (m-RNA) • Sputnik V (Viral vector)	WHO guidance for managing vaccines[a]
-70±10 °C	• Pfizer- BioNTech (m-RNA)	Significant investment in Ultra Cold Chain storage capacity, vaccines handling training and Ultra-Low Temperature equipment will be necessary.

[a](WHO, 2015d)

5.5 Distribution Phase

Massive waste is generated from distributional phase poses potential great problem for environmental sustainability. The amount of waste generated from inoculation is 472 ton till the date of September 28, 2021 includes syringes, vials, alcohol swab only which is mentioned in above table 3. Proper management plan should be taken to rescue environment from adverse impact of these waste. World Health Organization recommended standard operational procedure (SOP) for vaccine waste management is displayed in Figure. 7. The kind of waste need to be managed includes vaccine vials, syringes, sharp wastes (e.g., needles, auto-block syringes, scalpels, etc.), PPE, cottons, wrap etc. Collected waste should be stored in such a way that it will be easy to treat and final disposal. Incineration process can be adopted for all syringes and sharp waste treatment (WHO, 2021b). Globally, the most well-known strategies for medical waste management are incineration and sanitary landfills (Hong et al., 2018).

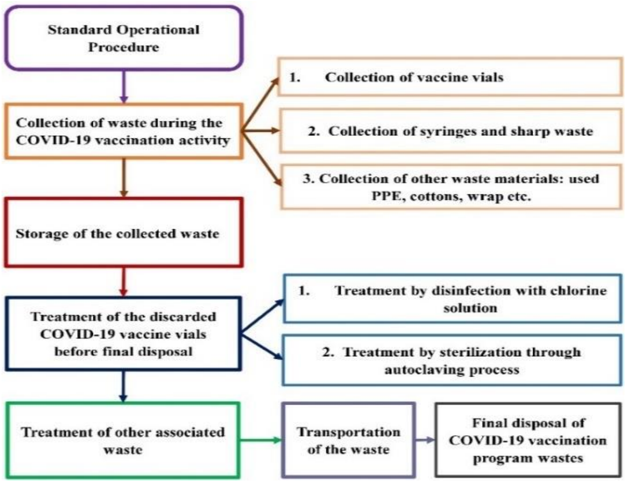

Figure 7: Procedure of vaccine waste management

6 CONCLUSION

This study explored the two major scenario of COVID-19 vaccination program in Bangladesh: holistic scenario and environmental impact assessment. Bangladesh has already planned to get vaccinated about 80 percent of people from total and the vaccination program is ongoing in all the districts of the country. The investigation of this study suggested that this vaccination campaign would cause environmental pollution significantly. The environmental impact is identified from several phases such as manufacturing, packaging, transportation, storage and distribution i.e., from sources to end consumption of vaccination campaign. The air pollution due to CO_2 emission would be the highest for the Pfizer vaccine (47%) that would adversely impact the atmospheric condition. In addition, solid waste generated from of medical waste of syringes, vials, alcohol swab, liquid waste are estimated to be 472 tons in Bangladesh. The amount of waste of one dose inoculation in vaccination centre drastically exposes into the environment. As a consequence, the proper management plan of vaccination program is a prerequisite for Bangladesh to achieve SDGs. This study pointed out the steps of vaccine waste management and suggested incineration and sanitary landfills for disposal of medical wastes to get proper immediate response for minimisation of environmental impacts.

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