



## CORRELATION BETWEEN WASTAGE RATE AND COVERAGE RATE FOR SPECIFIC ROUTINE VACCINES IN NINEVEH AT 2023

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### ABSTRACT

**Background:** National immunization programs administer routine vaccinations, but low coverage in developing countries is attributed to vaccine stock out and wastage. Minimizing wastage and associated costs is crucial for effective vaccine management. **Aim:** To estimate vaccine coverage and wastage rates needed to inform vaccination policies, programs, and investments. **Methodology:** A cross-sectional study was conducted in the Nineveh Governorate, focusing on the correlation between vaccine wastage and coverage rates. Data was collected from 2/1/2023 to 30/6/2023, analyzing routine vaccine wastage and coverage rates. The study was conducted within the Nineveh Department of Health, including 11 health districts, and was derived from records in the Public Health Department and primary health districts. **Results:** The study found that health workers in Ba, Aj, Hatra, and Makhmur districts were 100% trained, with Shikhan district having the highest coverage rates for Rota, Penta, OPV, Measles, MMR, and DPT. Ba'aj district had the highest coverage rates for IPV, BCG, and Pneumococcal vaccine. Aymen district had the highest HP-B coverage rate. However, Ba'aj district had the highest wastage ratios for DPT, HIP-B, IPV, OPV, Penta, Rota, and BCG. Hatra district had the highest wastage ratio for Measles, while Makhmur district had the highest wastage ratio for MMR and Pneumococcal vaccine. Significant direct correlations were found between vaccine coverage and wastage for Penta-vaccine and Measles. **Conclusions:** Health workers in Nineveh governorate undergo vaccination training, with high coverage rates and low wastage. There is a direct correlation between vaccine coverage and wastage.

**KEYWORDS:** Coverage rate, Vaccines, Wastage rate.

### INTRODUCTION

Prophylactic vaccination is a cost-effective and effective medical intervention that reduces the consequences of catastrophic infections and improves population health by improving collective immunity. The Expanded Program on Immunization (EPI) was initiated in 1974 by the World Health Organization and UNICEF to promote vaccination against preventable infectious diseases.<sup>[1]</sup> Routine vaccination is administered through national immunization programs, which develop policies, procure and distribute vaccines, and monitor coverage and effectiveness. The Global Vaccine Action Plan 2011-2020 (GVAP) calls for all countries to achieve 90% national coverage with all vaccines by 2020. Common determinants affecting vaccination coverage include vaccine hesitancy, lack of healthcare access, and inadequate vaccine supply and distribution systems.<sup>[2,3]</sup>

Routine vaccination is the regular administration of vaccines by public health officials to protect individuals from infectious diseases and prevent their spread within the community.<sup>[4]</sup>

Measles, mumps, and rubella are infectious diseases caused by distinct members of the paramyxovirus group. The MMR vaccine was introduced in 1988 for young children of both sexes, replacing the single measles vaccine. It consists of a single dose of a lyophilized preparation of live attenuated strains of the measles, mumps, and rubella viruses. Immunization results in sero-conversion to all three viruses in >95% of recipients.<sup>[5]</sup>

There have been three distinct strains of wild poliovirus (WPV1, WPV2, and WPV3) documented, but

coordinated vaccination efforts have resulted in the global eradication of WPV2 and WPV3 in 2015 and 2019, respectively. Both live and inactivated/killed vaccines compete in polio prophylaxis. Tuberculosis (TB) is a major cause of death and morbidity worldwide, particularly where poverty, malnutrition, and poor housing prevail. A live vaccine is required to elicit protection against TB, and both antibody and cell-mediated immunity are required for protective immunity. Vaccination with BCG, derived from an attenuated *M. bovis* strain, is commonly used in countries where TB is endemic.

DTaP vaccine can prevent diphtheria, tetanus, and pertussis, which spread from person to person. It is recommended that children receive 5 doses of DTaP, usually at the following ages: 2 months, 4 months, 6 months, 15-18 months, and 4-6 years. Rotaviruses are the leading cause of severe diarrhea in young children globally, causing an estimated 500,000 deaths and two million hospitalizations each year.<sup>[5-7]</sup>

The Pentavalent vaccine provides protection to a child from five life-threatening diseases—Diphtheria, Pertussis, Tetanus, Hepatitis B, and Hib. The combination of DPT and Hep B is called Pentavalent, and it comes in a liquid form in a vial that contains 10 doses. Measles is a highly contagious, serious viral disease, with an estimated 120,000 deaths in 2021, mostly children under the age of five years.<sup>[8-10]</sup>

Vaccine wastage is a significant issue that affects the efficiency of immunization, accounting for approximately 22% of vaccine-related costs in Senegal. It can be classified into two categories: wastage in unopened vials and wastage in opened vials. Causes of vaccine wastage include overestimation of vaccine demand, inadequate storage conditions, improper handling, expired vaccines, viral wastage, vaccinating hesitancy, insufficient demand, and the importance of high coverage rates for vaccines. Vaccine wastage can result from various causes, such as expiration, heat damage, physical damage, losses in transit or inventory, and incomplete use of the nominal number of doses in multi-dose vials.<sup>[11,12]</sup> High confidence in vaccination programs is crucial for maintaining high coverage rates, but vaccine delays and refusals are contributing to declining immunization rates and increasing disease outbreaks.<sup>[12]</sup> The World Health Organization reports over 50% of vaccine wastage worldwide, with the Ministry of Health and Family, Government of India recommending a wastage rate of 25%. Knowing the wastage rate helps assess vaccine wastage and its causes, enabling targeted efforts to reduce losses and increase funds for expensive vaccines.<sup>[12,13]</sup>

The current study aimed to estimate vaccine coverage and wastage rates needed to inform vaccination policies, programs, and investments.

## METHODOLOGY

A cross-sectional study is designed to achieve the correlation between vaccine wastage and coverage rates. The study was carried out in the Nineveh Governorate in the Nineveh Department of Health / Public Health Department, which included 11 health districts, and data collection occurred within the scope of health services that offer the specific routine vaccine.

Data were collected from 2/1/2023 to 30/6/2023 from 11 health districts. The duration of each sector was between (2-3) days.

Data on wastage and coverage rates was collected for certain routine vaccines. These data were derived from the records in Public Health Department, primary health district, and centers, in addition to the vaccination records.

**Administrative Data:** Use administrative data bases from Public Health Departments. These data bases contain information on the number of vaccines ordered, received, administered, and wasted.

**Medical Records:** Electronic health records (EHRs) or vaccination records from departments of public health and health districts of the Department of Health of the Nineveh Governorate.

## Data Collection Method

- 1. Extraction from Databases:** data was collected on waste and coverage rates from administrative databases and vaccination records.
- 2. Checklist administration:** Using a checklist, determine whether it will be administered by an interviewer. Data should be cleaned to ensure accuracy and address any errors or inconsistencies.

The checklist was designed to comprehensively reviewing the vaccination administration within a specific Primary Healthcare Centre (PHC) in terms of infrastructure, personnel, practices, vaccine coverage, and waste rates. Additionally, information about the vaccination staff included their qualification, had certified training or not, number of training courses, specified roles, vaccine administration, record keeping, vaccines to coverage and management, patient education, and monitoring of vaccine efficacy and side effects.

The checklist also included information related to vaccine status such as available, well stored, expiration date, cold chain, consistently maintained temperature, use of ice pack, and vaccination session such as every day, specific day.

Waste ratios were calculated at the primary level by first estimating using the following formula.<sup>[32]</sup>

$$\text{Coverage rate} = \frac{\text{No. of vaccinated children <5 years}}{\text{Total no. of children <5 years}} \times 100$$

$$\text{Wastage ratio} = \frac{\text{No. of doses wasted in specific time period}}{\text{No. of doses supplied in the same specific time period}} \times 100$$

### Statistical data analysis

This study used the statistical package for social science (SPSS) soft-ware version (25), and descriptive statistics were calculated as frequency, percentage, and chi-square tests for categorical variables.

### RESULTS

In this study, the distribution of the trained health care worker according to the health districts and illustrated that there were hundred percent trained personnel in Ba'aj, Hatra, and Makhmur districts followed by Aymen (91.6%) as was shown in figure (3.1).

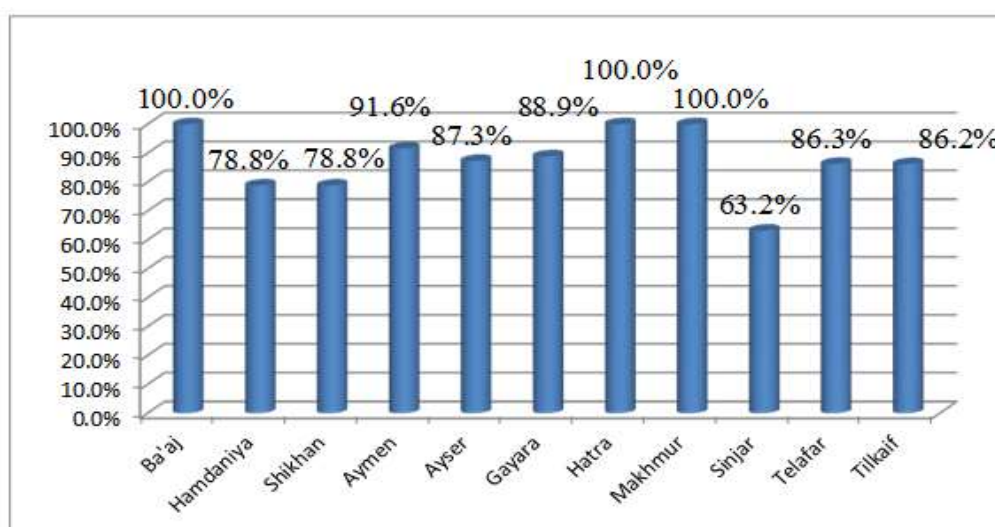


Figure (3.1): Distribution of the trained health care worker according to the health districts.

The current study shows the distribution of the vaccines coverage according to districts at 2023 was demonstrated in table (1) and showed that the highest rates for coverage of Rota (80.5%), Penta (104.7%), OPV (102.1%), Measles (100.0%), MMR (95.9%), and DPT

(81.7%), were found in Shikhan district while the highest rates for coverage of IPV (98.6%), BCG (99.2%), and Pneumococcal vaccine (14.1%) were found in Ba'aj district. The highest coverage rate of HP-B (98.8%) was found in Aymen district.

Table (1): Distribution of the vaccines coverage according to districts at 2023.

Districts	Coverage %									
	DPT	HP-B	IPV	Measles	MMR	OPV	Penta	Rota	BCG	Pneum
Ayser	33.8	75.4	79.6	65.3	62.1	84.6	84.0	29.5	89.7	9.4
Aymen	26.8	<b>98.8</b>	60.4	55.3	51.6	62.9	63.9	20.2	90.2	4.3
Hamdaniya	60.8	97.8	80.5	77.2	88.6	97.8	82.9	63.0	90.2	11.7
Shikhan	<b>81.7</b>	97.1	98.2	<b>100.0</b>	<b>95.9</b>	<b>102.1</b>	<b>104.7</b>	<b>80.5</b>	126.2	13.7
Ba'aj	46.1	94.3	<b>98.6</b>	99.3	103.9	104.6	97.9	46.5	<b>99.2</b>	<b>14.1</b>
Gayara	26.2	66.2	51.0	34.7	53.2	56.7	53.5	21.1	67.0	3.7
Hatra	42.4	59.4	71.5	51.5	79.2	78.6	73.4	43.2	97.2	5.4
Makhmur	41.8	40.2	62.7	60.1	54.6	67.6	66.5	41.1	86.8	6.0
Sinjar	45.1	37.2	54.5	65.9	71.1	59.5	59.5	33.5	58.2	7.0
Telafar	40.1	51.1	66.7	73.1	70.7	73.4	70.8	21.2	96.6	3.9
Tilkaif	38.4	33.1	63.9	57.8	65.8	64.9	68.3	28.1	77.2	6.1

Distribution of the vaccines wastage according to districts at 2023 was demonstrated in table (2). This table elicited that the highest wastage ratios for DPT (20.9%), HIP-B (10.7%), IPV (4.6%), OPV (8.0%), Penta (6.9%), Rota (7.9%), and BCG (23.6%) were found in Ba'aj

district. Concerning the Measles, the highest wastage ratio (14.9%) was found in Hatra district. Moreover, Makhmur district reported the highest wastage ration for MMR (10.3%) and Tilkaif (2.7%) district for Pneumococcal vaccine.

**Table (2): Distribution of the vaccines wastage according to districts at 2023.**

Districts	DPT	HP-B	IPV	Measles	MMR	OPV	Penta	Rota	BCG	Pneum
Ba'aj	20.9	10.7	4.6	8.9	8.8	8.0	6.9	7.9	23.6	0.0
Hamdaniya	6.1	4.5	3.8	10.0	6.1	6.5	4.9	0.1	15.2	0.0
Shikhan	3.3	5.7	3.5	11.6	9.5	6.1	4.6	1.3	17.7	0.0
Aymen	3.1	7.7	1.7	5.6	4.7	2.1	1.7	0.07	8.4	0.0
Ayser	5.4	5.0	3.4	7.7	6.3	4.8	3.4	0.05	10.4	0.05
Gayara	2.9	3.6	2.6	8.2	3.7	3.3	2.5	3.9	16.7	0.4
Hatra	3.1	4.9	2.5	14.9	5.3	2.6	3.0	0.0	16.0	0.0
Makhmur	1.8	6.4	2.6	9.2	10.3	1.5	1.2	0.4	11.6	0.0
Sinjar	4.2	3.9	3.0	6.0	2.8	3.9	3.0	0.2	12.0	0.0
Telafar	2.7	1.4	2.6	3.7	3.6	3.1	2.5	0.2	6.0	0.2
Tilkaif	5.6	8.4	2.7	11.1	8.0	4.4	4.2	1.3	15.5	2.7

The comparison of percentage of vaccinated persons and wastage for BCG at Heath districts 2023 revealed that the most high percentage of vaccinated persons found in

Telafar district (88.5%) with a statistically significant association ( $p=0.000$ ) as shown in table (3).

**Table (3): Percentage of vaccinated persons and wastage for BCG.**

Districts	BCG		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	1763(73.7)	628(26.3)	0.000
Hamdaniya	2734(70.0)	1173(30.0)	
Shikhan	916(65.4)	484(34.6)	
Aymen	11326(77.9)	3204(22.1)	
Ayser	12746(80.2)	3156(19.8)	
Gayara	3558(66.5)	1790(33.5)	
Hatra	1032(70.8)	425(29.2)	
Makhmur	1391(71.8)	546(28.2)	
Sinjar	1658(63.4)	959(36.6)	
Telafar	7359(88.5)	959(11.5)	
Tilkaif	3204(63.8)	1816(36.2)	

The comparison of percentage of vaccinated persons and wastage for Rota vaccine at Heath districts 2023 was demonstrated in table (4) and revealed that the most high

percentage of vaccinated persons found in Hatra district (100.0%) with a statistically significant association ( $p=0.000$ ).

**Table (4): Percentage of vaccinated persons and wastage for Rota at Heath districts 2023.**

Districts	Rota		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	1217 (94.4)	72(5.6)	0.000
Hamdaniya	3819(99.8)	8(0.2)	
Shikhan	1149(97.3)	32(2.7)	
Aymen	5059(99.8)	8(0.2)	
Ayser	8256(99.9)	7(0.1)	
Gayara	2169(90.5)	229(9.5)	
Hatra	870(100.0)	0(0.0)	
Makhmur	1311(98.9)	15(1.1)	
Sinjar	1875(99.5)	10(0.5)	
Telafar	3141(99.7)	10(0.3)	
Tilkaif	2321(96.9)	75(3.1)	

The comparison of percentage of vaccinated persons and wastage for Penta vaccine at Heath districts 2023 was demonstrated in table (5) and revealed that the most high

percentage of vaccinated persons found in Telafar district (93.2%) with a statistically significant association ( $p=0.000$ ).

**Table (5): Percentage of vaccinated persons and wastage for Penta.**

Districts	Penta		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	3842(89.1)	469(10.9)	<b>0.000</b>
Hamdaniya	7535(87.0)	1130(13.0)	
Shikhan	2242(90.3)	241(9.7)	
Aymen	24007(96.2)	954(3.8)	
Ayser	35263(94.0)	2259(6.0)	
Gayara	8247(90.3)	885(9.7)	
Hatra	2221(92.4)	183(7.6)	
Makhmur	3185(96.7)	108(3.3)	
Sinjar	5004(86.7)	769(13.3)	
Telafar	<b>15715(95.3)</b>	769(4.7)	
Tilkaif	8460(87.9)	1168(12.1)	

The comparison of percentage of vaccinated persons and wastage for OPV vaccine at Heath districts 2023 was demonstrated in table (6) and revealed that the most high

percentage of vaccinated persons found in Makhmur district (95.4%) with a statistically significant association ( $p=0.000$ ).

**Table (6): Percentage of vaccinated persons and wastage for OPV.**

Districts	OPV		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	6840(85.4)	1172(14.6)	<b>0.000</b>
Hamdaniya	14811(84.6)	2687(15.4)	
Shikhan	4306 (85.9)	704(14.1)	
Aymen	39423(94.4)	2335(5.6)	
Ayser	59154(88.9)	7358(11.1)	
Gayara	14577(89.7)	1678(10.3)	
Hatra	3959(90.7)	404(9.3)	
Makhmur	<b>5391(95.4)</b>	262(4.6)	
Sinjar	8339(82.7)	1747(17.3)	
Telafar	27161(94.0)	1747(6.0)	
Tilkaif	13411(86.3)	2128(13.7)	

The comparison of percentage of vaccinated persons and wastage for MMR vaccine at Heath districts 2023 was demonstrated in table (7) and revealed that the most high

percentage of vaccinated persons found in Telafar district (93.2%) with a statistically significant association ( $p=0.000$ ).

**Table (7): Percentage of vaccinated persons and wastage for MMR.**

Districts	MMR		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	2697(85.2)	468(14.8)	<b>0.000</b>
Hamdaniya	5367(84.0)	1023(16.0)	
Shikhan	1512(81.4)	345(18.6)	
Aymen	12925(86.5)	2025(13.5)	
Ayser	17377(85.7)	2896(14.3)	
Gayara	5475(79.9)	1376(20.1)	
Hatra	1596(84.8)	285(15.2)	
Makhmur	1744(70.6)	728(29.4)	
Sinjar	3982(83.8)	767(16.2)	
Telafar	<b>10471(93.2)</b>	767(6.8)	
Tilkaif	5436(81.0)	1273(19.0)	

The comparison of percentage of vaccinated persons and wastage for Measles vaccine at Heath districts 2023 was demonstrated in table (8) and revealed that the most high

percentage of vaccinated persons found in Telafar district (85.0%) with a statistically significant association ( $p=0.000$ ).

**Table (8): Percentage of vaccinated persons and wastage for Measles.**

Districts	Measles		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	1312(68.6)	600(31.4)	<b>0.000</b>
Hamdaniya	2341(59.5)	1593(40.5)	
Shikhan	900(61.1)	572(38.9)	
Aymen	6923(73.6)	2487(26.4)	
Ayser	9133(71.5)	3641(28.5)	
Gayara	1786(45.4)	2148(54.6)	
Hatra	519(51.0)	499(49.0)	
Makhmur	960(54.5)	803(45.5)	
Sinjar	1846(65.8)	959(34.2)	
Telafar	<b>5416(85.0)</b>	959(15.0)	
Tilkaif	2388(51.7)	2232(48.3)	

The comparison of percentage of vaccinated persons and wastage for IPV vaccine at Heath districts 2023 was demonstrated in table (9) and revealed that the most high

percentage of vaccinated persons found in Aymen district (95.3%) with a statistically significant association ( $p=0.000$ ).

**Table (9): Percentage of vaccinated persons and wastage for IPV.**

Districts	IPV		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	2840(91.9)	249(8.1)	<b>0.000</b>
Hamdaniya	4881(89.5)	573(10.5)	
Shikhan	1402(88.6)	180(11.4)	
Aymen	<b>15130(95.3)</b>	739(4.7)	
Ayser	22289(92.4)	1828(7.6)	
Gayara	5247(90.2)	567(9.8)	
Hatra	1442(92.8)	112(7.2)	
Makhmur	2002(92.0)	175(8.0)	
Sinjar	3052(83.9)	585(16.1)	
Telafar	9876(94.4)	585(5.6)	
Tilkaif	5273(91.0)	523(9.0)	

The comparison of percentage of vaccinated persons and wastage for HP-B vaccine at Heath districts 2023 was demonstrated in table (10) and revealed that the most

high percentage of vaccinated persons found in Telafar district (93.2%) with a statistically significant association ( $p=0.000$ ).

**Table (10): Percentage of vaccinated persons and wastage for HP-B.**

Districts	HP-B		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	1233(81.6)	278(18.4)	<b>0.000</b>
Hamdaniya	2963(87.2)	434(12.8)	
Shikhan	765(78.9)	205(21.1)	
Aymen	1639(59.7)	1107(40.3)	
Ayser	10547 (82.2)	2286(17.8)	
Gayara	3406(85.3)	587(14.7)	
Hatra	599(76.2)	187(23.8)	
Makhmur	641(75.6)	207(24.4)	
Sinjar	1041(79.0)	276(21.0)	
Telafar	<b>3780 (93.2)</b>	276(6.8)	
Tilkaif	1366(59.1)	944(40.9)	



The comparison of percentage of vaccinated persons and wastage for DPT vaccine at Heath districts 2023 was demonstrated in table (11) and revealed that the most

high percentage of vaccinated persons found in Makhmur district (92.1%) with a statistically significant association ( $p=0.000$ ).

**Table (11): Percentage of vaccinated persons and wastage for DPT HP-B at Heath districts 2023.**

Districts	DPT		p-value*
	Vaccinated person	Wastage	
	No. (%)	No. (%)	
Ba'aj	1205 (70.2)	512 (29.8)	<b>0.000</b>
Hamdaniya	3683 (69.8)	1590(30.2)	
Shikhan	1167 (88.6)	150(11.2)	
Aymen	6726 (85.5)	1145(14.5)	
Ayser	9463 (78.7)	2566(21.3)	
Gayara	2693 (83.0)	553(17.0)	
Hatra	854 (82.5)	181(17.5)	
Makhmur	<b>1333 (92.1)</b>	115(7.9)	
Sinjar	2529 (81.1)	591(18.9)	
Telafar	5940 (91.0)	591(9.0)	
Tilkaif	3167 (75.4)	1033(24.6)	

Comparison of percentage of vaccinated persons and wastage for Pneumococcal vaccine at Heath districts

2023 showed that the highest frequency of coverage found in Shikhan as shown in table (12).

**Table (12): Percentage of vaccinated persons and wastage for Pneumococcal vaccine.**

Percentage of vaccinated persons and wastage for Pneumococcal vaccine.					
Districts	Pneumococcal vaccine				p-value*
	Vaccinated person		Wastage		
	No. (%)		No. (%)		
Ba'aj	628	99.1	6	0.9	0.000
Hamdaniya	1173	99.3	8	0.7	
Shikhan	484	98.8	6	0.2	
Aymen	3204	99.5	17	0.5	
Ayser	3156	99.5	15	0.5	
Gayara	1790	99.6	7	0.4	
Hatra	425	98.6	6	0.4	
Makhmur	546	98.7	7	0.3	
Sinjar	959	99.1	9	0.9	
Telafar	959	99.2	8	0.8	
Tilkaif	1816	99.5	9	0.5	

Correlations of vaccine coverage with vaccine wastage at 2023 was demonstrated in table (13) and revealed

significant direct correlations between coverage and wastage for only Penta-vaccine and Measles.

**Table (13): Correlations of vaccine coverage with vaccine wastage at 2023.**

Pearson's R	r-value	Asymp. Std. Errora	Approx. Tb	p-value
BCG	0.560	0.191	1.353	0.247 <sup>c</sup>
OPV	0.679	0.118	1.848	0.138 <sup>c</sup>
IPV	0.757	0.154	2.320	0.081 <sup>c</sup>
HEP-B	0.308	0.246	0.648	0.552 <sup>c</sup>
Penta-vaccine	0.817	0.060	2.839	<b>0.047<sup>c</sup></b>
Measles	0.886	0.045	3.817	<b>0.019<sup>c</sup></b>
MMR	0.744	0.045	2.226	0.090 <sup>c</sup>
Rota-vaccine	0.433	0.315	0.960	0.391 <sup>c</sup>
DPT	0.408	0.174	0.894	0.422 <sup>c</sup>

## DISCUSSION

Vaccines are considered one of the most important successes in the history of public health and prevention of vaccine-preventable diseases.<sup>[34]</sup> Extensive vaccine

coverage in the world, especially in developing countries, has contributed to increased child survival rates, reduced rates of infection, and reduced long-term

disability; therefore, any declines in vaccination rates pose tremendous public health risks to children.<sup>[14]</sup>

The current study showed that the health care workers in districts and their related primary health care centers were trained on the immunization program; the entire workers in Ba, aj, Hatra, and Makhmur districts have been trained in comparison to 87.3% in Ayser and 91.6% in Aymen, and the lowest proportion of trained workers was found in Sinjar district 63.2%. In the interventional study,<sup>[15]</sup> conducted in Wasit Governorate to evaluate the immunization session practices (ISPs), only 36% of the health workers had training on ISPs. The vaccines coverage rate (VCR) among the current studied districts was high and variable; the highest rates for coverage of IPV (98.6%), BCG (99.2%), and Pneumococcal vaccine (14.1%) were found in Ba'aj district while the highest rates for coverage of Rota (80.5%), Penta (104.7%), OPV (102.1%), Measles (100.0%), MMR (95.9%), and DPT (81.7%), were found in were found in Shikhan district. The highest coverage rate for Hip-B (98.8%) was found in Aymen district. In a cross-sectional study was conducted by Alhaddad *et al.*,<sup>[16]</sup> in the city of Nasiriyah in southeastern Iraq, BCG had the highest rate (100% VCR) and measles had the lowest rate (83.7%), reaching 63.6% in 2020 ( $p < 0.001$ ). In a study conducted by Ahmadnezhad *et al.*,<sup>[17]</sup> similar high coverage rates were reported. Different studies done in urban areas across the India by Kadri *et al.*,<sup>[18]</sup> and Nath *et al.*,<sup>[19]</sup> have reported a wide range of variation in immunization coverage rate (20–85%). The coverage of immunization in urban areas of Kochi obtained in the Sharma *et al.*,<sup>[20]</sup> study though much higher when compared to District Level Household Survey (DLHS 4) and National Family Health Survey (NFHS 4) surveys is not much different from the results of recent similar studies done in rural areas in the district.<sup>[21]</sup> Despite these challenges, the EPI has achieved substantial success in the past few years. Garcia *et al.*,<sup>[22]</sup> study reported that the coverage of DTP3 increased from 68% in 2015 to 84% in 2019. Similarly, coverage of the second dose of measles containing vaccine increased from 76% in 2015 to 86% in 2019. However, routine vaccination still lags behind other countries in the Middle East and in North Africa where coverage for most vaccines exceeds 90%. Coverage in Iraq remains low for newer vaccines like PCV13 (37%) and rotavirus (60% in 2018) due to frequent stock outs, and the 2018 Multiple Indicator Cluster Survey found only 46.9% of children 12–23 months were fully vaccinated as per the Iraq vaccination schedule.

The Vaccine wastage rates (VWR) vary according to vial whether it is one dose vaccine or multiple doses vaccine and age of delivery, ranging from 50% for BCG vaccine given at birth to 5% for vaccines in single dose vials.<sup>[23]</sup> The general guidelines on the VWR per vaccine notes the wastage rates of 50% for BCG and 25% for the measles vaccine are considered acceptable for reconstituted vaccines; 10% for OPV; 15% for liquid

vaccines in multi-dose vials of 10 or more doses; and 5% for liquid vaccines in single or two-dose vials such as PENTA and PCV.<sup>[24]</sup> In the current study, VWR was low but within the acceptable range of general guidelines on the VWR and distributed according to the health districts as; DPT (20.9%), HIP-B (10.7%), IPV (4.6%), OPV (8.0%), Penta (6.9%), Rota (7.9%), and BCG (23.6%) were found in Ba'aj district. Concerning the Measles, the highest wastage ratio (14.9%) was found in Hatra district. Moreover, Makhmur district reported the highest wastage ration for MMR (10.3%) and Tilkaif (2.7%) district for Pneumococcal vaccine. In the study conducted by Nkenyi *et al.*,<sup>[25]</sup> the VWR of BCG was the highest (32.19%), followed by measles and rubella (19.05%) among all EPI vaccines in the Littoral Region of Cameroon during 2016 and 2017. Single-dose vaccine vials exhibited lower VWRs than multi-dose vials. In comparing to urban health districts that mostly employ a fixed vaccination strategy (children are brought to health facilities for vaccination), to rural districts, an outreach vaccination strategy is typically facilities.<sup>[26]</sup> Usually, vaccine vials taken out for this strategy do not return to the vaccine storage facilities if vaccine vial monitors (VVM); Existing studies have reported high VWRs in rural areas due to vial breakage while opening, the burden of cost expenditure, and improper handling and storage, all of which were often related to the lack of skilled personnel in rural immunization activities.<sup>[27]</sup> Furthermore, the possibility of accidents occurring in rural areas leading to unopened vial breakage is higher than in urban areas. Relatively less skilled personnel may also be involved in rural immunization activities.<sup>[28]</sup> Not fully understanding the importance of vaccination due to that the rural populations tend to have negligent behavior toward meeting vaccination appointments.<sup>[29]</sup> This often leads to waste of open vials, especially lyophilized vaccines. Notably, such differences in rural and urban vaccine wastage were not significant in a study conducted in The Gambia, likely due to enhanced vaccine management and high vaccination coverage.<sup>[30]</sup> The overall wastage rate for BCG was 38.9%, and OPV was 33.6% as reported by Dadari *et al.*,<sup>[31]</sup> study. The wastage rates in Nigeria were in the range of 21–35% at outreach sessions and 18–27% at the stores.<sup>[32]</sup> The wastage rates were lower in Gambia,<sup>[31]</sup> for most of the vaccines, except the BCG (54.9%). Moreover, the average wastage rate for MMR opened vials in a study conducted in Iran was estimated 1–29%. The vaccine wastage in Iran is over the GAVI guidelines. The total MMR wastage rate in relation to the size of the target population showed that there is no clear or systematic correlation between the target population and MMR total wastage rates. It could be caused by the recommendations from the higher levels to seize any opportunity to vaccinate children and giving priority to vaccination coverage rather than to the wastage rate.<sup>[33]</sup> Thorough researching was done but no comparable study was found concerning the correlation between coverage and wastage. The current study found direct and good correlations between the vaccine coverage and wastage



for the penta vaccine and measles in all the health districts in Nineveh governorate.

## CONCLUSIONS

The study found that most health workers in Nineveh governorate were trained in immunization programs, with high coverage rates for all vaccinations. However, wastage varies across districts but is generally low. A direct correlation was found between vaccine coverage and wastage.

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