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# Editorial Board



# Editorial Office



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# Youth Editorial Board

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Preplanned Studies

# Spatiotemporal Epidemiological Characteristics of Dengue Fever and Its Relationship with Meteorological Factors — Yunnan Province, China, 2012–2024

Lihua Chen[1,2,&]; Heng Shao[3,&]; Dan Li[4]; Ruiqi Ren[4]; Wenqing Bai[4]; Jibo He[2]; Yihui Cao[2,#]; Chao Li[4,#]

**Summary**

**What is already known about this topic?**

Dengue fever (DF) is a major mosquito-borne disease in tropical and subtropical regions. Transmission shows seasonal and spatial patterns and is associated with meteorological factors, including temperature and precipitation.

**What is added by this report?**

From 2012–2024, dengue fever in Yunnan Province showed seasonal peaks and significant spatial and spatiotemporal clusters, particularly in border prefectures. Temperature and precipitation were key drivers of dengue incidence.

**What are the implications for public health practice?**

Integrating meteorological indicators into dengue surveillance and early warning systems may improve outbreak prevention and control in high-risk border areas.

## ABSTRACT

**Objective:** This study aimed to analyze the spatiotemporal characteristics of dengue fever in Yunnan Province and its relationship with meteorological factors.

**Methods:** Circular and spatiotemporal scan analyses were performed to investigate dengue fever, and a negative binomial regression model was used to estimate the impact of meteorological factors on the incidence of dengue fever.

**Results:** The peak period of dengue fever cases in Yunnan Province was from August to October, with clustering observed in border prefectures.

**Conclusion:** Dengue fever in Yunnan Province exhibited distinct spatiotemporal clustering and was significantly influenced by meteorological factors, particularly temperature and precipitation. These findings highlight the importance of multidimensional surveillance and early warning systems.

Yunnan Province, located at the junction of the tropical and subtropical zones, presents distinct local characteristics in the epidemiology of dengue fever. However, research on the relationship between dengue fever and environmental factors in Yunnan Province is limited. This study utilized dengue fever surveillance data from 2012–2024 and employed multiple analytical methods to explore the spatiotemporal patterns and their association with meteorological factors. These findings provide insight into dengue transmission dynamics and offer a scientific basis for targeted prevention and control strategies.

Dengue fever case data from Yunnan Province between 2012–2024 were collected from the China Disease Prevention and Control Information System. Cases were confirmed according to the Dengue Fever Diagnosis and Treatment Guidelines. Meteorological data, including temperature, relative humidity, precipitation, and sunshine duration, were obtained from the China Meteorological Data Platform for all prefecture-level cities in Yunnan Province. All meteorological variables were collected at a monthly temporal resolution; monthly averages were used for temperature and relative humidity, whereas monthly cumulative values were used for precipitation and sunshine duration. Dengue fever cases were aggregated by prefecture and month, and meteorological variables from the same prefecture and month were matched to the corresponding monthly dengue incidence for subsequent regression analyses. The potential lag effects of meteorological factors on dengue transmission were not explicitly modeled in this study and are discussed as a limitation.

The circular distribution method was used to analyze the temporal rhythmic characteristics of dengue fever outbreaks (*1*–*2*), and the Rayleigh test was used to assess temporal clustering (*3*). The intensity of clustering was measured by the length of

the M vector: M<0.2 indicates no seasonality; 0.2–0.4 indicates weak seasonality; 0.4–0.6 indicates moderate seasonality; 0.6–0.8 indicates strong seasonality; and 0.8–1.0 indicates pronounced seasonality.

Spatial and spatiotemporal clustering of dengue fever was identified using the SaTScan™ (version 10.1, Martin Kulldorff in collaboration with Information Management Services, Inc., Calverton, MD, USA; Harvard Medical School, Boston, MA, USA) based on a discrete Poisson probability model, where the maximum spatial scanning window was set to 50% of the population at risk, and the maximum temporal scanning window was set to 50% of the study period. The statistical significance of the identified clusters was evaluated using 999 Monte Carlo replications, and clusters with the maximum log-likelihood ratio (LLR) and $P$<0.05 were considered statistically significant.

In addition, a negative binomial regression model was constructed to assess the association between meteorological factors and dengue fever incidence. Meteorological variables were entered into the model in their original units and were not standardized. Therefore, the regression coefficients represent the change in dengue fever incidence associated with a one-unit increase in each variable (1 °C for temperature, 1 mm for precipitation, and 1% for relative humidity).

From 2012–2024, a total of 34,307 dengue fever cases were reported in Yunnan Province, including 31,575 cases among Chinese nationals and 2,732 cases among foreigners (Figure 1). Most cases were among farmers, homemakers, and unemployed individuals, accounting for 14,334 cases (41.78%, 14,334/34,307). This was followed by workers in the commercial services sector (5,337 cases, 15.56%) and students (2,666 cases, 7.77%). Additionally, imported cases totaled 5,719 (16.67%, 5,719/34,307), with 99.39% originating from Southeast Asia (5,684/5,719). Relatively few cases were imported from South Asia and Africa (14 and 21 cases, respectively) (Supplementary Table S1, available at https://weekly.chinacdc.cn).

Between 2012–2024, the overall incidence of dengue fever in Yunnan Province remained relatively stable, with noticeable seasonal fluctuations.

Circular distribution analysis identified the peak day of dengue fever incidence as October 10, with the peak period spanning from September 29 to October 20 and the overall epidemic period from September 20 to October 29. The Rayleigh test revealed statistically significant clustering (Z=23,691.32, $P$<0.001). The monthly values were presented in Supplementary Table S2 (available at https://weekly.chinacdc.cn) and Figure 1. The concentration index ranged from 0.72 to 0.95, indicating strong seasonality (Supplementary Table S3, available at https://weekly.chinacdc.cn).

The overall incidence of dengue fever showed a gradual eastward spread from western regions, with cases predominantly concentrated in border areas such as Xishuangbanna and Dehong Prefectures (Supplementary Table S4, available at https://weekly.chinacdc.cn).

A temporal scan was used to identify two clustering levels. The primary cluster was located in Xishuangbanna Prefecture, with a relative risk (RR) of 58.80 and a log-likelihood ratio (LLR) of 40,969.68 ($P$<0.001), occurring during the period from 2019–2024. Secondary clusters were detected in Baoshan City, Dehong Prefecture, and Lincang City, with an RR of 19.5 and an LLR of 10,711.39 ($P$<0.001) and were primarily clustered in 2023 (Table 1).

The incidence of dengue fever was moderately correlated with temperature, humidity, and precipitation. Residual analysis indicated an overdispersion between the number of cases and meteorological factors (Figures 2–3).

The negative binomial regression results demonstrated that temperature and precipitation were statistically significant predictors of dengue fever incidence (Table 2 and Supplementary Table S5, available at https://weekly.chinacdc.cn), whereas relative humidity was not. The model exhibited good stability, as indicated by the goodness-of-fit indicators

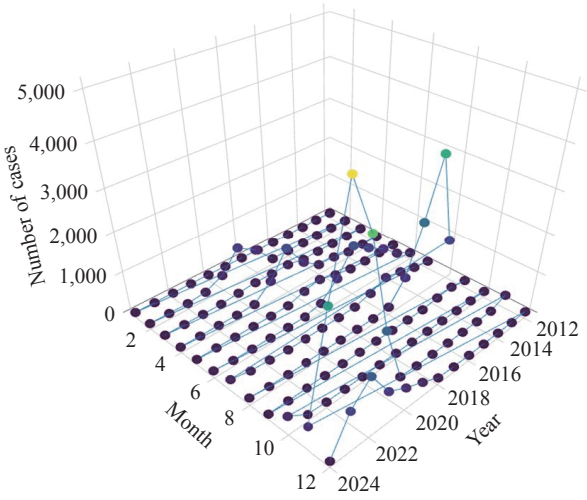


FIGURE 1. Temporal distribution of dengue fever cases in Yunnan Province, China, 2012–2024.

TABLE 1. Spatiotemporal scan statistical analysis of dengue fever in Yunnan Province, China, 2012–2024.

| Type of clustering | Location IDs included | Time frame | Number of cases | Expected cases | Population | Relative risk | Log likelihood ratio | *P* | Clusters Detected |
|---|---|---|---|---|---|---|---|---|---|
| Primary | 1 | 2019–2024 | 14,614 | 425.38 | 1,208,413 | 58.8 | 40,969.68 | <0.001 | Xishuangbanna Prefecture |
| Secondary | 3 | 2023 | 5,517 | 333.47 | 6,258,606 | 19.5 | 10,711.39 | <0.001 | Baoshan City, Dehong Prefecture, Lincang City |

Note: Clusters were identified using SaTScan based on a discrete Poisson model; location IDs refer to prefecture-level administrative units.

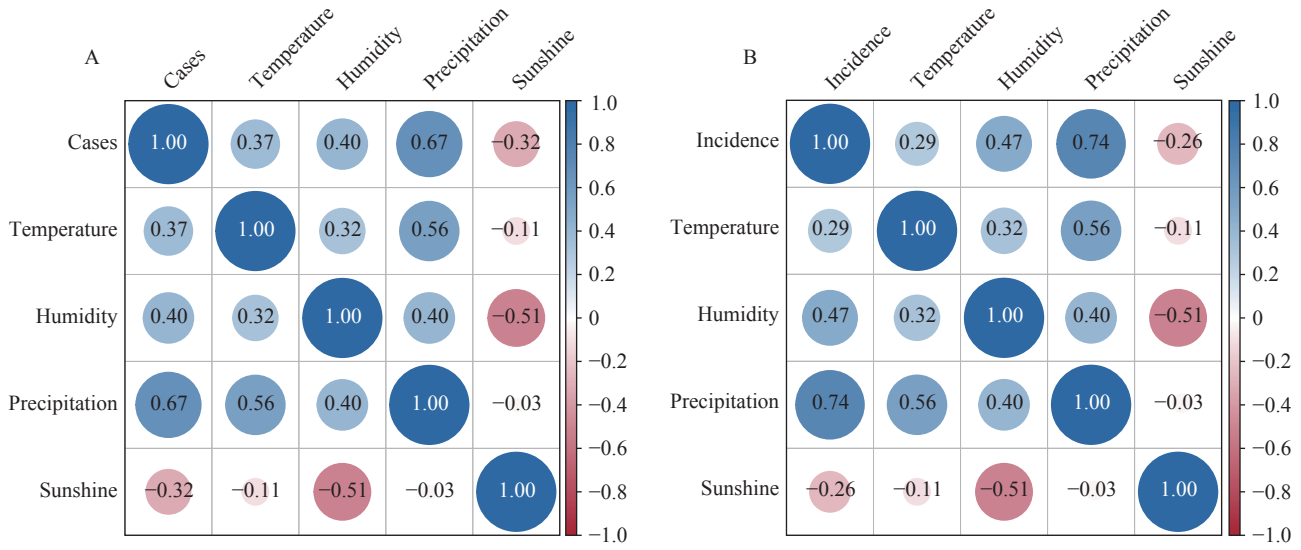


FIGURE 2. Correlation coefficients between (A) dengue fever cases, or (B) incidence rates, and meteorological factors.
Note: Each correlation coefficient in the figure is represented by a circle; the size and color intensity of the circle indicate strength. Larger circles denote stronger correlation, whereas deeper colors signify higher correlation values; smaller circles with lighter colors represent weaker correlations. Residual diagnostics revealed clear evidence of overdispersion and heteroscedasticity in the relationship between dengue cases and meteorological factors. Therefore, a negative binomial regression model was adopted in place of the Poisson model.

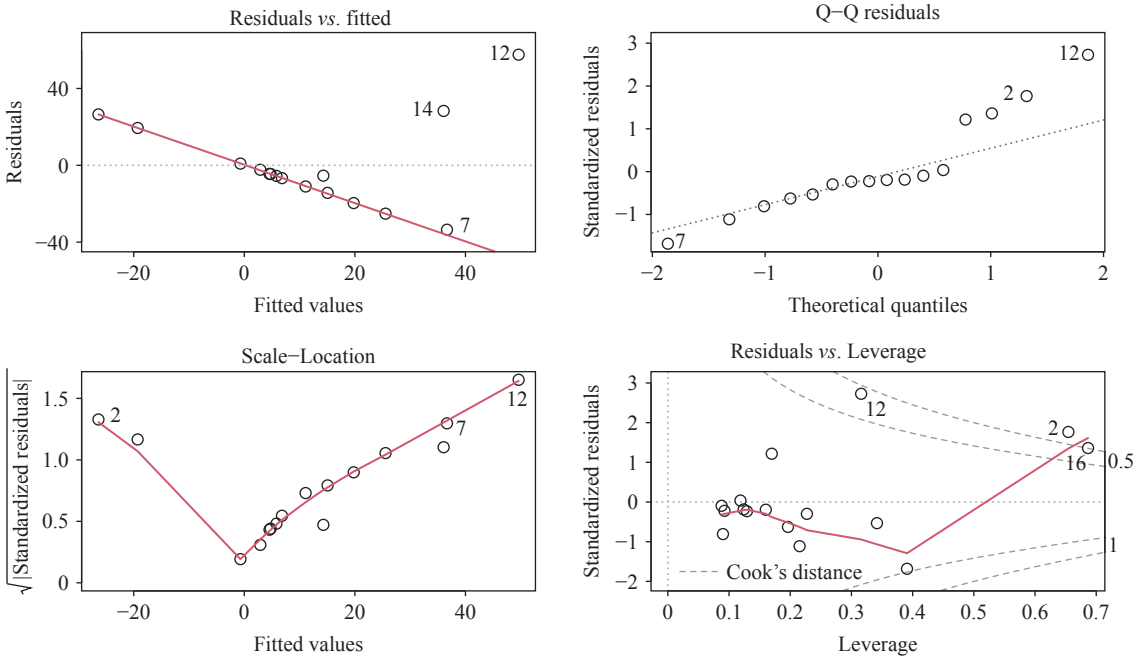


FIGURE 3. Residual distribution plot.

TABLE 2. Results of the negative binomial regression model.

| Variable | Estimate | Std. Error | z value | *Pr* (>\|z\|) |
|---|---|---|---|---|
| Intercept | −13.85 | 7.07 | −1.96 | 0.05 |
| Humidity | −0.00 | 0.09 | −0.04 | 0.97 |
| Temperature | 0.61 | 0.32 | 1.98 | 0.04 |
| Precipitation | 0.00 | 0.00 | 2.57 | 0.01 |

Note: Pr (>|z|) represents the two-sided P value associated with the z statistic in the negative binomial regression model.

shown in Table 2.

The predictive equation derived from the model was as follows:

$P_{\text{Incidence}} = \exp(-13.84836 - 0.003813 \times \text{Humidity} + 0.609941 \times \text{Temperature} + 0.003365 \times \text{Precipitation})$

## DISCUSSION

This study found a significant association between dengue fever incidence and meteorological factors such as temperature and precipitation (*4*). An increase in temperature was associated with higher dengue fever incidence, whereas higher precipitation showed a modest increase in cases (*5*). These findings are consistent with previous studies that have underscored the critical role of meteorological factors in dengue transmission.

From biological and ecological perspectives, higher ambient temperatures can accelerate the development of Aedes mosquitoes, shorten their gonotrophic cycle, increase biting frequency, and enhance viral replication, thereby reducing the extrinsic incubation period and increasing transmission efficiency. In contrast, precipitation influences dengue transmission by increasing the availability of larval breeding sites through the accumulation of standing water in domestic and peridomestic environments. However, this effect may be nonlinear, as excessive rainfall can also flush breeding sites and temporarily reduce mosquito density.

In the context of climate change, these factors may further influence epidemic patterns and control strategies (*6*). Cases were primarily concentrated between August and October, likely because of rising temperatures and increased rainfall, which promote higher mosquito breeding rates (*7*). Targeted control measures during the peak season should focus on vector surveillance and control, public health education, and timely case detection and reporting to reduce the risk of large-scale outbreaks and alleviate the overall disease burden (*8*).

Spatiotemporal scan analysis revealed notable clustering of dengue fever cases in the border areas of Yunnan Province, with Xishuangbanna Prefecture identified as a high-risk region. This is likely due to Xishuangbanna's tropical monsoon climate, characterized by high annual temperatures and abundant rainfall, combined with frequent cross-border population movement, which favors Aedes mosquito breeding and facilitates viral transmission (*9*). The geographic distribution of meteorological factors in both the primary and secondary clusters showed relatively higher temperature and precipitation levels, which is consistent with the observed associations between these climatic conditions and dengue fever incidence (*10*).

Additionally, Xishuangbanna and Dehong are border regions adjacent to Southeast Asian countries such as Myanmar and Laos, which are dengue-endemic areas with frequent cross-border human exchange. Imported cases from these regions may trigger secondary local transmission, thereby increasing the risk of regional outbreaks (*11*). Strengthening border surveillance and enhancing cross-border cooperation are crucial strategies for controlling dengue fever spread.

This study also found that most imported dengue cases in Yunnan originated from Southeast Asia. In 2023, the initial dengue cases reported in Pu'er and Xishuangbanna were imported from overseas, which subsequently led to local outbreaks in other regions of Yunnan. Therefore, it is essential to strengthen the management of imported dengue cases by enhancing immunological screening at entry and exit ports. Where applicable, vaccination campaigns should be promoted for travelers, migrant workers, and individuals who frequently move between endemic areas and Yunnan (*12*).

This study has several limitations. First, potential confounding factors such as population density, urbanization level, human mobility intensity, and the implementation of mosquito control measures were not included in the regression models, mainly because

of the lack of consistent, long-term prefecture-level data covering the entire study period from 2012–2024. Consequently, residual confounding could not be fully excluded. Second, this study did not incorporate entomological surveillance indicators (e.g., mosquito density or the Breteau index) or detailed information on local vector control interventions, which may have influenced dengue transmission dynamics. Future studies integrating multisource data, including sociodemographic indicators, vector surveillance data, and intervention intensity, are warranted to improve causal inference and model interpretability.

Integrating mosquito vector surveillance, socio-ecological data, human mobility information, and viral genetic sequencing to develop a multifactorial early warning system may enable more precise and effective dengue fever prevention and control in Yunnan Province.

This study revealed a distinct spatiotemporal clustering pattern of dengue fever in Yunnan Province, with its incidence closely associated with meteorological factors such as temperature and precipitation. Relative humidity was not identified as a statistically significant predictor in the negative binomial regression model and should therefore be interpreted with caution, as the model helps quantify the associations between key meteorological variables and dengue fever incidence. Based on these findings, strengthening epidemic surveillance in key border areas, enhancing dynamic monitoring and early warning of meteorological conditions, and integrating vector control into public health education are recommended. Promoting multisectoral collaboration will improve the precision and effectiveness of dengue prevention and control and provide a solid scientific foundation for targeted dengue management in Yunnan Province.

**Conflicts of interest**: No conflicts of interest.

**Ethical statements**: This study was part of routine public health surveillance and outbreak response activities. Ethical approval was waived.

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# SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Reported dengue fever cases in Yunnan Province, China, from 2012–2024.

| Year | Number of dengue cases by region of origin (*n*) | | | |
|---|---|---|---|---|
| | Southeast Asia | South Asia | Africa | Total |
| 2012 | 25 | 2 | 1 | 28 |
| 2013 | 145 | 0 | 3 | 148 |
| 2014 | 176 | 0 | 6 | 182 |
| 2015 | 610 | 2 | 0 | 612 |
| 2016 | 291 | 2 | 1 | 294 |
| 2017 | 1,465 | 3 | 1 | 1,469 |
| 2018 | 238 | 2 | 0 | 240 |
| 2019 | 1,370 | 2 | 7 | 1,379 |
| 2020 | 14 | 0 | 2 | 16 |
| 2021 | 2 | 1 | 0 | 3 |
| 2022 | 4 | 0 | 0 | 4 |
| 2023 | 1,183 | 0 | 0 | 1,183 |
| 2024 | 161 | 0 | 0 | 161 |
| Total | 5,684 | 14 | 21 | 5,719 |

SUPPLEMENTARY TABLE S2. Results of circular distribution analysis of dengue fever in Yunnan Province, China, 2012–2024.

| Month | Cases | Mean Angle (°) | Sine | Cosine | $f_i \cos \alpha_i$ | $f_i \cos \alpha_i$ |
|---|---|---|---|---|---|---|
| 1 | 42 | 15.29 | 0.26 | 0.96 | 11.07 | 40.51 |
| 2 | 23 | 44.38 | 0.70 | 0.71 | 16.09 | 16.44 |
| 3 | 14 | 73.48 | 0.96 | 0.28 | 13.42 | 3.98 |
| 4 | 20 | 103.56 | 0.97 | −0.23 | 19.44 | −4.69 |
| 5 | 54 | 133.64 | 0.72 | −0.69 | 39.08 | −37.27 |
| 6 | 218 | 163.73 | 0.28 | −0.96 | 61.09 | −209.27 |
| 7 | 2334 | 193.81 | −0.24 | −0.97 | −557.06 | −2,266.55 |
| 8 | 6632 | 224.38 | −0.70 | −0.71 | −4,638.81 | −4,739.71 |
| 9 | 11,507 | 254.47 | −0.96 | −0.27 | −11,086.66 | −3,081.74 |
| 10 | 9641 | 284.55 | −0.97 | 0.25 | −9,331.89 | 2,421.72 |
| 11 | 3544 | 314.63 | −0.71 | 0.70 | −2,522.11 | 2,489.76 |
| 12 | 278 | 344.71 | −0.26 | 0.96 | −73.30 | 268.16 |
| Total | 34,307 | | | | −28,049.63 | −5,098.65 |

Note: $f_i$ represents the number of dengue cases in month i, and $\alpha_i$ represents the corresponding mean angle.

SUPPLEMENTARY TABLE S3. Concentration index of dengue fever cases in Yunnan Province, China, 2012–2024.

| Year | $R_x$ | $R_y$ | M |
|---|---|---|---|
| 2012 | −0.47 | −0.05 | 0.49 |
| 2013 | −0.77 | −0.58 | 0.96 |
| 2014 | −0.73 | −0.38 | 0.82 |
| 2015 | −0.86 | −0.11 | 0.86 |
| 2016 | −0.63 | 0.35 | 0.72 |
| 2017 | −0.76 | −0.29 | 0.81 |
| 2018 | −0.74 | −0.24 | 0.78 |
| 2019 | −0.8 | −0.37 | 0.88 |
| 2020 | −0.77 | −0.14 | 0.78 |
| 2021 | −0.75 | 0.24 | 0.78 |
| 2022 | −0.94 | 0.17 | 0.95 |
| 2023 | −0.7 | −0.59 | 0.91 |
| 2024 | −0.8 | −0.18 | 0.82 |

Note: $R_x$ and $R_y$ represent the x- and y-components of the resultant vector in circular distribution analysis; M represents the concentration index.

SUPPLEMENTARY TABLE S4. Spatial distribution characteristics of dengue fever in Yunnan Province, China, 2012–2024.

| Region | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kunming | 4 | 20 | 16 | 16 | 16 | 29 | 36 | 230 | 4 | 2 | 0 | 119 | 28 |
| Qujing | 1 | 0 | 1 | 5 | 0 | 4 | 3 | 38 | 0 | 0 | 0 | 29 | 6 |
| Yuxi | 0 | 1 | 0 | 3 | 0 | 0 | 2 | 22 | 0 | 0 | 0 | 53 | 1 |
| Baoshan | 0 | 2 | 3 | 5 | 2 | 30 | 5 | 46 | 0 | 0 | 0 | 115 | 7 |
| Zhaotong | 0 | 0 | 2 | 2 | 0 | 4 | 10 | 50 | 2 | 0 | 0 | 15 | 1 |
| Lijiang | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 23 | 2 |
| Pu'er | 2 | 1 | 0 | 7 | 1 | 2 | 2 | 154 | 0 | 0 | 0 | 735 | 6 |
| Lincang | 0 | 0 | 1 | 211 | 0 | 375 | 54 | 722 | 2 | 0 | 18 | 1,158 | 49 |
| Chuxiong Prefecture | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 9 | 0 | 0 | 0 | 16 | 0 |
| Honghe Prefecture | 0 | 0 | 0 | 3 | 0 | 6 | 2 | 134 | 1 | 0 | 0 | 55 | 6 |
| Wenshan Prefecture | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 1 | 0 | 0 | 11 | 12 |
| Xishuangbanna Prefecture | 23 | 1,328 | 1 | 1,161 | 48 | 1,483 | 677 | 3,932 | 1 | 0 | 0 | 7,173 | 3,507 |
| Dali Prefecture | 0 | 1 | 2 | 2 | 0 | 1 | 5 | 25 | 0 | 0 | 0 | 55 | 1 |
| Dehong Prefecture | 2 | 245 | 304 | 723 | 456 | 1,601 | 128 | 1,483 | 253 | 11 | 546 | 4,244 | 84 |
| Nujiang Prefecture | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| Diqing Prefecture | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| Total | 32 | 1,599 | 331 | 2,139 | 524 | 3,539 | 927 | 6,853 | 264 | 13 | 564 | 13,812 | 3,710 |

SUPPLEMENTARY TABLE S5. Goodness-of-fit indicators for the negative binomial regression model of dengue fever and meteorological factors.

| Fit Indicators | Value | Description |
|---|---|---|
| Residual Deviance | 18.519 | Small residuals indicate a good model fit |
| AIC | 70.779 | The model shows low information loss, facilitating model selection and comparison |
| Theta | 0.715 | There is moderate overdispersion present, making the negative binomial regression model appropriate for use |
| VIF | 1.0–2.0 | The model shows strong stability and explanatory power |

Note: Theta refers to the dispersion parameter of the negative binomial model.
Abbreviation: AIC=Akaike Information Criterion; VIF=Variance Inflation Factor.

Preplanned Studies

# Unmanned Aerial Vehicle Surveillance of Rooftop Aedes Breeding Sites Before Dengue Season — Dongguan City, Guangdong Province, China, 2024–2025

Zhenyu Huang[1]; Siyu He[1]; Guandong Xu[1]; Wenteng Wang[1]; Dengfeng Li[1]; Yaocheng Zhong[1]; Weiguang Xie[1,#]; Lin Xu[2,3,4,#]

**Summary**

**What is already known about this topic?**

Aedes mosquitoes commonly breed in domestic water-holding containers; however, rooftop environments are difficult to access and are often absent from routine surveillance, especially in densely populated urban settings.

**What is added by this report?**

This study demonstrated that unmanned aerial vehicles (UAVs) can rapidly and reliably identify rooftop water-holding containers, reduce on-site inspection workload by 67.7%, and provide early indications of seasonal changes in Aedes larval activity. UAV-detected containers were closely aligned with ground-verified entomological indices.

**What are the implications for public health practice?**

Integrating UAV-assisted surveillance into routine vector control programs could strengthen early detection of Aedes breeding sites, improve operational efficiency, and support targeted dengue prevention efforts in urban communities.

## ABSTRACT

**Introduction:** Rooftop water-holding containers are breeding sites for *Aedes* mosquitoes but are often inaccessible for routine surveillance in densely populated urban settings. This study assessed the feasibility and operational value of unmanned aerial vehicle (UAV) surveillance prior to the dengue season in Dongguan, China.

**Methods:** Repeated cross-sectional surveys were conducted between April and July in 2024 and 2025 in randomly selected villages and communities. A total of 100 rooftops per site were inspected using UAVs. Among households with UAV-identified water-holding containers, 10% were randomly selected for onsite validation. Entomological indices were calculated. No sampling weights were applied.

**Results:** UAVs surveyed 4,700 rooftops and identified water-holding containers in 24.3%. The inspection time averaged 22.2 minutes per 100 rooftops, reducing field workload by 67.7% compared with traditional methods. Storage containers for plant watering accounted for 62.9% of detected containers. On-site validation revealed larvae in 18.2% of containers, with seasonal increases from April to July. No significant interannual differences were observed ($P$>0.05).

**Conclusion:** UAV-assisted surveillance enhanced operational efficiency and reliably identified rooftop breeding risks. Integrating UAV scanning into routine pre-season vector surveillance and implementing targeted removal of identified containers may strengthen early dengue prevention in urban communities.

Dengue and chikungunya, transmitted predominantly by Aedes mosquitoes, remain critical public health concerns in tropical and subtropical regions. In Guangdong Province, southern China, climatic conditions conducive to year-round vector proliferation increase the risk of local outbreaks of imported infections will seed local outbreaks (*1*). Effective vector surveillance is therefore critical, yet conventional door-to-door inspections have become increasingly difficult, as urban residents adopt stronger privacy norms and restrict access to residential rooftops, which are often overlooked but important sources of Aedes breeding.

To address these operational constraints, the Dongguan Center for Disease Control and Prevention has explored the use of unmanned aerial vehicles (UAVs) as a novel surveillance tool for detecting

rooftop water-holding containers. This study assessed the feasibility, efficiency, and epidemiological value of UAV-assisted surveillance as an approach complementary to conventional vector control strategies.

We conducted repeated cross-sectional surveys in randomly selected villages and urban communities in Dongguan, southern China, from April to July in 2024 and 2025, corresponding to the months preceding the dengue transmission season. The study sites were selected by simple random sampling from a list of all registered villages and urban communities in Dongguan to ensure broad geographic coverage. Within each selected site, 100 residential rooftops were systematically surveyed using unmanned aerial vehicles (UAVs) (DJI Mavic Air 2), irrespective of household characteristics. Each month, two UAVs scanned residential rooftops to identify potential mosquito breeding sites, defined as any visible water-holding container. From households identified by the UAV as having water-holding containers, 10% were randomly selected for onsite rooftop inspection by trained vector control personnel to validate UAV findings and assess larval positivity.

We quantified the rooftop breeding site burden using standard entomological indices. The roof index (RI) is defined as the proportion of rooftops with at least one water-holding container among all rooftops inspected by the UAV. For households visited onsite, the house index (HI) represents the proportion of inspected rooftops with at least one larva-positive container, the container index (CI) represents the proportion of containers found to contain larvae, and the breteau index (BI) represents the number of larva-positive containers per 100 houses inspected.

All data were entered into Excel 2024 (Microsoft, USA) and analyzed using SPSS (version 25.0; IBM Corp., Armonk, NY, USA). Differences among entomological indices were assessed using the Kruskal–Wallis test, and temporal differences across months were examined using t-tests. Statistical significance was defined as a two-sided $P<0.05$.

UAV surveillance has demonstrated markedly greater operational efficiency than traditional onsite inspections (Figure 1). As shown in Table 1, scanning 100 rooftops required a mean of 22.16 minutes (range 12.5–40.0 minutes), whereas conventional onsite inspection required an average of 305 minutes (range 250–650 minutes). This difference corresponds to a 67.7% reduction in field workload when UAV imagery is used to guide targeted inspections. Efficiency patterns were consistent across 2024 and 2025.

Across both survey years, the UAVs assessed 4,700 rooftops, of which 21.79% had rooftop planting (7.74% vegetable planting; 14.04% flowers) (Supplementary Table S1, available at https://weekly.chinacdc.cn/). UAV imagery identified 1,143 households with at least one water-holding container, corresponding to an overall roof index (RI) of 24.32 (19.70 in 2024; 28.75 in 2025). A total of 1,711 containers were documented (Supplementary Table S2, available at https://weekly.chinacdc.cn/), dominated by storage containers used for watering plants (62.95%), followed by idle containers (29.05%), structural water pooling (6.02%), and tires (1.99%). Monthly analysis (Figure 2A–D) showed that RI remained relatively stable from April to July, whereas larval indices (BI, HI, and CI) exhibited the expected seasonal increase, being consistently lowest in April and rising from May through July in both years.

Among the 111 households selected for on-site validation, inspectors identified 374 containers (mean

(A) (B)

FIGURE 1. UAV imagery of residential rooftops. (A) Overview showing rooftop vegetable and flower planting; (B) Close-up view highlighting water-holding containers (circled).
Abbreviation: UAV=unmanned aerial vehicle.

TABLE 1. Comparison of time required for UAV surveillance and on-site household inspection.

| Year | UAV surveillance time (min per 100 rooftops) | | | On-site inspection time (min per 100 households) | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| 2024 | 12.50 | 30.00 | 19.85 | 250 | 550 | 309 |
| 2025 | 14.00 | 40.00 | 24.38 | 250 | 650 | 303 |
| Total | 12.50 | 40.00 | 22.16 | 250 | 650 | 305 |

Abbreviation: UAV=unmanned aerial vehicle.

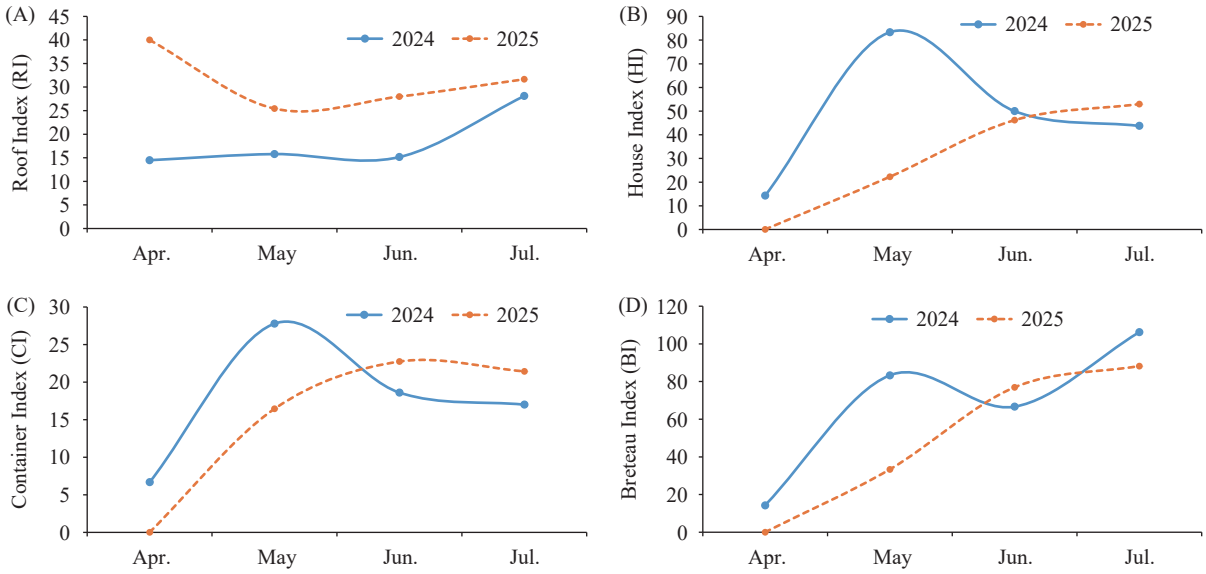


FIGURE 2. Monthly distribution of rooftop surveillance indices: (A) RI; (B) HI; (C) CI; and (D) BI, for 2024 and 2025.
Abbreviation: RI=roof index; HI=house index; CI=container index; BI=breteau index.

3.37 per household), including 68 larvae-positive containers (mean 0.61 per household). The on-site-derived indices were, HI 37.84, CI 18.18, and BI 61.26 (Supplementary Table S3, available athttps://weekly.chinacdc.cn/). Although the RI, HI, CI, and BI differed numerically between years, these differences were not statistically significant (H=6.67; $P$>0.05). This concordance supports the good agreement between UAV-detected container presence and ground-verified entomological indices.

## DISCUSSION

This study showed that UAV-assisted rooftop surveillance is a feasible, efficient, and epidemiologically informative approach for identifying Aedes breeding sites in densely populated urban settings. By rapidly scanning high-rise rooftops, which are traditionally inaccessible and frequently overlooked, UAVs detected a substantial burden of water-holding containers, particularly plant-watering storage vessels and idle miscellaneous containers. The consistently elevated Roof Index across months suggested that rooftop container availability remained stable throughout the pre–dengue season, whereas the seasonal rise in on-site larval indices indicated increasing larval productivity from April to July. These findings demonstrate that UAVs can identify breeding site precursors earlier than conventional entomological surveys, thereby offering a timelier indication of vector proliferation risk.

Consistent with previous reports from other settings, UAV-guided surveillance also markedly reduced the field workload (*2*–*3*). The 67.7% reduction in on-site inspection requirements represents a significant operational advantage in communities where access barriers and privacy concerns have increasingly hindered traditional door-to-door inspections. The alignment between UAV-detected containers and ground-verified entomological indices further supports UAV surveillance as a reliable method for characterizing rooftop-level Aedes infestation. In Guangdong, where dengue and chikungunya transmission is closely linked to the introduction of

imported cases (*4*–*5*), earlier and more comprehensive risk detection could strengthen preparedness and enable targeted vector control operations (*6*).

Within this operational and epidemiological context, the visually different monthly trajectories of the RI, HI, CI, and BI observed between 2024 and 2025 (Figure 2) likely reflect normal interannual variability rather than systematic differences in surveillance performance or transmission risk. Year-to-year variation in early-season temperature and rainfall may have shifted the timing and magnitude of larval amplification. Meanwhile, differences in rooftop planting practices and water-storage container availability, which are more prominent in 2025, may explain the higher early-season RI values and a lagged increase in larval indices. Variability in the timing or intensity of routine vector control activities may have further contributed to the divergence between the container-based and larval-based indices. Importantly, despite these visual differences, no statistically significant differences in entomological indices were detected between years, suggesting that the observed patterns represent the expected interannual fluctuations.

These findings highlight the epidemiological relevance of rooftop environments (*7*). Despite being invisible in ground-based surveys, rooftops harbored diverse water-holding containers and supported measurable larval activity (*7*). As urbanization continues and rooftop usage increases, routine surveillance of rooftop environments may become increasingly important for dengue prevention (*8*–*9*).

The findings have at least three limitations. First, the UAV imagery did not permit direct confirmation of larval presence, and the selection of households for on-site validation may have introduced sampling errors. Nonetheless, the close correspondence between RI and on-site larval indices suggests that UAV detection of container presence is a reasonable proxy for entomological risk. Second, although on-site rooftop inspections were conducted to validate the UAV-detected breeding sites, this study did not link the entomological findings to dengue or chikungunya cases at the household level. The surveys were conducted as part of routine pre-season vector surveillance and were not designed to capture individual-level clinical outcomes. In addition, the limited number of households undergoing on-site inspections and low incidence of reported cases during the study period precluded meaningful correlation analyses. Furthermore, surveillance was conducted during the pre-dengue season (April–July) and did not extend into the peak transmission period (August–October). This study was designed to assess the value of UAV-assisted surveillance for the early detection of rooftop breeding site risks before routine emergency vector control activities are intensified. Consequently, these findings may not reflect the entomological conditions during peak transmission months when container availability and larval indices are strongly influenced by reactive interventions. Fifth, UAV visibility was influenced by rooftop structure, vegetation, and physical obstruction, which may have led to small or concealed containers being missed. Sixth, differences in the specific villages selected between the survey years may have contributed to the interannual variability in the entomological indices, although the same sampling framework was applied in both years. Finally, the study was conducted in a single city over two years, which may limit its generalizability to regions with different urban forms, household practices, or regulatory environments.

These analyses suggest that UAV-assisted rooftop surveillance can provide a rapid and scalable strategy for identifying water-holding containers that could serve as potential breeding sites for Aedes [2, 3]. Integrating UAV-based scanning into routine vector surveillance might strengthen early-season detection of entomological risk, improve operational efficiency by guiding targeted field deployment, and enhance the precision of community-level interventions. In settings where residential access is restricted or where high-rise housing is predominant, UAV surveillance could complement established entomological monitoring systems and reinforce preparedness for dengue and chikungunya transmission. More broadly, UAV-supported surveillance may help advance earlier, more targeted, and more resource-efficient vector control programs (*10*).

In conclusion, UAV-assisted rooftop surveillance is an efficient and reliable method for identifying potential Aedes breeding sites in densely populated urban areas. These findings suggest that the incorporation of UAVs into routine vector surveillance can enhance early risk detection and support targeted dengue control efforts.

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# SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. UAV-based rooftop survey results in Dongguan communities.

| Year | Rooftops surveyed (*n*) | Rooftops with vegetable planting | | Rooftops with flower planting | | Households with water-holding containers | RI |
|---|---|---|---|---|---|---|---|
| | | *n* | % | *n* | % | *n* | % |
| 2024 | 2,300 | 132 | 5.74 | 295 | 12.83 | 453 | 19.70 |
| 2025 | 2,400 | 232 | 9.67 | 365 | 15.21 | 690 | 28.75 |
| Total | 4,700 | 364 | 7.74 | 660 | 14.04 | 1,143 | 24.32 |

Abbreviation: UAV=unmanned aerial vehicle; RI=roof index.

SUPPLEMENTARY TABLE S2. Types of rooftop water-holding containers identified by UAV in Dongguan communities.

| Year | Total containers (*n*) | Storage containers | | Idle containers | | Structural water pooling | | Tires | |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | % | *n* | % | *n* | % | *n* | % |
| 2024 | 739 | 390 | 52.77 | 286 | 38.70 | 55 | 7.44 | 8 | 1.08 |
| 2025 | 972 | 687 | 70.68 | 211 | 21.71 | 48 | 4.94 | 26 | 2.67 |
| Total | 1,711 | 1,077 | 62.95 | 497 | 29.05 | 103 | 6.02 | 34 | 1.99 |

Abbreviation: UAV=unmanned aerial vehicle.

SUPPLEMENTARY TABLE S3. On-site rooftop inspection results in Dongguan communities.

| Year | Rooftops surveyed (*n*) | Households with water-holding containers (*n*) | Households inspected on-site (*n*) | Containers identified (*n*) | Larvae-positive containers (*n*) | Positive households (*n*) | Mean containers per household |
|---|---|---|---|---|---|---|---|
| 2024 | 2,300 | 453 | 41 | 176 | 31 | 19 | 4.29 |
| 2025 | 2,400 | 690 | 70 | 198 | 37 | 23 | 2.83 |
| Total | 4,700 | 1,143 | 111 | 374 | 68 | 42 | 3.37 |

| Year | Rooftops surveyed (n) | RI (%) | HI (%) | CI (%) | BI | H-value | *P** |
|---|---|---|---|---|---|---|---|
| 2024 | 2,300 | 19.70 | 46.34 | 17.61 | 75.61 | 3.00 | >0.05 |
| 2025 | 2,400 | 28.75 | 32.86 | 18.69 | 52.80 | 3.66 | >0.05 |
| Total | 4,700 | 24.32 | 37.84 | 18.18 | 61.26 | 6.67 | >0.05 |

Abbreviation: RI=roof index; HI=house index; CI=container index; BI=breteau index.
* *P*>0.05 indicates no statistically significant difference across survey years.

Methods and Applications

# Establishment and Validation of a Competency-Based Evaluation Indicator System for On-Site Disinfection Service Providers — Shanghai Municipality, China, 2023

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## ABSTRACT

**Introduction**: Effective on-site disinfection of epidemic foci is a critical role in preventing the transmission of infectious diseases. On-site disinfection service providers (ODSP) are a key force in the emergency response systems. This study assessed ODSP capabilities and developed a standardized evaluation indicator system to aid managers in provider selection and supervision.

**Methods**: A capability evaluation indicator system for ODSP was developed and applied to 88 providers in Shanghai in 2024. Receiver operating characteristic (ROC) curves were plotted by correlating the capability evaluation scores of ODSP with historical disinfection efficacy to determine the optimal threshold. Kappa consistency analysis evaluated the agreement between the new scoring system and historical performance outcomes.

**Results**: The scoring rates for management systems, material reserves, personnel capability, and quality control were 93.75%, 90.45%, 75.08%, and 51.97%, respectively. ODSP with a history of failed on-site disinfection efficacy evaluations scored significantly lower in personnel capability and quality control than those with consistently passing evaluations ($P$<0.01). The area under the ROC curve (AUC) for the assessment indicators was 0.954 [95% confidence interval (*CI*): 0.898, 1], with an optimal capability score threshold of 70 points. The Kappa coefficient was 0.822.

**Conclusion**: ODSP should further strengthen its quality control measures. There is a significant gap in capability scores among these providers; therfore a hierarchical certification system should be established. The evaluation indicator system for these providers can serve as a tool to assist in dynamic supervision.

## INTRODUCTION

With the increasing complexity of natural and social environments, infectious disease pathogens often undergo adaptive evolution, leading to enhanced survival ability and infectivity. Severe Acute Respiratory Syndrome (SARS) coronavirus, Middle East Respiratory Syndrome (MERS) coronavirus, and endemic Human Coronaviruses (HCoV) have been shown to persist on inanimate surfaces such as metal, glass or plastic for up to 9 days (*1*). Comprehensive reviews have indicated that contact with contaminated environments is the primary transmission pathway for certain respiratory viruses, including influenza (*2*). Therefore, effective disinfection is a key measure to interrupt the transmission routes of infectious diseases.

The efficacy of disinfection is significantly influenced by multiple factors, including temperature, disinfectant concentration, and exposure duration (*3*). Consequently, improper disinfection practices often result in disinfection failure may inadvertently facilitate disease transmission. Empirical evidence has underscored these challenges. A study evaluating disinfection efficacy in epidemic foci found that approximately 10% of object surfaces failed to meet the disinfection standards, and the factors influencing, this failure included the type of disinfectant, the operation by disinfection personnel, on-site operation related to the use of disinfection equipment, and other issues (*4*). There have been reports of cases of operational errors during disinfection, resulting in occupational exposure among personnel (*5*). Current evaluation of disinfection efficacy mainly relies on the inactivation rate of natural flora or indicator microorganisms post-disinfection as primary evaluation indicator (*6*).

However, the evaluation results of disinfection efficacy can only be determined after disinfection is completed, making pre-intervention impossible.

Therefore, it is important to establish a pre-disinfection indicator system to evaluate the capability of on-site disinfection service providers (ODSP) before intervention. This system aims to minimize disinfection failures and prevent subsequent disease transmission.

## METHODS

This study investigated disinfection service providers registered in Shanghai until June 2024. Eighty-eight providers participated in the study. Data collection included questionnaire surveys and on-site investigations conducted by providers. The workflow for data collection, indicators establishment, and validation is shown in Supplementary Figure S1(available at https://weekly.chinacdc.cn/).

Competency evaluation indicators for ODSP were formulated in accordance with legal standards such as the *Measures for the Administration of Disinfection*, *General Principles for Disinfection of Epidemic Foci* (GB 19193-2015), and *Standards for On-site Disinfection Evaluation* (WS/T797-2022). The framework of the indicator system and the indicator weights were determined based on two rounds of expert interviews. Fifteen experts were recruited for this study, and only those with professional titles of associate senior or above and at least five years of experience in fields such as disinfection, epidemic prevention, emergency response, health policy, and health supervision theory and practice were eligible. The experts assigned the importance of indicators to the framework and used the analytic hierarchy process (AHP) to determine the weight of each indicator. The consistency ratio (CR) values of the judgment matrices for all indicators obtained from the consistency test ranged from 0.015 to 0.069, indicating good consistency (CR<0.1), and the weights of each indicator were thereby determined.

The competency evaluation indicators for ODSP were primarily based on the regulatory guidelines, such as on-site disinfection effect evaluation standards and expert interviews. This study systematically constructed a multidimensional capability evaluation indicator system with 4 primary and 13 secondary indicators (Table 1).

The above-mentioned indicators were used to evaluate and analyze 88 ODSP. Among all providers, 52 had carried out infectious disease disinfection and conducted on-site disinfection effect evaluation, whereas the other 36 mainly carried out preventive disinfection work. To further explore the factors influencing, infectious disease disinfection failure in ODSP, the providers were grouped according to whether they had a history of disinfection failure, and the differences among different indicators were compared. To evaluate the agreement between the newly established competency thresholds and historical efficacy outcomes, taking the results of historical effect evaluation as the gold standard, the sensitivity and specificity corresponding to different capability scores were calculated, and the receiver operating characteristic (ROC) curve was plotted. The area under the curve (AUC) was calculated to quantify the evaluation accuracy, where AUC=1 indicated perfect discrimination and AUC=0.5 suggested random classification. Subsequently, Kappa consistency analysis was performed. Data entry and cleaning were performed using Excel (Microsoft Office Home and Student Edition 2021, Microsoft Corporation, Redmond, USA). Statistical analyses were conducted using R Statistical Software (version 4.3.3, R Development Core Team, Vienna, Austria). The significance level was set at $\alpha$ =0.05.

## RESULTS

Analysis of the capability scoring results of the 88 ODSP showed that they achieved relatively high scoring rates in terms of management systems (93.75%) and material reserves (90.45%). However, their scoring rates in personnel capability (75.08%) and implementation of quality control (51.97%) were relatively low (Supplementary Table S1, available at https://weekly.chinacdc.cn/). The total scores of providers with experience in infectious disease disinfection were significantly higher than those of providers without experience. A further analysis of the 52 providers with experience showed that the scores of the providers that failed the on-site disinfection effect evaluation were significantly lower in terms of personnel capability and quality control than those with all passing results ($P$<0.01) (Table 2).

The AUC of the ROC curve is 0.954 [95% (*CI*): 0.898–1] (Figure 1). The sensitivity and specificity corresponding to different scores are shown in Supplementary Table S2 (available at https://weekly.chinacdc.cn/). Based on the Youden index for each score, when the total score was less than 70, the on-site disinfection service institution did not have sufficient capability to carry out disinfection for infectious disease. A consistency test was conducted using 70 points as the evaluation criterion. These results were in

TABLE 1. Evaluation indicators for on-site disinfection service providers.

| Evaluation indicators | Evaluation items | Indicator weight |
|---|---|---|
| A1 Management system | | |
| B1 System for verifying and inspecting certificates of disinfection products and purchase records | Checking the filing records of disinfection products and their inbound/outbound records | 6 |
| B2 Management system and maintenance for disinfection products and PPE | Checking the usage records of disinfection products, maintenance records of disinfection equipment, and product validity periods | 6 |
| B3 Quality control system for disinfection services | Checking the disinfection quality management mechanism and historical rectification records | 12 |
| A2 Material reserve | | |
| B4 Reserve of disinfection agents and PPE | Checking the scope of application of equipped disinfectants, types of PPE, quantity of materials, and types of disinfection equipment provided | 12 |
| B5 Warehouse conditions | Checking the moisture-proof and fire-prevention equipment in warehouses, safety management systems, and whether disinfection materials are stored in a standardized manner by zoning | 10 |
| A3 Personnel capability | | |
| B6 Number of disinfection personnel | Verifying whether the number of existing disinfection operators and disinfection quality control personnel meet the requirements of disinfection service work | 6 |
| B7 Personnel training status | Checking the certificates held by disinfection personnel and their participation in training programs | 6 |
| B8 Assessment of disinfection-related knowledge for disinfection personnel | Assessing disinfection personnel's knowledge of laws and regulations, infectious disease-related knowledge, basic disinfection principles, and selection of personal protection equipment | 6 |
| B9 Assessment of operational skills for disinfection personnel | Evaluating disinfection personnel's practical skills, including on-site disinfection operations, donning and doffing of PPE, maintenance of disinfection equipment, and preparation of disinfectants | 6 |
| A4 Implementation of quality control | | |
| B10 Disinfection implementation plan | Reviewing the disinfection plan, including: disinfection areas, targets, concentration of disinfectants, disinfection processes, operating procedures, protection requirements, quality control methods, personnel division of labor, and post-responsibilities | 14 |
| B11 Evaluation data of disinfection process | Checking quality control records, including key parameters such as disinfectant usage volume, disinfectant concentration, donning/doffing of personal protection equipment, and disinfection duration | 8 |
| B12 Evaluation data of disinfection effect | Reviewing the evaluation results of disinfection efficacy test reports | 5 |
| B13 Disinfection operation report | Verifying the completeness of disinfection work records | 3 |

Abbreviation: PPE=personalprotection equipment

good consistency with the evaluation results of the on-site disinfection, with a kappa value of 0.822 (Table 3).

## DISCUSSION

Currently, the *Measures for the Administration of Disinfection* does not contain relevant requirements for ODSP. In the practices of various provinces and cities, management is primarily based on local regulations and industry association standards. The existing inspection frameworks cover aspects such as basic information, facilities and equipment, personnel qualifications, and management systems. This study found that ODSP scored relatively high in the above-mentioned aspects, but some still had deficiencies in terms of personnel capability and disinfection quality control. Moreover, issues related to disinfection quality control may cause on-site disinfection failures. Studies have shown that effective on-site disinfection can be achieved through training and re-education of disinfection staff, adding more cleaning staff or supervisors, and/or the use of implementation or quality checklists (*7*).

When on-site disinfection at infectious disease loci fails to meet efficacy standards, re-disinfection becomes necessary, leading to substantial economic and temporal costs. This study found that there are significant differences in the capabilities of different ODSP. Although many of these providers, have long been engaged in disinfection, they lack the capability to conduct on-site disinfection for infectious diseases. During a pandemic, the demand for on-site disinfection increases significantly. Disinfection service providers are unsure whether their own capabilities are sufficient to carry out infectious disease disinfection, and managers lack the tools to identify qualified

TABLE 2. Capability scoring of on-site disinfection service providers with disinfecting infectious diseases experience (*n*=52).

| Indicators | With experience in failing the on-site disinfection effect evaluation (*n*=12) | | NO experience in failing the on-site disinfection effect evaluation (*n*=40) | | *t'* | *P* |
|---|---|---|---|---|---|---|
| | Average score | Average scoring rate(%) | Average score | Average scoring rate(%) | | |
| A1 Management system | 23.75±0.87 | 98.96 | 23.55±1.99 | 98.13 | 0.34 | 0.74 |
| B1 System for verifying and inspecting certificates of disinfection products and purchase records | 6.00±0 | 100.00 | 6.00±0 | 100.00 | – | – |
| B2 Management system and maintenance for disinfection products and personal protective equipment | 6.00±0 | 100.00 | 6.00±0 | 100.00 | – | – |
| B3 Quality control system for disinfection services | 11.75±0.87 | 97.92 | 11.55±1.99 | 96.25 | 0.34 | 0.74 |
| A2 Material reserve | 19.75±3.65 | 89.77 | 20.88±2.51 | 94.91 | −1.22 | 0.23 |
| B4 Reserve of disinfection agents and personal protective equipment | 9.75±3.65 | 81.25 | 10.88±2.51 | 90.67 | −1.22 | 0.23 |
| B5 Warehouse conditions | 10.00±0 | 100.00 | 10.00±0 | 100.00 | – | – |
| A3 Personnel capability | 15.8±5.24 | 65.83 | 21.42±2.88 | 89.25 | −4.82 | 0.00 |
| B6 Number of disinfection personnel | 3.00±2.56 | 50.00 | 5.25±1.77 | 87.50 | −3.47 | 0.00 |
| B7 Personnel training status | 5.50±1.73 | 91.67 | 6.00±0 | 100.00 | −1.87 | 0.07 |
| B8 Assessment of disinfection-related knowledge for disinfection personnel | 3.68±1.29 | 61.33 | 4.80±0.71 | 80.00 | −3.94 | 0.00 |
| B9 Assessment of operational skills for disinfection personnel | 3.63±1.23 | 60.50 | 5.37±0.58 | 89.50 | −6.86 | 0.00 |
| A4 Implementation of quality control | 8.14±8.75 | 27.13 | 26.49±5.93 | 88.30 | −8.37 | 0.00 |
| B10 Disinfection implementation plan | 3.99±5.08 | 28.50 | 12.37±3.24 | 88.36 | −6.83 | 0.00 |
| B11 Evaluation data of disinfection process | 1.60±3.13 | 20.00 | 7.04±2.31 | 88.00 | −6.57 | 0.00 |
| B12 Evaluation data of disinfection effect | 1.30±1.93 | 26.00 | 4.34±1.16 | 86.80 | −6.77 | 0.00 |
| B13 Disinfection operation report | 1.25±1.41 | 41.67 | 2.74±0.75 | 91.33 | −4.83 | 0.00 |
| Total score | 67.44±11.65 | 67.44 | 92.33±8.23 | 92.33 | −8.32 | 0.00 |

Note: "−" the *t* and *P* were not calculable because the standard deviation of both groups was 0, indicating no within-group variation and identical data values between the two groups.

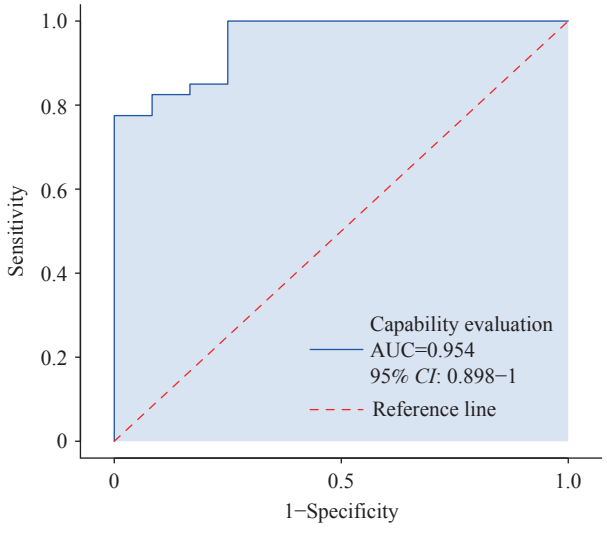


FIGURE 1. ROC curve for predicting results of on-site disinfection effect evaluation by the assessment indicators of on-site disinfection service providers.
Abbreviation: ROC=receiver operating characteristic; AUC=area under curve.

providers. Therefore, for infectious disease disinfection, especially during major epidemics, it is necessary to establish a mechanism for hierarchical certification and dynamic supervision to ensure the competence of providers engaged in disinfection, thereby guaranteeing the effectiveness of on-site disinfection.

The evaluation indicator system developed in this study addresses the challenges associated with major infectious disease outbreaks. During emergencies, the system enables managers to quickly and accurately identify the capability level of ODSP, thereby facilitating timely initial selection and task allocation. For example, institutions can be classified into different grades based on their evaluation scores, such as those qualified to conduct preventive disinfection, on-site disinfection for common infectious diseases, and disinfection for Class A and B infectious diseases. Conversely, in non-emergency situations, it can promote the capability improvement of ODSP, allowing them to identify their own deficiencies and

TABLE 3. Consistency check test for the results of capacity evaluation of on-site disinfection service providers and on-site disinfection evaluation results (*n*=52).

| On-site disinfection effect evaluation results | On-site disinfection service providers capacity evaluation results | | Total | Kappa |
|---|---|---|---|---|
| | Unqualified | Qualified | | |
| Unqualified | 9 | 3 | 12 | 0.822 |
| Qualified | 0 | 40 | 40 | |
| Total | 9 | 43 | 52 | |

Note: Qualified score criteria means on-site disinfection service providers capacity evaluation results ≥ 70.

carry out targeted upgrades in both infrastructure and personnel training.

This study had several limitations. First, this was a retrospective study. ODSP capabilities were investigated after the evaluation of the providers' capabilities, which mainly relied on historical records. This may have affected the reliability of the research results owing to inaccurate data. Future prospective studies are required to optimize this evaluation system. Second, as this study was conducted in Shanghai, the results may not be generalizable to other regions or populations. External validation through multicenter or national studies is essential for future research.

**Conflicts of interest**: No conflicts of interest.

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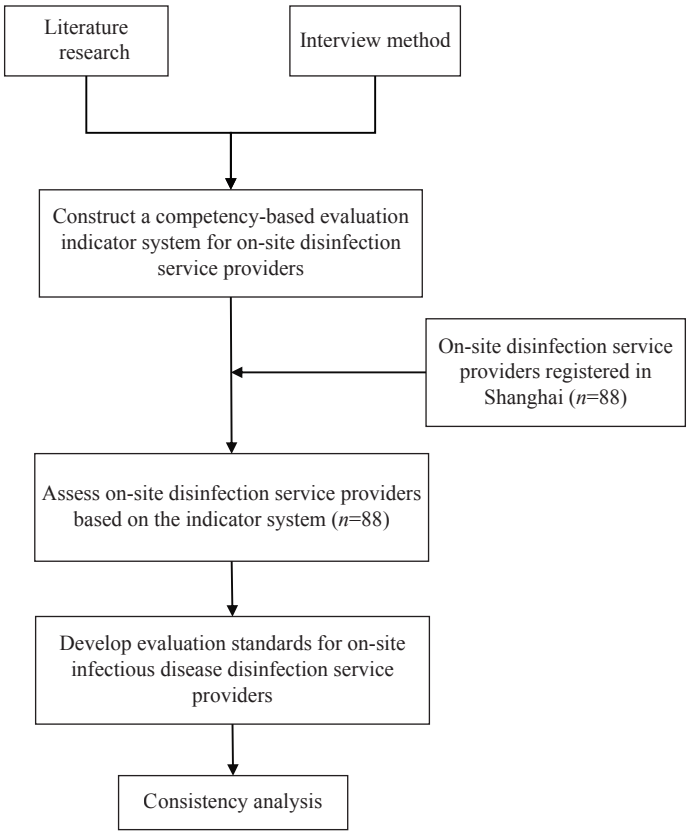
# SUPPLEMENTARY MATERIAL




SUPPLEMENTARY FIGURE S1. Technical roadmap for constructing and validating a competency-based evaluation indicator system for on-site disinfection service providers.

SUPPLEMENTARY TABLE S1. Capability scoring of on-site disinfection service providers (*n*=88).

| Indicators | Total (*n*=88) | | No disinfecting infectious diseases experience (*n*=36) | | With disinfecting infectious diseases experience (*n*=52) | |
|---|---|---|---|---|---|---|
| | Average Score | Average Scoring Rate (%) | Average Score | Average Scoring Rate (%) | Average Score | Average Scoring Rate (%) |
| A1 Management system | 22.50±3.86 | 93.75 | 20.92±5.29 | 87.17 | 23.60±1.79 | 98.33 |
| B1 System for verifying and inspecting certificates of disinfection products and purchase records | 5.80±0.76 | 96.67 | 5.50±1.13 | 91.67 | 6.00±0 | 100.00 |
| B2 Management system and maintenance for disinfection products and personal protective equipment | 5.76±0.99 | 96.00 | 5.42±1.49 | 90.33 | 6.00±0 | 100.00 |
| B3 Quality control system for disinfection services | 10.94±2.81 | 91.17 | 10.00±3.66 | 83.33 | 11.60±1.79 | 96.67 |
| A2 Material reserves | 19.90±3.37 | 90.45 | 18.86±3.85 | 85.73 | 20.62±2.82 | 93.73 |
| B4 Reserve of disinfection agents and personal protective equipment | 10.13±3.03 | 84.42 | 9.42±3.22 | 78.50 | 10.62±2.82 | 88.50 |
| B5 Warehouse conditions | 9.77±1.29 | 97.70 | 9.44±1.99 | 94.40 | 10.00±0 | 100.00 |
| A3 Personnel capability | 18.02±5.63 | 75.08 | 14.98±6.03 | 62.42 | 20.12±4.24 | 83.83 |
| B6 Number of disinfection personnel | 3.99±2.60 | 66.50 | 2.92±2.82 | 48.67 | 4.73±2.17 | 78.83 |
| B7 Personnel training status | 5.59±1.52 | 93.17 | 5.17±2.1 | 86.17 | 5.88±0.83 | 98.00 |
| B8 Assessment of disinfection-related knowledge for disinfection personnel | 4.11±1.30 | 68.50 | 3.49±1.46 | 58.17 | 4.54±0.98 | 75.67 |
| B9 Assessment of operational skills for disinfection personnel | 4.33±1.40 | 72.17 | 3.40±1.33 | 56.67 | 4.97±1.06 | 82.83 |
| A4 Implementation of quality control | 15.59±12.18 | 51.97 | 5.98±7.44 | 19.93 | 22.25±10.22 | 74.17 |
| B10 Disinfection implementation plan | 7.64±5.99 | 54.57 | 3.60±4.74 | 25.71 | 10.43±5.13 | 74.50 |
| B11 Evaluation data of disinfection process | 4.00±3.81 | 50.00 | 1.42±2.78 | 17.75 | 5.78±3.40 | 72.25 |
| B12 Evaluation data of disinfection effect | 2.15±2.30 | 43.00 | 0±0 | 0 | 3.64±1.87 | 72.80 |
| B13 Disinfection operation reports | 1.81±1.37 | 60.33 | 0.96±1.25 | 32.00 | 2.39±1.12 | 79.67 |
| Total score | 76.01±19.25 | 76.01 | 60.73±15.29 | 60.73 | 86.59±13.89 | 86.59 |

SUPPLEMENTARY TABLE S2. Youden indexes of each qualified score criterion for capacity evaluation of on-site disinfection service providers (*n*=52).

| Evaluation Indexes | Qualified score criteria | | | | | |
|---|---|---|---|---|---|---|
| | 60 | 65 | 70 | 80 | 85 | 90 |
| Sensitivity | 1.00 | 1.00 | 1.00 | 0.85 | 0.80 | 0.65 |
| Specificity | 0.33 | 0.50 | 0.75 | 0.75 | 0.92 | 1.00 |
| Youden index | 0.33 | 0.50 | 0.75 | 0.60 | 0.72 | 0.65 |

Healthy China

# Comprehensive Analysis of Mpox Prevention and Control Policies in China: a Three-Dimensional Framework for Policy Tool Evaluation

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## ABSTRACT

In 2023, the emergence of the mpox virus (MPXV) subclade Ⅰb in the Democratic Republic of the Congo triggered a new wave of mpox outbreaks that subsequently spread to other African countries and beyond. Policies provide the framework for mpox epidemic prevention and control in China, requiring systematic analysis of policy evolution and content characteristics. This study employs policy tool theory to construct a three-dimensional analytical framework encompassing policy instruments (X), policy objects (Y), and policy measures (Z), and utilizes content analysis methodology to evaluate China's national regulatory mpox prevention and control policies. The results demonstrate that China's national-level mpox prevention and control policies are in substantial agreement with the World Health Organization (WHO) core recommendations, with distinct emphases on the application of policy instruments, policy objects and policy measures, the prioritization of comprehensive epidemic response capabilities, and aligning with both domestic and international mpox epidemic conditions and national prevention strategies. Moving forward, China should further enhance its mpox prevention and control system resilience by optimizing vaccine strategies and expanding social mobilization initiatives.

Since the 2022 mpox outbreak in non-endemic countries, mpox has become a major global public health threat, prompting WHO to declare it a "Public Health Emergency of International Concern" twice (*1–2*). From 2 June 2023 to 30 June 2025, China reported 2,769 confirmed cases, 99% of which were attributed to MPXV clade Ⅱb, with 20 imported cases involving clades Ia and Ib (*3–4*). The persistent risk of clade I importation and complex MPXV mutation patterns poses sustained challenges for effective control.

Policy analysis identifies priorities and gaps in disease control. Policy tools bridge policy objectives and outcomes (*5*). A three-dimensional framework was developed to comprehensively analyze China's national mpox policies, considering the policy evolution stages and policy content. A comparative analysis was conducted between these policies and the WHO's five interdependent core components (5Cs) for the prevention and control of mpox. This analysis elucidates the characteristics of China's mpox control policies, informing and guiding future improvements in policies addressing mpox and other emerging infectious diseases.

## METHODS

Mpox-related policies were retrieved from official websites of the National Health Commission (NHC) and National Disease Control and Prevention Administration (NDCPA), and the Peking University Law Database. The publication date range was set from 1 January 1950 to 1 July 2025. The search strategy utilized the terms: FT=("猴痘" OR "猴痘病毒" OR "Mpox" OR "MPXV" OR "猴痘疫情" OR "monkeypox"). Overall, 175 relevant policies were initially identified. Currently effective policies excluded 3 invalid documents (replaced by updated versions were selected, with only the latest version retained for each policy type), 4 with low policy authority (e.g., draft for public comment), 31 unrelated to mpox control, and 117 not issued at the national-level. Ultimately, 20 policies were included for analysis.

Prior to conducting the three-dimensional analysis across policy instruments (X), policy objects (Y), and policy measures (Z), content analysis was performed. NVivo 15 (Lumivero, Denver, Colorado, US, version 15.0.0, August 2024) was used to code prevention and control measures. Two researchers independently

coded each sentence in the policies based on semantic meaning, following the principle of non-divisibility. When discrepancies occurred between the two coders, they were resolved through expert adjudication. This process yielded 811 policy items.

## X: Policy Instruments

China's infectious disease prevention and control operates under government leadership. Based on government intervention levels, Howlett and Ramesh's classification (*6*) and infectious disease-specific subdivisions (*7*) were adapted to define mandatory, mixed, and voluntary tools (Supplementary Table S1, available at https://weekly.chinacdc.cn/).

## Y: Policy Objects

Policy objects represent implementation subjects of policy measures. The Y dimension was categorized into territorial governments, departments, institutions, and individuals, subdivided into 19 types based on responsibilities (Figure 1).

## Z: Policy Measures

The infectious disease prevention and control framework, established under the *Law of the People's Republic of China on the Prevention and Control of Infectious Diseases* defines primary measures encompassing disease prevention, epidemic response, medical treatment, and support measures, which are further subdivided into 19 secondary measures.

## Overview of the Mpox Epidemic and Policy Evolution Phases

Four policy phases were identified: International Surveillance and Domestic Preparedness, First Imported Clade IIb Case to Local Transmission, Shift

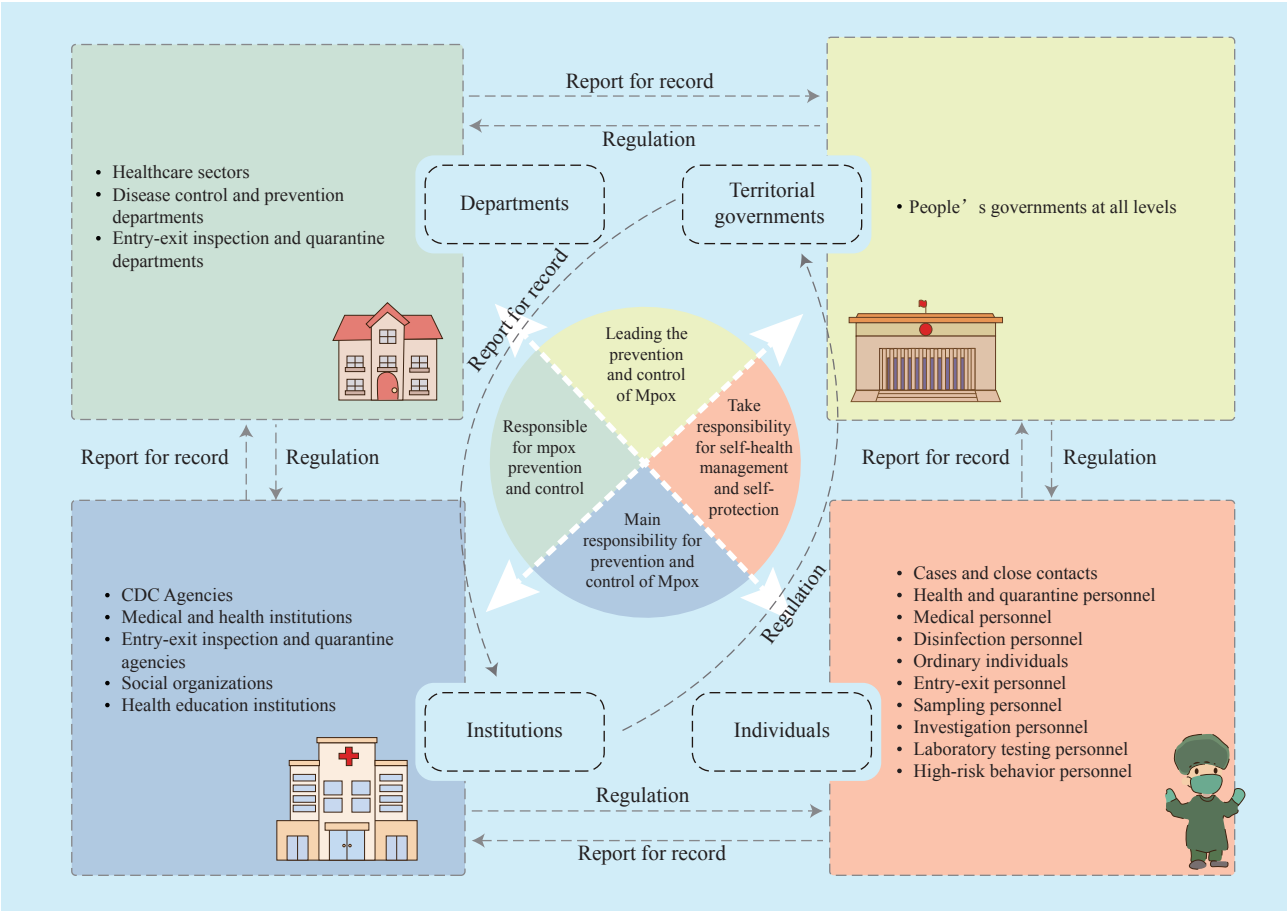


FIGURE 1. Relationship diagram of policy objects in China's mpox control.
Note: This figure illustrates how territorial governments, departments, institutions, and individuals constitute the four-party responsibility framework stipulated in China's *Law of the People's Republic of China on the Prevention and Control of Infectious Diseases*. These four categories correspond to the implementation subjects for mpox prevention and control measures, establishing clear divisions of labor and well-defined responsibilities.

to Category B Management to the First Imported Clade Ib Case, and Preparedness for Clade Ib Outbreak, with policies released and global mpox reported cases for each phase (Figure 2).

By May 2022, nearly 12 non-endemic countries outside Africa had reported multiple MPXV infections (*8*). During this initial phase, China reported no cases and implemented an "external prevention of importation" strategy. China closely monitored the international epidemic while strengthening surveillance capacity, issuing 10 policies. Technical guidelines, including the "*Notice on Issuing the Technical Guidelines for Mpox Prevention and Control (2022 Edition)*" were developed. Entry quarantine was strengthened through the *"Contingency Plan for Mpox Prevention and Control at Ports of Entry-Exit*" and the "*Announcement on the List of Quarantinable Animal Diseases for Entry into the People's Republic of China*." The General Administration of Customs of China requested incoming personnel to conduct health declarations and undergo quarantine screening.

In 2022, Chongqing Municipality identified China's

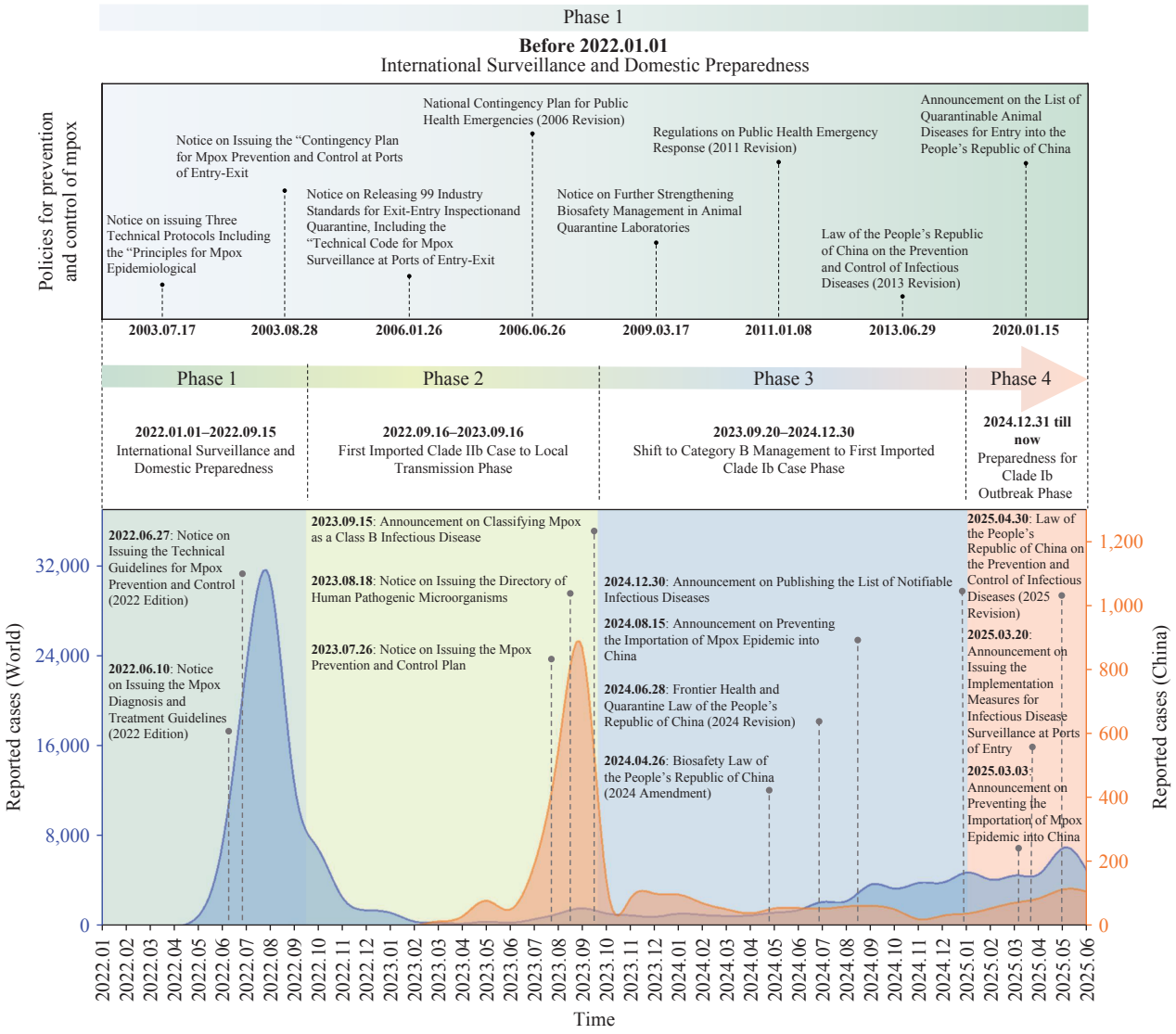


FIGURE 2. Phased analysis of China's mpox prevention and control policies and domestic and international reported mpox cases.

Note: Domestic and international mpox case data are sourced from the WHO website. Since WHO has not published global mpox case surveillance data prior to 1 January 2022, this figure only displays the available case trend information.

This figure presents the timeline of China's mpox prevention and control policies alongside domestic and international reported mpox cases. The upper section displays the policy dimension, showing the evolution of China's mpox prevention and control policies by phase.

first imported clade IIb mpox case (*9*) . Following the first domestic infection in 2023, cases were documented across 28 provinces (autonomous regions and municipalities) nationwide, primarily among men who have sex with men (MSM) (*4*). China adjusted its strategy to "precision prevention and control + rapid response," improving the technical support system and issuing two policies. First, mpox was included in the "*directory of human pathogenic microorganisms causing human infections*" (*10*) . Second, medical institutions screened patients in key departments such as dermatology; disease control institutions conducted wastewater surveillance and implemented peer education; customs authorities conducted health quarantine on individuals with mpox-like symptoms. The "medical institutions — disease control institutions — customs" joint mechanism effectively controlled the epidemic spread.

China classified mpox as a legally Class B disease in September 2023. The reported cases declined thereafter, averaging 55 cases per week and decreasing to 13 cases per week in 2024. While most global outbreaks were attributed to clade IIb, clade Ib presented new challenges. Evidence indicates that clade Ib demonstrates higher fatality rates compared to clade IIb, and its genetic diversity is also 54% higher than that of clade I (*11*). China faces both significant importation risks and domestic transmission control pressure. Four policies were issued requiring enhanced mpox prevention and control activities, including surveillance, early warning systems, and outbreak response protocols. The revised 2024 *Biosecurity Law* and *Frontier Health and Quarantine Law* provide a legal framework for mpox prevention and control.

To address emerging and common infectious diseases, including mpox, China strengthened its infectious disease prevention infrastructure, issuing four policies. In 2025, China revised the *Law of the People's Republic of China on the Prevention and Control of Infectious Diseases*, providing enhanced legal foundations for mpox prevention and control. Through accumulated expertise in surveillance, laboratory testing, and intervention measures developed across previous phases, China established robust rapid response capabilities for infectious disease outbreak management, effectively containing potential domestic epidemic transmission.

## Analysis Results of Policies Content

In policy instruments, mandatory instruments served as the primary tools. Command and authority tools predominated (41.14%, *n*=230). Among mixed tools, capacity-building tools were primary (46.57%, *n*=95), with information and persuasion tools secondary (32.35%, *n*=66). Voluntary tools consisted primarily of family and individual instruments (93.75%, *n*=45), while social organization tools were rarely employed (6.25%, *n*=3) (Table 1).

Among the four policy objects, institutions comprised the largest proportion (46.73%, *n*=379), followed by individuals (21.82%, *n*=177), departments (21.21%, *n*=172), and territorial governments

TABLE 1. Distribution of policy measures across different policy regulatory powers.

| Dimension | Disease prevention | Epidemic response | Medical treatment | Support measures | Total |
|---|---|---|---|---|---|
| Mandatory | 95 (17.28) | 298 (53.26) | 31 (5.47) | 135 (23.99) | 559 (68.93) |
| Command and authority | 58 (25.22) | 147 (63.91) | 1 (0.43) | 24 (10.43) | 230 (41.14) |
| Institutions and regulations | 32 (18.29) | 47 (26.86) | 1 (0.57) | 95 (54.29) | 175 (31.31) |
| Direct provision | 5 (3.57) | 104 (74.82) | 29 (20.86) | 1 (0.72) | 139 (24.87) |
| Supervision and punishment | – | – | – | 15 (100.00) | 15 (2.68) |
| Mixed | 42 (20.67) | 43 (21.63) | 3 (1.44) | 116 (56.25) | 204 (25.15) |
| Capacity building | 5 (5.26) | 7 (7.37) | 1 (1.05) | 82 (86.32) | 95 (46.57) |
| Information and persuasion | 37 (56.06) | 25 (37.88) | 2 (3.03) | 2 (3.03) | 66 (32.35) |
| Support and subsidies | – | 11 (25.58) | – | 32 (74.42) | 43 (21.08) |
| Voluntary | 18 (37.50) | 30 (62.50) | – | – | 48 (5.92) |
| Families and individuals | 15 (33.33) | 30 (66.67) | – | – | 45 (93.75) |
| Social organizations | 3 (100.00) | – | – | – | 3 (6.25) |
| Total | 155 (19.11) | 371 (45.75) | 34 (4.19) | 251 (30.95) | 811 (100.00) |

Note: Data in the table represent the number of codes (percentage).
"–" indicates a percentage of 0.00% (code count of 0).

(10.23%, *n*=83). At the institutional level, the disease control institutions represented the highest proportion (42.48%, *n*=161), while social organizations accounted for an extremely low proportion (0.79%, *n*=3). At the departmental level, health departments (50.58%, *n*=87) and disease control departments (25.00%, *n*=43) predominated. At the territorial level, people's governments at all levels served as the main implementation objects. At the individual level, cases and close contacts accounted for a relatively high proportion (16.95%, *n*=30) (Supplementary Table S2, available at https://weekly.chinacdc.cn/).

Within policy measures, epidemic response dominated (45.75%, *n*=371), followed by support measures (30.95%, *n*=251), disease prevention (19.11%, *n*=155), and medical treatment (4.19%, *n*=34). Case detection and reporting were the primary focus of epidemic response measures (33.42%, *n*=124). Resource reserves and laboratory management received limited attention in support measures, each accounting for approximately 10.00%. Vaccination represented the smallest component within disease prevention (9.68%, *n*=15). Case transfers showed the lowest proportion among medical treatment measures (17.65%, *n*=6) (Supplementary Table S3, available at https://weekly.chinacdc.cn/).

Cross-dimensional analysis of X and Z revealed mandatory tools were predominantly employed in epidemic response (53.31%, *n*=298) and support measures (24.15%, *n*=135). Mixed tools comprised the largest proportion in support measures (56.86%, *n*=116). Voluntary tools had limited application, used exclusively for disease prevention (37.50%, *n*=18) and epidemic response (62.50%, *n*=30) (Supplementary Table S3).

Cross-analysis of dimensions X and Y revealed that mandatory instruments were most frequently applied to institutions (52.24%, *n*=292) and departments (22.00%, *n*=123). Mixed instruments were used across institutions, departments, individuals, and territorial governments. Voluntary instruments were predominantly directed at individuals (89.58%, *n*=43) (Supplementary Table S4, available at https://weekly.chinacdc.cn/).

Cross-analysis of dimensions Y and Z showed that the number of coded items at the institution level significantly exceeded those for other objects across all policy measures. Territorial governments primarily undertook support measures (73.49%, *n*=61). Departments and institutions were mainly responsible for epidemic response and support measures, whereas individuals were primarily involved in epidemic response (68.36%, *n*=121) (Supplementary Table S3).

Three-dimensional cross-analysis of X, Y, and Z indicated that institutions and individuals were the most frequently targeted policy objects across different policy instruments and measures. Across all policy measure categories, mandatory instruments were used more frequently than mixed or voluntary instruments (Supplementary Table S5, available at https://weekly.chinacdc.cn/).

After constructing a two-dimensional analytical framework of Y versus X/Z, it was found that the results closely resembled those from the unidimensional analysis of Y. This pattern aligns with the clearly defined "four-party responsibility" framework in China's mpox and infectious disease control system.

### Comparison of China's Mpox Prevention and Control Policies with WHO Core Recommendations

WHO's 5Cs (*12*) provide a framework for adjusting and optimizing strategies worldwide. Comparative analysis reveals that China's mpox prevention strategies demonstrate high consistency with WHO recommendations with minor variations. The primary difference is that antiviral drugs and vaccines for mpox have not been deployed nationwide (Table 2).

## DISCUSSION

### Policy Deployment Demonstrates Efficiency and Epidemic-responsive Adaptation

Policies were efficiently deployed and adapted in response to the epidemic. China's policies prioritize surveillance and early warning, providing a legal foundation for their implementation. The successful containment of the initial clade Ib outbreak in 2024 (*3*), suggests the effectiveness of China's surveillance and response systems.

Policies were formulated rapidly using scientific evidence. Following the first domestic case, the NHC developed diagnostic and technical guidelines within 8 and 25 days, respectively. A national control plan was jointly issued within one month. Regarding case and close contact management, China's patient management measures demonstrate both precision and

TABLE 2. Comparison of WHO core mpox recommendations with China's mpox prevention and control policies.

| WHO 5Cs | WHO recommendations | China's mpox prevention and control policies | Connections and differences |
|---|---|---|---|
| C1: Emergency coordination | Strengthen emergency operations and foster coordination between Member States and stakeholders for responsive public health and adaptive health services | Joint Prevention and Control Mechanism | **Connections**: WHO recommends establishing and maintaining multi-sectoral, multi-partner coordination mechanisms at global, regional, national, and subnational levels. China's joint prevention and control mechanism represents a successful practice aligned with WHO recommendations and adapted to national conditions. Both approaches emphasize the critical importance of multi-sectoral collaboration.<br>**Differences**: WHO recommends establishing coordination mechanisms at global, national, and regional levels. China's coordinated prevention efforts and information sharing involve multiple departments, including disease control centers, medical institutions, customs, public security, and industry and information technology agencies, which are designed to detect and respond to mpox outbreaks promptly and enhance rapid identification capabilities for the mpox virus. |
| C2: Collaborative surveillance | (a) Surveillance, epidemiological investigation, and contact tracing<br>(b) Laboratories and diagnostics | (a) MSM population surveillance, symptom surveillance, wastewater surveillance, infectious disease network direct reporting system, risk assessment, epidemiological investigations, and close contact screening, etc.<br>(b) Mpox virus nucleic acid testing, gene sequencing, and related analyses. | **Connections**: China's surveillance system and epidemic response measures closely align with WHO recommendations. Both China and the WHO have established multidimensional surveillance networks and emphasize the critical importance of laboratory testing and virus typing in epidemic surveillance.<br>**Differences**: WHO recommends that countries and regions strengthen surveillance and reporting mechanisms while providing essential support to diagnostic laboratories with rapid, safe, and accurate testing capabilities. This approach enables early identification of mpox cases, provision of optimal clinical care, patient isolation, contact management, protection of high-risk populations, and implementation of effective control and prevention measures. It focuses on framework measures for capacity building in countries.<br>China's prevention and control efforts have become increasingly proactive and standardized. It has implemented a comprehensive multi-channel surveillance strategy through disease control centers, customs authorities, and medical institutions. This includes enhanced port quarantine measures, active surveillance of MSM populations, symptom monitoring and sewage surveillance in medical facilities, and integration of mpox into the national infectious disease network direct reporting system. Simultaneously, epidemiological investigations and nucleic acid testing are conducted for mpox cases. Gene sequencing was performed when necessary, and close contacts were traced as thoroughly as possible. |
| C3: Community protection | (a) RCCE and infodemic management<br>(b) Points of entry, international travel and transport, mass gatherings, and population movements<br>(c) Vaccination | (a) Collaborate with social organizations to conduct peer education, outreach services, testing and counseling services for individuals with mpox-like symptoms, and health education at MSM key venues and social media platforms. Timely disclosing the current status of the mpox epidemic and carry out risk communication while strictly protecting the personal information of cases.<br>(b) Port quarantine and the establishment of information sharing mechanisms among disease control centers, medical institutions, customs, and other relevant agencies.<br>(c) There is currently no commercially available vaccine for mpox. | **Connections**: Both the WHO and China recognize the importance of community interventions and health education, particularly educational and behavioral interventions targeting high-risk populations. China's community interventions—such as peer education, outreach services, port quarantine, and entry quarantine measures—align with WHO recommendations.<br>**Differences** : WHO recommends implementing health education through established community networks and providing targeted health education and risk information for high-risk population communities and those potentially exposed to infected animals to reduce viral transmission. It is also recommended that relevant national departments develop guidelines on border measures and international travel and establish a communication mechanism between ports and health authorities, which holds significant macro-level guiding value.<br>China places special emphasis on collaboration between disease control centers and social organizations, focusing on raising awareness among MSM populations through comprehensive online and offline training programs. A mature information sharing mechanism has been established among the CDC, customs authorities, and hospitals. Imported mpox patients can access medical care using a convenient hospital card, which better aligns with national conditions.<br>The most notable difference between China and WHO lies in their vaccination strategies. WHO recommends vaccinating high-risk groups during outbreaks. Currently, China's mpox prevention and control strategy primarily relies on non-vaccine measures. However, a live attenuated mpox vaccine has been approved for clinical trials, and several genetically engineered vaccines are currently under development (*13*). As mpox vaccines progress in China, this difference is expected to diminish gradually. |

Continued

| WHO 5Cs | WHO recommendations | China's mpox prevention and control policies | Connections and differences |
|---|---|---|---|
| C4: Safe and scalable care | (a) Case management and clinical operations<br>(b) Infection prevention and control | (a) For mpox cases and close contacts, hospitalization or home isolation is implemented. No marketed mpox antiviral therapeutic drugs are available, symptomatic supportive treatment and complication treatment.<br>(b) Establish hospital infection control systems, ensure personal protection for medical staff at risk of occupational exposure, provide training for medical personnel, conduct pre-examination and triage in hospitals, and perform environmental disinfection, among other measures. | **Connections**: WHO recommends case screening and isolation based on local epidemiological circumstances. WHO recommends providing optimal supportive care for mpox patients while minimizing complications wherever possible. Regarding treatment protocols, WHO advocates for the use of approved antiviral medications while continuing relevant clinical studies to evaluate drug efficacy and safety in mpox treatment. Healthcare institutions should implement infection prevention and control measures. Regarding case management-including symptomatic support, complication management, and prevention and control of nosocomial infections, China aligns with WHO recommendations and is capable of enforcing standardized isolation protocols for confirmed cases.<br>**Differences**: China aligns with WHO recommendations concerning symptomatic support and complication management strategies. The primary difference lies in therapeutic drug availability, as WHO recommends utilizing approved antiviral agents. Although several drugs are progressing through research and development and clinical trial phases, China currently lacks specific mpox medications on the market. Simultaneously, China is exploring the integration of traditional Chinese medicine into mpox patient treatment protocols. |
| C5: Countermeasures and research | Sharing information globally | Sharing mpox case information with WHO and timely sharing of research findings and practical experience | **Connections**: Both WHO and China emphasize the timely sharing of case information.<br>**Differences**: WHO advocates for timely and transparent global information sharing, including epidemiological data, research findings, and best practices, to enable countries to rapidly adjust their response strategies and reduce disease transmission. It emphasizes voluntary and transparent information exchange.<br>China rigorously fulfills its International Health Regulations obligations regarding mpox outbreak information sharing in accordance with WHO requirements, while actively conducting mpox-related scientific research and establishing robust epidemic reporting mechanisms to ensure timely information reporting and sharing capabilities. |

Abbreviation: WHO=World Health Organization; RCCE=Risk Communication and Community Engagement; MSM=men who have sex with men.

humanitarian care in the prevention and control strategies. Suspected and confirmed cases require transfer to medical institutions and can only undergo home isolation treatment after lesion sites have crusted over. For confirmed cases with mild symptoms who meet home isolation treatment conditions, after joint assessment by medical institutions and disease control agencies, they may directly undergo home isolation treatment with follow-up by medical personnel.

## Prevention and Control Policies Highlight Multi-departmental Coordination

China's mpox prevention and control policies are formulated by the NHC and NDCPA, implemented by customs authorities at all levels, CDCs, and medical institutions, with social organizations participating in prevention and control efforts and the entry-exit inspection and quarantine departments involved in response activities. This represents a particularly prominent feature of China's mpox prevention and control approach.

In China, the prevention and control programs of mpox are carried out at all levels of CDCs and medical institutions. The management system and organizational structure of the unit can ensure the timely implementation of the prevention and control requirements. Although territorial policy objects are limited, this does not indicate the absence of territorial function. Its role has been reflected through cross-departmental coordination and resource allocation. Based on the existing prevention and control system of mpox, multi-sectoral collaboration and information sharing can be promoted. Individual and family policy tools can be added to clarify the responsibilities and obligations of individuals and families in mpox prevention and control.

## The Policies Demonstrate Normative Force, Though Prevention and Control Measures Require Better Balance

China's prevention and control policies exhibit normative force. This framework ensures both the speed and quality of prevention and control implementation, which enabled an effective response to the mpox clade Ib outbreaks since 2023 (*3*–*4*,*9*). However, mpox control efforts should develop intervention models grounded in trust and voluntary participation. Incorporating a varied combination of voluntary policy tools can enhance the engagement of all stakeholders, while improving both the efficiency and effectiveness of policy implementation.

China's mpox prevention and control measures focus predominantly on epidemic response, more attention and effort are needed for disease prevention. WHO recommends vaccination for high-risk groups, a strategy adopted in several African countries. China is currently advancing vaccine research and development initiatives. Moving forward, China should accelerate vaccine development or import a vaccine (*14*) to improve preparedness.

Non-endemic regions such as the Americas have experienced outbreaks closely associated with high-risk sexual behaviors, primarily transmitted through male-to-male contact among MSM populations. Targeted education and self-protection awareness for high-risk groups are essential. Social organizations play a crucial role in mpox prevention and control (*14*). These organizations can access MSM activity venues to promote testing initiatives and facilitate the detection of additional positive cases (*15*). Future strategies should incorporate voluntary policy tools to enhance social organization participation in mpox prevention and control (*16*). Future policy should integrate specific goals and scenarios for mpox prevention and control, clearly define the conditions under which mandatory measures are warranted, ensure the effective application of mandatory tools, and continue to enhance the use of mixed tools to improve the efficiency of mpox prevention and control.

China's mpox policies align closely with epidemic trends, emphasize multi-sector coordination, including CDCs, medical institutions, and customs authorities, and are consistent with WHO recommendations, enabling early detection, reporting, isolation, and treatment. These policies exhibit robust normative force and prioritize comprehensive epidemic response capabilities. Future efforts should optimize vaccine strategies and social mobilization to enhance public health resilience.

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# SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. Types and definitions of policy normative force.

| Policy normative force secondary classification | Definition and explanation | Keywords |
|---|---|---|
| Mandatory | | |
| Command and authority | Strict implementation of all public health measures, with strict adherence to existing standards and regulations when conducting all prevention and control activities | Require, shall not, stipulate, in accordance with, standards, assessment, evaluation, prohibit, strengthen, strict compliance, restrict, must |
| Direct provision | Direct reporting and provision of surveillance data, epidemiological investigation information, testing results, epidemic information notification, public release of epidemic information, and direct provision of medical services | Suspicious symptom reporting, case reporting, network direct reporting, travel history reporting, information disclosure, information notification, diagnosis and treatment |
| Institutions and regulations | Guiding orderly epidemic prevention and control and routine prevention work through improving internal regulations of departments or units, improving work processes and mechanisms related to health emergency and prevention measures, and clarifying the responsible personnel and their division of responsibilities for prevention and control work | Organizational leadership, institutional mechanisms, work regulations, division of responsibilities, planning schemes, emergency systems, prevention and control systems, emergency plans |
| Supervision and punishment | Supervising and managing the implementation of epidemic prevention and control, emergency drills and other related work by subordinate units, while strictly punishing illegal behaviors | Supervision and management, supervision and inspection, risk screening, problem rectification, disciplinary violations and illegal acts |
| Mixed | | |
| Information and persuasion | Conducting publicity and education regarding epidemic prevention measures and related policies, providing health risk alerts and scientific prevention and control recommendations, and strengthening public opinion guidance for all sectors of society | Science popularization and education, awareness-raising, guidance, reminders, alerts, recommendations, instruction, promotion |
| Capacity building | Conducting medical personnel training to strengthen medical treatment capabilities, improving protection capabilities and epidemic response capabilities of personnel in different positions through training and drills, enhancing information support capabilities through seeking information technology support and other means, improving the applied level of infectious disease prevention and treatment through scientific research, and timely summarizing prevention and treatment experiences | Emergency teams, expert teams, technical support, data analysis, personnel allocation, skills training, pre-job training, drills, information systems, scientific research |
| Support and subsidies | Effectively ensuring personnel allocation for epidemic prevention work through implementing funding subsidies, labor protection, and commendation and rewards for epidemic prevention personnel, ensuring smooth progress of prevention and control work through guaranteeing work funding, and ensuring supply of epidemic prevention materials through allocation and stockpiling of related materials | Protective equipment, protective materials, disinfection and temperature measurement facilities, subsidies and compensation, allowances and subsidies, commendation and rewards, instruments and equipment, work funding |
| Voluntary | | |
| Social organizations | Encouraging social organizations to participate in epidemic prevention and control | Understanding and support |
| Families and individuals | Emphasizing conscious compliance of families and individuals with the relevant epidemic prevention requirements | Conscious compliance, self-health monitoring, personal hygiene |

Note: Mandatory tools refer to government-mandated measures that use command and authority, direct provision, institutions and regulations, supervision, and punishment to impose strong constraints on target entities. Voluntary instruments are led by nongovernmental organizations and involve collaborative efforts among the families and individuals, as well as social organizations to achieve policy goals, with the government playing an encouraging and guiding role. Mixed tools involve government interventions or prompts that support the implementation of measures and decision-making, primarily through information and persuasion, capacity building, support and subsidies.

SUPPLEMENTARY TABLE S2. Distribution of policy objects.

| Policy target | Specific target | Number (*n*) | Percentage (%) |
|---|---|---|---|
| Institutions | CDC Agencies | 161 | 42.48 |
| | Medical and health institutions | 116 | 30.61 |
| | Entry-Exit inspection and quarantine agencies | 98 | 25.86 |
| | Social organizations | 3 | 0.79 |
| | Health education institutions | 1 | 0.26 |
| | Subtotal | 379 | 46.73 |
| Departments | Healthcare sectors | 87 | 50.58 |
| | Disease control and prevention departments | 43 | 25.00 |
| | Entry-exit inspection and quarantine departments | 42 | 24.42 |
| | Subtotal | 172 | 21.21 |
| Individuals | Health and quarantine personnel | 34 | 19.21 |
| | Cases and close contacts | 30 | 16.95 |
| | Medical personnel | 26 | 14.69 |
| | Disinfection personnel | 21 | 11.86 |
| | Ordinary individuals | 19 | 10.73 |
| | Entry-exit personnel | 16 | 9.04 |
| | Sampling personnel | 12 | 6.78 |
| | Investigation personnel | 12 | 6.78 |
| | Laboratory testing personnel | 6 | 3.39 |
| | High-risk behavior personnel | 1 | 0.56 |
| | Subtotal | 177 | 21.82 |
| Territorial governments | People's governments at all levels | 83 | 100.00 |
| | Subtotal | 83 | 10.23 |
| Total | | 811 | 100.00 |

SUPPLEMENTARY TABLE S3. Two-dimensional cross-tabulation of policy instruments and policy objects, policy measures and policy objects for mpox prevention and control.

| Dimension | Mandatory | Mixed | Voluntary | Total | Territorial governments | Depart-ments | Institu-tions | Indivi-duals | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Disease prevention** | 95 (16.99) | 42 (20.59) | 18 (37.50) | 155 (19.11) | 6 (7.23) | 31 (18.02) | 74 (19.53) | 44 (24.86) | 155 (19.11) |
| Port quarantine | 49 (90.74) | 3 (5.56) | 2 (3.70) | 56 (36.13) | 2 (3.70) | 20 (37.04) | 29 (53.70) | 3 (5.56) | 54 (34.84) |
| Surveillance and early warning | 29 (80.56) | 6 (16.67) | 1 (2.78) | 36 (23.23) | 1 (2.78) | 10 (27.78) | 24 (66.67) | 1 (2.78) | 36 (23.23) |
| Health education | 3 (7.89) | 31 (81.58) | 4 (10.53) | 38 (24.52) | 3 (7.89) | 13 (34.21) | 20 (52.63) | 2 (5.26) | 38 (24.52) |
| Vaccination | 4 (26.67) | – | 11 (73.33) | 15 (9.68) | – | 2 (13.33) | 3 (20.00) | 10 (66.67) | 15 (9.68) |
| Risk assessment | 10 (83.33) | 2 (16.67) | – | 12 (7.74) | – | 3 (25.00) | 7 (58.33) | 2 (16.67) | 12 (7.74 |
| **Epidemic response** | 298 (53.31) | 43 (21.08) | 30 (62.50) | 371 (45.75) | 13 (15.66) | 48 (27.91) | 189 (49.87) | 121 (68.36) | 371 (45.75) |
| Case detection and reporting | 108 (87.10) | 12 (9.68) | 4 (3.23) | 124 (33.42) | 10 (8.06) | 37 (29.84) | 57 (45.97) | 20 (16.13) | 124 (33.42) |
| Disinfection and infection control | 72 (75.79) | 14 (14.74) | 9 (9.47) | 95 (25.61) | – | – | 40 (42.11) | 55 (57.89) | 95 (25.61) |
| Case and close contact management | 34 (53.13) | 13 (20.31) | 17 (26.56) | 64 (17.25) | – | 3 (4.69) | 30 (46.88) | 31 (48.44) | 64 (17.25) |
| Laboratory testing | 42 (91.30) | 4 (8.70) | – | 46 (12.40) | – | – | 37 (80.43) | 9 (19.57) | 46 (12.40) |
| Epidemiological investigation | 29 (100.00) | – | – | 29 (7.82) | – | 2 (6.90) | 21 (72.41) | 6 (20.69) | 29 (7.82) |
| Emergency response | 13 (100.00) | – | – | 13 (3.50) | 3 (23.08) | – | 6 (46.15) | 4 (30.77) | 13 (3.50) |
| **Medical treatment** | 31 (5.55) | 3 (1.47) | – | 34 (4.19) | 3 (3.61) | 1 (0.58) | 25 (6.60) | 5 (2.82) | 34 (4.19) |
| Case diagnosis and treatment | 25 (89.29) | 3 (10.71) | – | 28 (82.35) | 3 (10.71) | 1 (3.57) | 19 (67.86) | 5 (17.86) | 28 (82.35) |
| Case transport | 6 (100.00) | – | – | 6 (17.65) | – | – | 6 (100.00) | – | 6 (17.65) |
| **Support measures** | 135 (24.15) | 116 (56.86) | – | 251 (30.95) | 61 (73.49) | 92 (53.49) | 91 (24.01) | 7 (3.95) | 251 (30.95) |
| Technical support | 24 (40.68) | 35 (59.32) | – | 59 (23.51) | 16 (27.12) | 20 (33.90) | 23 (38.98) | – | 59 (23.51) |
| Training and drills | 2 (4.26) | 45 (95.74) | – | 47 (18.73) | 6 (12.77) | 9 (19.15) | 25 (53.19) | 7 (14.89) | 47 (18.73) |
| Organizational leadership | 47 (100.00) | – | – | 47 (18.73) | 15 (31.91) | 29 (61.70) | 3 (6.38) | – | 47 (18.73) |
| Supervision and management | 30 (75.00) | 10 (25.00) | – | 40 (15.94) | 8 (20.00) | 27 (67.50) | 5 (12.50) | – | 40 (15.94) |
| Laboratory management | 30 (93.75) | 2 (6.25) | – | 32 (12.75) | 1 (3.13) | 1 (3.13) | 30 (93.75) | – | 32 (12.75) |
| Resource reserves | 2 (7.69) | 24 (92.31) | – | 26 (10.36) | 15 (57.69) | 6 (23.08) | 5 (19.23) | – | 26 (10.36) |
| **Total** | 559 (68.93) | 204 (25.15) | 48 (5.92) | 811 (100.00) | 83 (10.23) | 172 (21.21) | 379 (46.73) | 177 (21.82) | 811 (100.00) |

Note: Data in the table represent the number of codes (percentage);
"–" indicates a percentage of 0.00% (code count of 0). From left to right, the table displays: X (Policy instruments) -Z (Policy measures) , and Y (Policy objects)-Z (Policy measures).

SUPPLEMENTARY TABLE S4. Two-dimensional cross-tabulation of policy instruments and policy objects for mpox prevention and control.

| Dimension | Coercive | Mixed | Voluntary | Total |
|---|---|---|---|---|
| Departments | 123 (22.00) | 47 (23.04) | 2 (4.17) | 172 (21.21) |
| Entry-exit inspection and quarantine departments | 29 (69.05) | 13 (30.95) | – | 42 (24.42) |
| Disease control and prevention departments | 32 (74.42) | 11 (25.58) | – | 43 (25.00) |
| Health care sectors | 62 (71.26) | 23 (26.44) | 2 (2.30) | 87 (50.58) |
| Institutions | 292 (52.24) | 84 (41.18) | 3 (6.25) | 379 (46.73) |
| Entry-exit inspection and quarantine agencies | 78 (79.59) | 20 (20.41) | – | 98 (25.86) |
| CDC agencies | 119 (73.91) | 42 (26.09) | – | 161 (42.48) |
| Health education institutions | – | 1 (100.00) | – | 1 (0.26) |
| Social organizations | – | – | 3 (100.00) | 3 (0.79) |
| Medical and health institutions | 95 (81.90) | 21 (18.10) | – | 116 (30.61) |
| Individuals | 104 (18.60) | 30 (14.71) | 43 (89.58) | 177 (21.82) |
| Cases and close contacts | 6 (20.00) | 2 (6.67) | 22 (73.33) | 30 (16.95) |
| Sampling personnel | 5 (41.67) | 6 (50.00) | 1 (8.33) | 12 (6.78) |
| Entry-exit personnel | 11 (68.75) | – | 5 (31.25) | 16 (9.04) |
| Investigation personnel | 7 (58.33) | 2 (16.67) | 3 (25.00) | 12 (6.78) |
| High-risk behavior personnel | – | – | 1 (100.00) | 1 (0.56) |
| Ordinary individuals | 17 (89.47) | 1 (5.26) | 1 (5.26) | 19 (10.73) |
| Laboratory testing personnel | 2 (33.33) | 2 (33.33) | 2 (33.33) | 6 (3.39) |
| Health and quarantine personnel | 26 (76.47) | 4 (11.76) | 4 (11.76) | 34 (19.21) |
| Disinfection personnel | 14 (66.67) | 6 (28.57) | 1 (4.76) | 21 (11.86) |
| Medical personnel | 16 (61.54) | 7 (26.92) | 3 (11.54) | 26 (14.69) |
| Territorial governments | 40 (7.16) | 43 (21.08) | – | 83 (10.23) |
| People's governments at all levels | 40 (48.19) | 43 (51.81) | – | 83 (100.00) |
| Total | 559 (68.93) | 204 (25.15) | 48 (5.92) | 811 (100.00) |

Note: Data in the table represent the number of codes (percentage);
"-" indicates a percentage of 0.00% (code count of 0). From left to right, the table displays: X (Policy instruments)-Y (Policy objects).

SUPPLEMENTARY TABLE S5. Distribution of Policy Objects by Policy Instruments and Policy Measures.

| Dimension | Disease prevention | Epidemic response | Medical treatment | Support measures | Total |
|---|---|---|---|---|---|
| Mandatory | 95 | 298 | 31 | 135 | 559 (68.93) |
| Departments | 14 | 41 | 1 | 67 | 123 (22.00) |
| Institutions | 52 | 172 | 23 | 45 | 292 (52.24) |
| Individuals | 26 | 73 | 5 | – | 104 (18.60) |
| Territorial governments | 3 | 12 | 2 | 23 | 40 (7.16) |
| Mixed | 42 | 43 | 3 | 116 | 204 (25.15) |
| Departments | 16 | 6 | – | 25 | 47 (23.04) |
| Institutions | 19 | 17 | 2 | 46 | 84 (41.18) |
| Individuals | 4 | 19 | – | 7 | 30 (14.71) |
| Territorial governments | 3 | 1 | 1 | 38 | 43 (21.08) |
| Voluntary | 18 | 30 | – | – | 48 (5.92) |
| Departments | 1 | 1 | – | – | 2 (4.17) |
| Institutions | 3 | – | – | – | 3 (6.25) |
| Individuals | 14 | 29 | – | – | 43 (89.58) |
| Territorial governments | – | – | – | – | – |
| Total | 155 (19.11) | 371 (45.75) | 34 (4.19) | 251 (30.95) | 811 (100.00) |

Note: Data in the table represent the number of codes (percentage); "-" indicates a percentage of 0.00% (code count of 0).

Notifiable Infectious Diseases Reports

# Reported Cases and Deaths of National Notifiable Infectious Diseases — China, January 2026*

| Diseases | Cases | Deaths |
|---|---|---|
| Plague | 0 | 0 |
| Cholera | 0 | 0 |
| COVID-19 | 17,916 | 1 |
| SARS-CoV | 0 | 0 |
| Acquired immune deficiency syndrome† | 2,805 | 1,649 |
| Hepatitis | 127,961 | 70 |
| Hepatitis A | 1,167 | 0 |
| Hepatitis B | 109,248 | 37 |
| Hepatitis C | 14,084 | 31 |
| Hepatitis D | 25 | 0 |
| Hepatitis E | 2,865 | 2 |
| Other hepatitis | 572 | 0 |
| Poliomyelitis | 0 | 0 |
| Human infection with noval influenza virus | 3 | 0 |
| Measles | 138 | 0 |
| Epidemic hemorrhagic fever | 336 | 6 |
| Rabies | 31 | 33 |
| Japanese encephalitis | 0 | 1 |
| Dengue | 93 | 0 |
| Monkey pox§ | 28 | 0 |
| Anthrax | 12 | 0 |
| Dysentery | 1,481 | 0 |
| Tuberculosis | 52,889 | 164 |
| Typhoid fever and paratyphoid fever | 252 | 0 |
| Meningococcal meningitis | 23 | 2 |
| Pertussis | 971 | 0 |
| Diphtheria | 0 | 0 |
| Neonatal tetanus | 1 | 0 |
| Scarlet fever | 2,935 | 0 |
| Brucellosis | 3,766 | 0 |
| Gonorrhea | 10,415 | 0 |
| Syphilis | 55,170 | 0 |
| Leptospirosis | 11 | 1 |
| Schistosomiasis | 1 | 0 |
| Malaria | 383 | 0 |
| Influenza | 1,361,570 | 3 |
| Mumps | 4,842 | 0 |

Continued

| Diseases | Cases | Deaths |
|---|---|---|
| Rubella | 30 | 0 |
| Acute hemorrhagic conjunctivitis | 1,634 | 0 |
| Leprosy | 24 | 0 |
| Typhus | 51 | 0 |
| Kala azar | 39 | 0 |
| Echinococcosis | 451 | 0 |
| Filariasis | 0 | 0 |
| Hand, foot and mouth disease | 66,264 | 0 |
| Infectious diarrhea[¶] | 185,768 | 0 |
| **Total** | 1,898,294 | 1,930 |

* According to the National Bureau of Disease Control and Prevention.
† The number of deaths of Acquired immune deficiency syndrome (AIDS) is the number of all-cause deaths reported in the month by cumulative reported AIDS patients.
§ Since September 20, 2023, Monkey pox was included in the management of Class B infectious diseases.
¶ Infectious diarrhea excludes cholera, dysentery, typhoid fever and paratyphoid fever.
The number of cases and cause-specific deaths refer to data recorded in National Notifiable Disease Reporting System in China, which includes both clinically-diagnosed cases and laboratory-confirmed cases. Only reported cases of the 31 provincial-level administrative divisions in the Chinese mainland are included in the table, whereas data of Hong Kong Special Administrative Region, Macau Special Administrative Region, and Taiwan, China are not included. Monthly statistics are calculated without annual verification, which were usually conducted in February of the next year for de-duplication and verification of reported cases in annual statistics. Therefore, 12-month cases could not be added together directly to calculate the cumulative cases because the individual information might be verified via National Notifiable Disease Reporting System according to information verification or field investigations by local CDCs.

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