

Supplementary Information

Dynamic COVID Zero Strategy triggered a significant increase of Chlorine-based Disinfectant consumption in Beijing

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Supplementary Figures

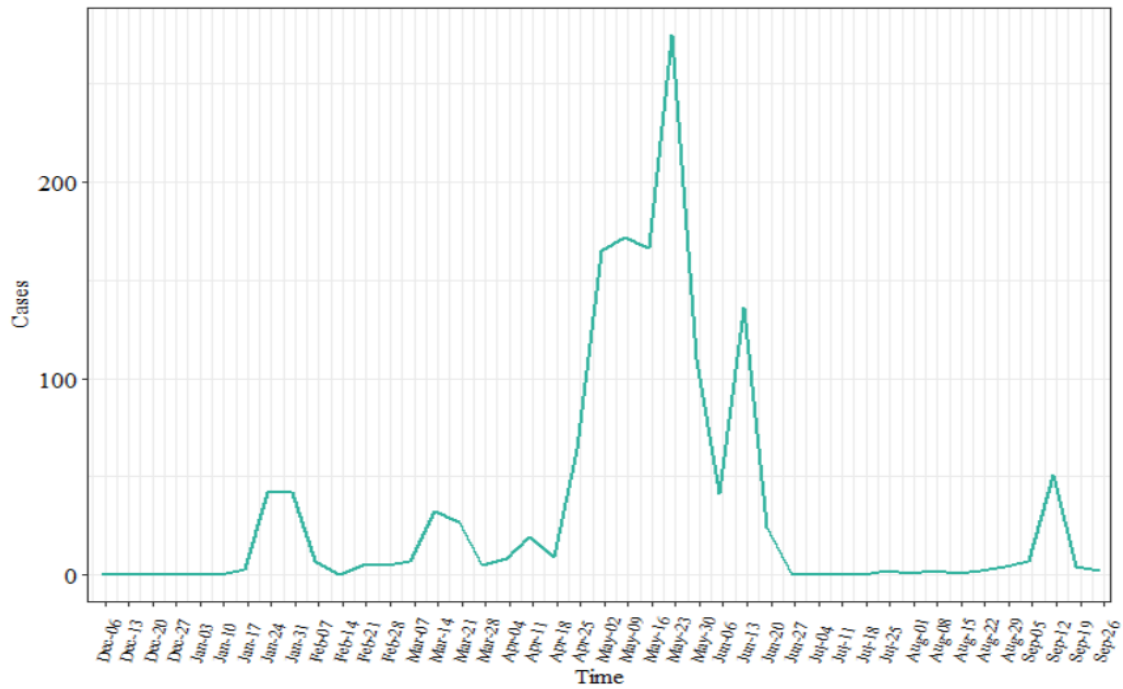


Figure S1 Number of new cases in the urban region of Beijing from December 1, 2021 to September 28, 2022.

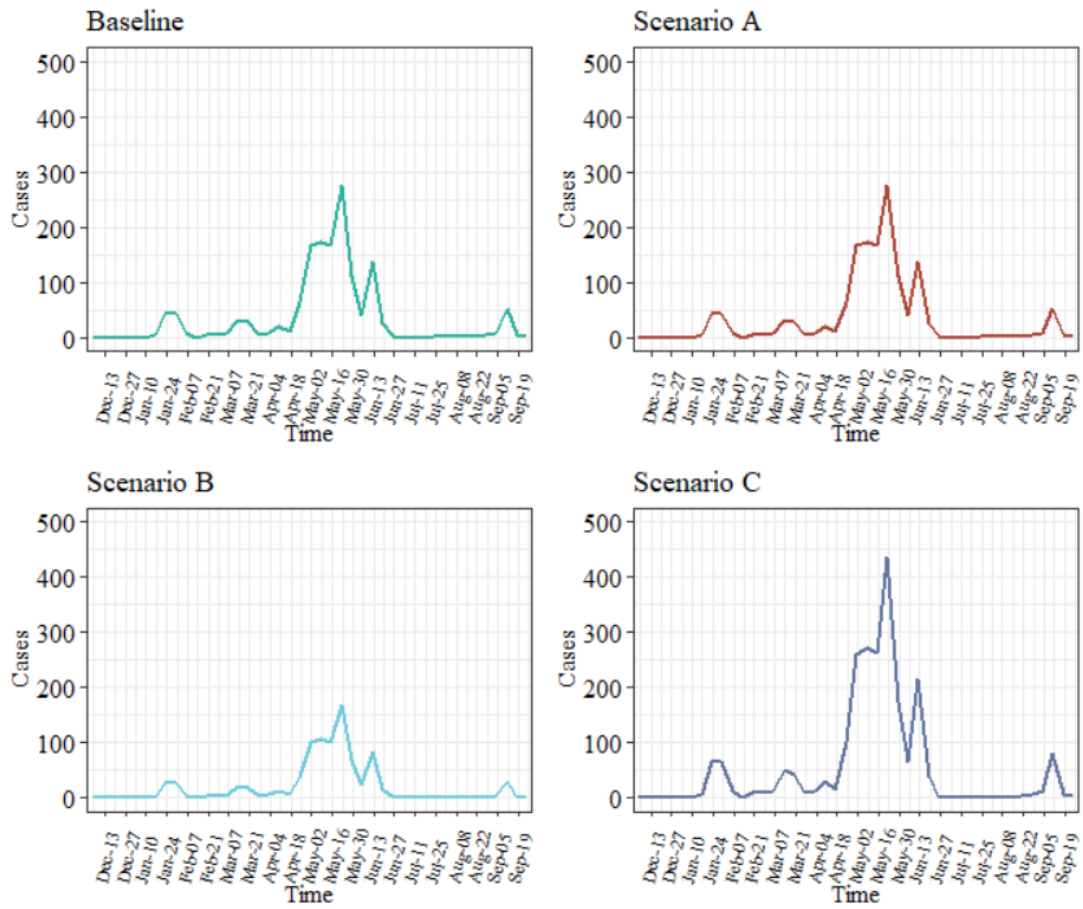
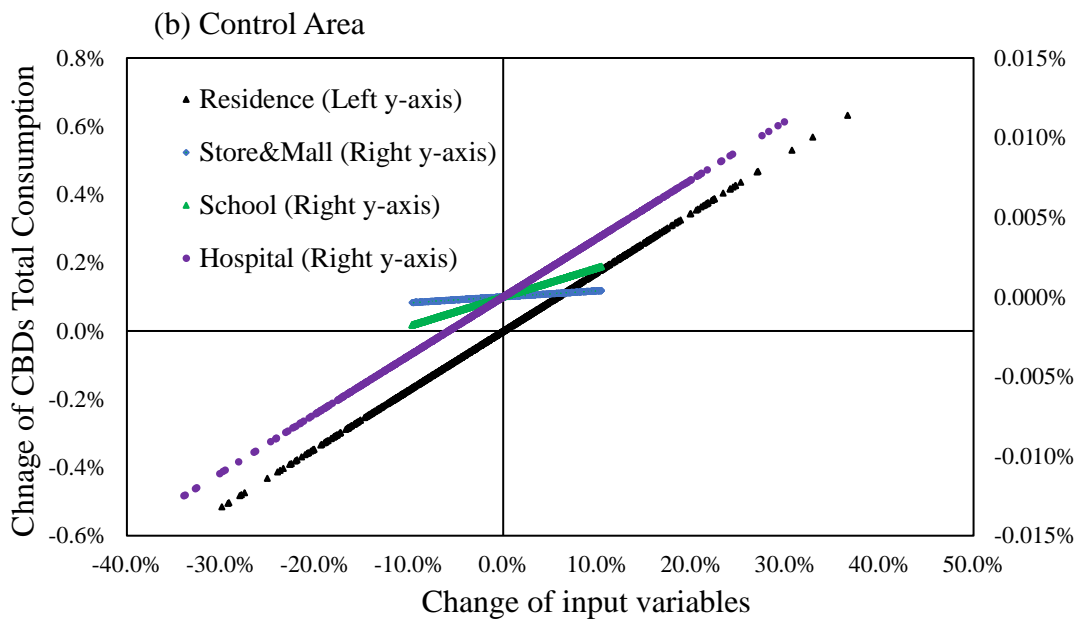
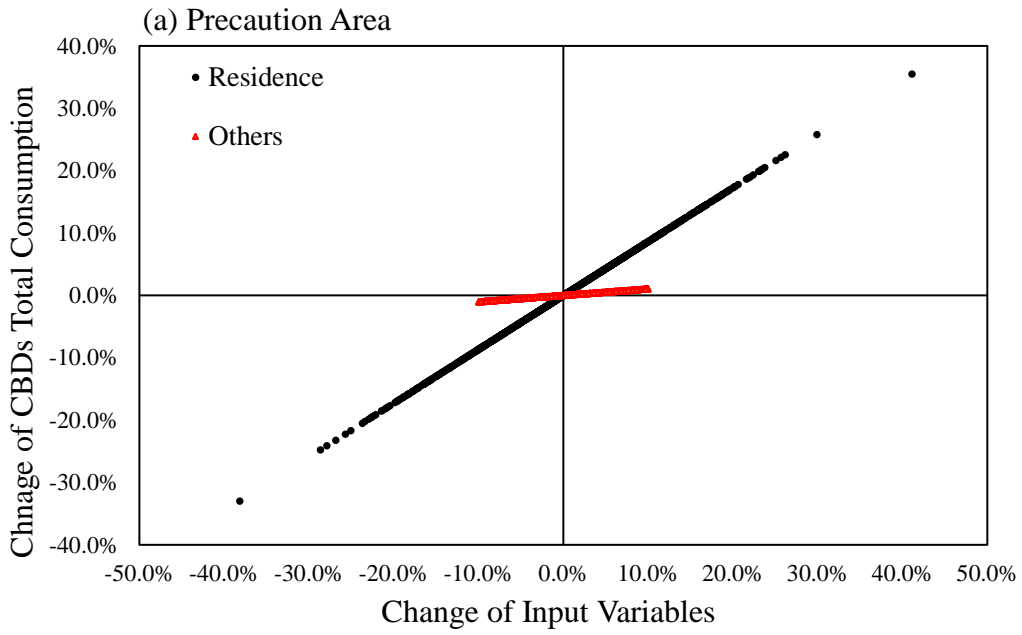


Figure S2 Number of new cases in the urban region of Beijing from December 1, 2021 to September 28, 2022 under baseline and three other scenarios.



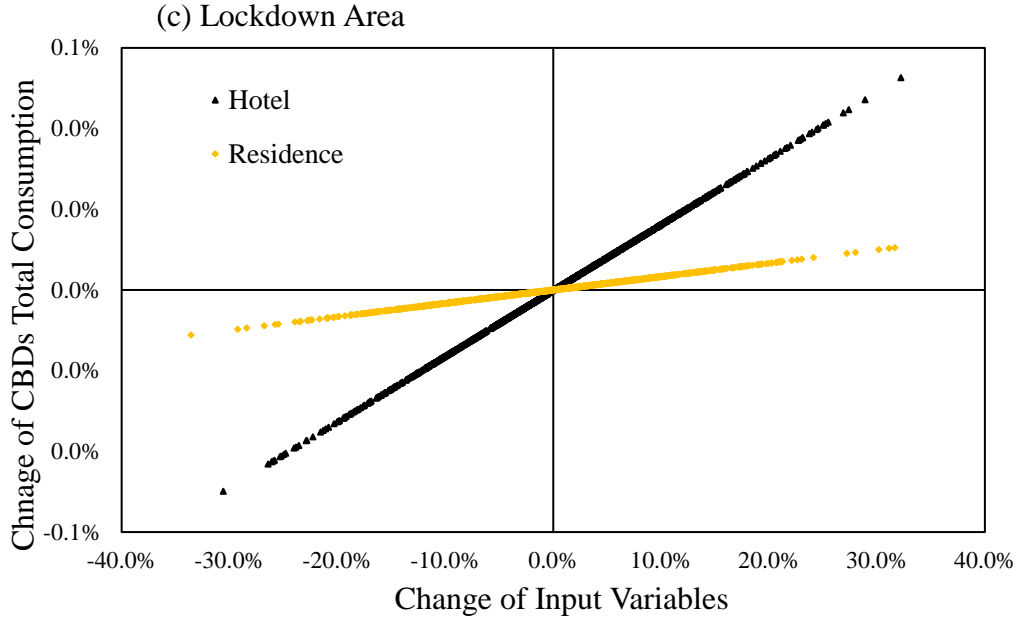


Figure S3 Change of disinfection intensities for different building types & risk area and the impact for total CBDs consumption

Supplementary Equations

The CBD consumption calculation is based on the following equations: (Eq.1- Eq.5)

$$TC_{urban} = \sum_{w=1}^{43} (C_{CLw} + C_{Cw} + C_{Pw}) \times 10^{-6} \quad (\text{Eq. 1})$$

$$C_{CLw} = \sum_{i=1}^{n_w} \begin{cases} FS_i \times I_{CO} + FS_i \times (f_i - 1) \times I_{T_i(LD)} & T_i \in [\text{Residence, Hotel, School}] \\ FS_i \times f_i \times I_{(CO)} & T_i \notin [\text{Residence, Hotel, School}] \end{cases} \quad (\text{Eq. 2})$$

$$C_{Cw} = \sum_{j=1}^{m_w} FS_j \times f_j \times I_{T_j(C)} \quad (\text{Eq. 3})$$

$$C_{Pw} = A_{Pw} \times P_R \times I_{T=Rsidence(P)} + A_{Pw} \times (1 - P_R) \times I_{T=Others(P)} \quad (\text{Eq. 4})$$

$$A_{Pw} = A - \sum_{i=1}^{n_w} FS_i \times f_i - \sum_{j=1}^{m_w} FS_j \times f_j \quad (\text{Eq. 5})$$

where

TC_{urban} : total CBDs consumption in the urban region (tons).

w : Week.

C_{CLw} : CBDs consumption in closed-off and lockdown areas in week w .

C_{Cw} : CBDs consumption in the control area in week w .

C_{Pw} : CBDs consumption in the precautionary area in week w .

n_w : Number of locations identified as closed/locked areas in week w .

m_w : Number of locations identified as control areas in week w .

FS_i : Floor space of the building at closed-off or lockdown location i , 1000 m².

FS_j : Floor space of the building at control location j , 1000 m².

f_i : Number of floors of buildings at closed-off or lockdown location i .

f_j : floors of building at control location j .

T_i : Type of building in closed-off or lockdown location i .

$I_{T_i(LD)}$: Intensity of disinfection for lockdown area i when building type is identified as T ,

grams of active chlorine/ 1000 m² / week.

$I_{(CO)}$: Intensity of disinfection in closed areas, unrelated to building type.

$I_{T_j(C)}$: Intensity of disinfection for control area j when building type is identified as T .

A : Total floor area in the urban region, 1000 m².

A_{P_w} : Total precaution area in week w .

P_R : Proportion of residential area to total floor area of urban regions.

$I_{T=Residence(P)}$: Intensity of disinfection for residential areas in the risk category of precautions.

$I_{T=Others(P)}$: intensity of disinfection in other areas under the risk category of precautions.

City geospatial data provide essential information on a specific place or building, including its location, type, floor area, and stories. The risk area data can be used to classify the risk level for each building or area when a confirmed case occurs according to the DCZ strategy. Buildings or areas were categorized and updated weekly as close-off, lockdown, control, and precaution following the development of the epidemic. The disinfection pattern data qualify CBD consumption in a given building in a certain area during a specific period. The CBD requirements vary significantly for different spaces or buildings under different risk prevention categories. For example, commercial places such as stores and shopping malls consume approximately 1.7 g of CBDs per 1000 m² per week when defined as a precaution area. When new cases are identified in these places and then categorized as closed-off areas, the disinfection standard sharply rises to 750–1000 g per 1000 m² per week according to the DCZ strategy.

The sensitivity index was calculated as follows: (Eq. 6)

$$S_i = \frac{\sum_1^{1000} |TC_j - TC_{Baseline}|}{\sum_1^{1000} |i_j - i_{initial}|} \quad (\text{Eq. 6})$$

where

S_i : Sensitivity index of selected parameter i .

TC_j : Total CBD consumption of run j .

$TC_{Baseline}$: Total CBDs consumption at baseline stimulation.

i_j : The sampling value of parameter i in run j .

$i_{initial}$: sampling value of parameter i in run j .

Each parameter was sampled and tested 1000 times using Monte Carlo sampling.

Supplementary Texts

Text S1 Interview outline for field research (Translated from Chinese into English)

Notes: To increase the accuracy of the data, we conducted periodic surveys for 19 of the 44 respondents monthly during the study period to investigate changes in CBD consumption.

A. Building Information

Q1. What is the spatial feature of the building, such as the occupied area, floors, and number of environmental sanitation facilities?

Q2. What is the turnover of personnel characteristics of the building?

B. Disinfection Information

Q3. In the case of normalized prevention and control or other risk prevention level, which areas/facilities within the building was being disinfected?

Q4. What kinds of disinfectant was used? What was the ratio being used for diluting?

Q5. What are the specific methods for disinfecting different areas/facilities?

Q6. What is the consumption situation of disinfectants (how often do you use a bucket of disinfectant)?

Q7. During the work of disinfection, how do you deal with the residual disinfectant?

Q8. What are the channels for purchasing different disinfection products (online shopping/offline purchase, etc.)?

Text S2 Translated online questionnaire

A. General Information

Q1. Age

____years

Q2. Sex

Male

Female

Q3. Address

____ province ____ city ____ region

Q4. The population at your residence

____ person

Q5. The floor area of your residence

____ m² (0~300)

B. Perceptions towards risks and disinfection

Q6. In China, some local departments responsible for disease control and prevention had published "Guidelines for the Prevention and Control of Epidemics in High, Medium and Low-Risk Areas". Do you know the relevant information?

No

Yes, but did not read it in detail

Yes, and read it in detail

Q7. Do you follow the instructions such as "When flushing the toilet, cover the lid first and then flush." according to the "Guidelines for the Prevention and Control of Epidemics in High, Medium and Low-Risk Areas" in your daily life?

Yes

No

Not always

Q8. On what degree do you know about the types and usage of disinfectants towards SARS-CoV-2? Please select the one that best fits your situation.

I don't know which products can inactivate the SARS-CoV-2

I know some types of products that can inactivate the SARS-CoV-2

I know some types of products that can inactivate the SARS-CoV-2, and know the ratio or usage of them

I know some types of products that can inactivate the SARS-CoV-2, and know the ratio or usage of them, and also understand the potential risks of using them.

C. Disinfection Pattern

Q9. What disinfectants did you use for cleaning your residence during the pandemic?
 [Multiple Choice Questions]

- Chlorine-containing disinfectants
- Alcohol-containing disinfectants
- Iodine-containing disinfectants
- Phenol-containing disinfectants
- Other products (Please provide the name)

Q10. Which of the following objects or facilities do you clean? For disinfectants that have never been used, please select the "Unused" option.

	Chlorine-containing disinfectants	Alcohol-containing disinfectants	Iodine-containing disinfectants	Phenol-containing disinfectants	Other products
Unused	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hard surfaces (such as tables, and chairs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Doors and windows	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Clothes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ground	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sink, flush toilet, and other water facilities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (Please specify)	_____	_____	_____	_____	_____

Q11. How much disinfectants do you use on average during the pandemic (Assume a bottle of disinfectant with a size of 500 g or 500 ml)? For disinfectants that have never been used, please select the "Unused" option.

	Chlorine-containing disinfectants	Alcohol-containing disinfectants	Iodine-containing disinfectants	Phenol-containing disinfectants	Other products
Unused	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

No more than 1 bottle (per month)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1~2 bottle (per month)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2~4 bottle (per month)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
More than 4 bottle (per month)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (Please specify)	_____	_____	_____	_____	_____

Q12. What is your pattern of using different disinfectants? For disinfectants that have never been used, please select the "Unused" option.

	Unused	Spray	Wipe	Soak/wash	Other patterns (Please specify)
Chlorine-containing disinfectants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Alcohol-containing disinfectants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Iodine-containing disinfectants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Phenol-containing disinfectants	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Other products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____

D. Hand washing

Q13. What is the type and frequency of hand cleaning products you use? For products that have never been used, please select the "Unused" option.

	Soap/ Liquid soap	Hand sanitizer	Disinfectant wipes
Unused	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1~5 times per day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5~10 times per day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11~20 times per day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
> 20 times per day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

E. Product purchase pattern

Q14. How do you purchase disinfectants/cleaning products before and during pandemic?
Please select the one that best fits your situation.

	All purchased via stores or markets	All purchased via online shopping	Mainly purchased via stores or markets	Mainly purchased via online shopping	Stores or markets and online shopping account for half of each
Before the pandemic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
During the pandemic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Text S3 Other inputs data collections

City space data were compiled based on the building dataset from Bigemap¹ and the point-of-interest (POI) dataset from Baidu². The building dataset was tailored using ArcGIS, following the boundary of the urban region, to screen buildings in our case area. More than 72,000 buildings were considered in this study. The filtered building dataset was then spatially combined with the POI dataset to supplement the information on the floor area, floors, and type of each building.

New case and risk area data were collected from historical local press conference reports 错误!未找到引用源。 on COVID-19 prevention and control from December 1, 2021, to September 28, 2022.

The epidemic development and pinpointing of the locations according to the risk prevention categories are described in detail in the SI (cf., Fig. S1). New cases and risk areas were updated weekly to synchronize with the cycle of risk level adjustments.

Text S4 Sensitivity Analysis results

According to sensitivity analysis, the disinfection intensity of residential buildings in the precautionary area was the most sensitive parameter in the ALICE model (SI Table S3). A 1%

change in this parameter resulted in an average change of 0.86% in total CBD consumption.

The sensitivity index for disinfection intensities of the “others” building type (except for the disinfection intensity of residential buildings in the precautionary area) under the precaution area and residence building under the control area is higher than 0.01. Additionally, the sensitivity index of residential disinfection intensity in the precaution and control areas had the highest ranking compared with other parameters. Still, it was less sensitive than the hotel’s disinfection intensity in the lockdown area. The input and model output changes graphically follow a linear relationship for all selected parameters.

Supplementary Tables

Table S1 Population and area of studied region

District	Population (million)	Area (km²)
Dongcheng	0.70	41.8
Xicheng	1.10	50.7
Chaoyang	3.44	470.8
Haidian	3.12	431
Fengtai	2.01	306
Shijingshan	0.56	85.7

A Monte Carlo simulation was used to obtain input values of the disinfection pattern for ALICE and was conducted using Crystal Ball (version 11.1) in an Excel environment.

Table S2 Detailed input of ALICE

Data	Characteristic	Measurement
City geospatial data	Location	Address (simplify as different integers in the method)
	Space/Building type	Residence; Office place; Hotel; Restaurant; School; Hospital; Store/Mall; Others
	Geometric information	Floor area (in unit of 1,000 m ²) Floors (integers as 1,2,3...)
COVID-19 risk area	Location	Address (simplify as different integers in the method)
	Risk prevention category	Close off ¹ ; Lockdown ² ; Control ³ ; Precaution ⁴
	Temporary scale	Week
Disinfection pattern	Disinfection intensity	A gram of active chlorine/ 1000 m ² / week (which varies according to space/building type and risk prevention categories, detailed in SI Table S1)
	Space/Building type	Residence; Office place; Hotel; Restaurant; School; Hospital; Store/Mall; Others
	Risk prevention category	Close off; Lockdown; Control; Precaution

¹**Close off:** The area where a new patient frequently visited before testing positive. The area requires a shutdown, and personnel must withdraw during this interim. The area will be unblocked if no cases are reported within 14 days.

²**Lock down:** The area or communities where a new patient lived before testing positive. The area will be locked down. Personnel in this area remain within doors during this interim. The area will be unblocked if no cases are reported within 14 days.

³**Control:** The area where a new patient worked or visited within two days before testing positive. The area will be locked down. Personnel in this area are not allowed to leave during this interim. The area will be unblocked if no cases are reported within 14 days.

⁴**Precaution:** If a close-off, lockdown, or control area is designated, the urban area beyond any of the three will be defined as the precaution area. Events and gatherings of people will be strictly limited during this interim in this area. The area will be unblocked once there is no close-off, lockdown, and control area in the district.

Table S3 Summary of model parameters

Parameters	Default Value (g/1000m²/week)	Distribution	Range/Distribution settings
$I_{(CO)}$	875	Triangle	[40, 1000]
$I_{T=Residence(LD)}$	13.04	Normal	Std Dev = 1.3
$I_{T=Office\ place(LD)}$	875	Triangle	[40, 1000]
$I_{T=Hotel(LD)}$	466.2	Normal	Std Dev = 46.6
$I_{T=Restaurant(LD)}$	875	Triangle	[40, 1000]
$I_{T=School(LD)}$	3.51	Uniform	[3.16, 3.86]
$I_{T=Hospital(LD)}$	875	Triangle	[40, 1000]
$I_{T=Store/Mall(LD)}$	875	Triangle	[40, 1000]
$I_{T=Others(LD)}$	875	Triangle	[40, 1000]
$I_{T=Residence(C)}$	9.78	Normal	Std Dev = 0.98
$I_{T=Office\ place(C)}$	0.26	Normal	Std Dev = 0.03
$I_{T=Hotel(C)}$	349.65	Normal	Std Dev = 35.0
$I_{T=Restaurant(C)}$	37.5	Normal	Std Dev = 3.75
$I_{T=School(C)}$	2.63	Uniform	[2.37, 2.90]
$I_{T=Hospital(C)}$	525	Normal	Std Dev = 52.5
$I_{T=Store/Mall(C)}$	2.63	Normal	Std Dev = 0.26
$I_{T=Others(C)}$	4.22	Uniform	[3.80, 4.64]
$I_{T=Residence(P)}$	6.52	Normal	Std Dev = 0.65
$I_{T=Others(P)}$	2.81	Uniform	[2.53, 3.09]

Notes: The parameters of the disinfection intensities were set in the form of value ranges with different probability distributions. Specifically, the probability distribution of each disinfection intensity for certain types of buildings with certain risk prevention levels was differentiated based on data obtained through questionnaire surveys or field research.

Table S4 Sensitivity index of disinfection intensities under different building types & risk areas

Area	Space/building type	Sensitivity index (%)
Precaution Area	Residence	0.86387
	Others	0.10351
Control Area	Residence	0.01725
	Store & Mall	0.00004
	School	0.00018
	Hospital	0.00037
Lockdown Area	Residence	0.00033
	Hotel	0.00163

References

1. BIGEMAP. "Bigemap database." Bigemap, <http://www.bigemap.com/> Accessed 15 May, 2023
2. Resource and Environment Science and Data Center. "Annual national POI database." resdc, <https://www.resdc.cn/data.aspx?DATAID=341>. Accessed 15 May, 2023.