

The Community Outbreak in Amoy Gardens

3.67 Amidst the outbreak in Prince of Wales Hospital and the mini-outbreaks in other healthcare establishments, the SARS coronavirus had found its way to a housing estate in the densely populated Kwun Tong District in Kowloon. The community outbreak in Amoy Gardens, fuelled by an unfortunate sequence of environmental and health events happening at the same time, turned out to be

the most devastating and ferocious outbreak. At the end of the outbreak, a total of 329 residents had been infected, with 42 deaths. Amongst all, Block E of the housing estate was the hardest hit, accounting for 41% of the cases in the Amoy Gardens outbreak.

3.68 The epidemic curve of the Amoy Gardens outbreak is illustrated in Figure 3.9.

Figure 3.8 Location of Amoy Gardens and United Christian Hospital

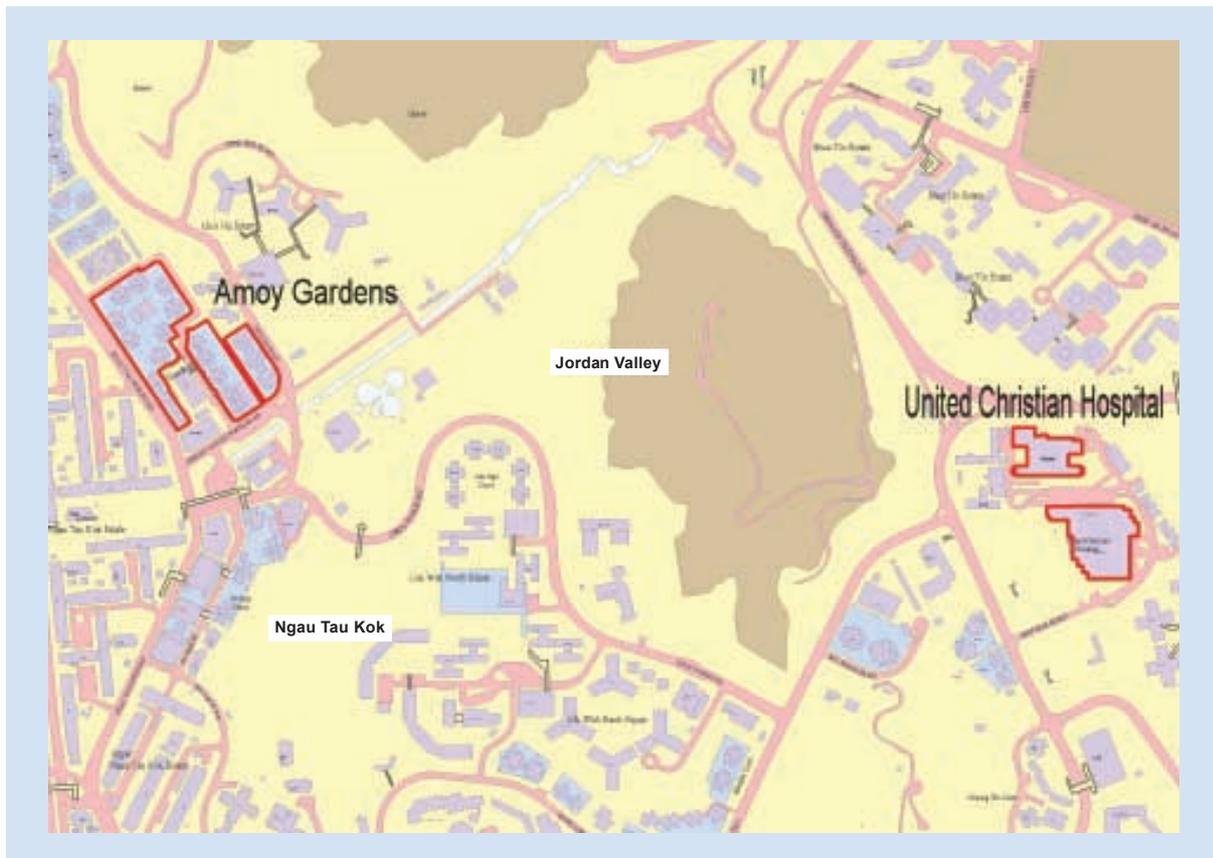
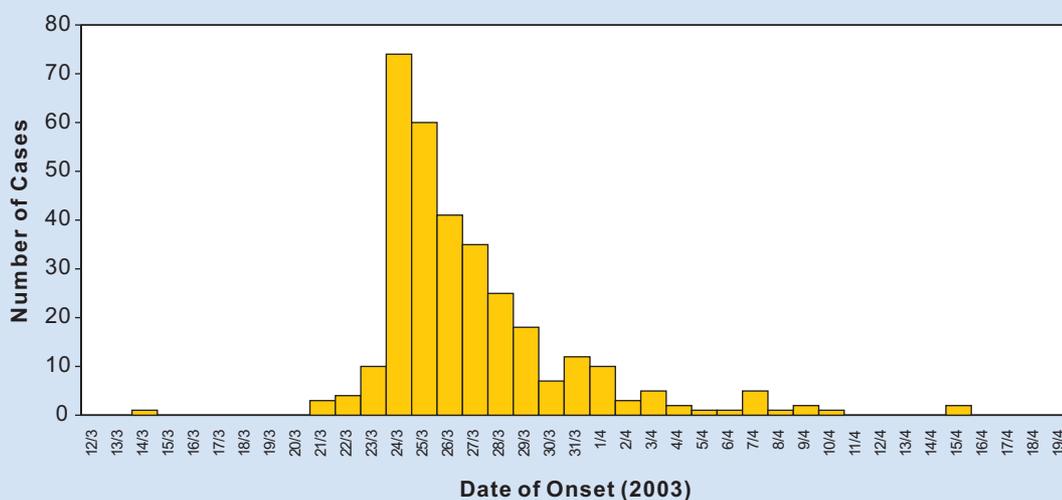


Figure 3.9 Amoy Gardens Outbreak
Epidemic curve by date of onset



The housing estate

3.69 Amoy Gardens, a private housing estate built in 1981, was made up of 19 housing blocks (Blocks A - S) and a ground-level shopping mall below the podium. Each housing block typically has 33 floors, with 8 units on each floor. The size of each unit is approximately 48 square metres. Each unit is furnished with one toilet and one kitchen, together with a living room and bedrooms. The bathroom unit is small in size, about 3.5 square

metres. Units of the same stack on different floors are served by plumbing and drainage piping systems running vertically along the external wall. Adjacent units, for instance unit 7 and 8, are separated by a narrow 1.5 metre lightwell, where bathroom windows, exhaust fans, master bedroom windows, air conditioners and laundry drying racks faced one another. Amoy Gardens has an estimated 19,000 residents.

3.70 Given below are the layout of the housing blocks in Amoy Gardens and their typical floor plan.

Figure 3.10 Layout of Housing Blocks in Amoy Gardens

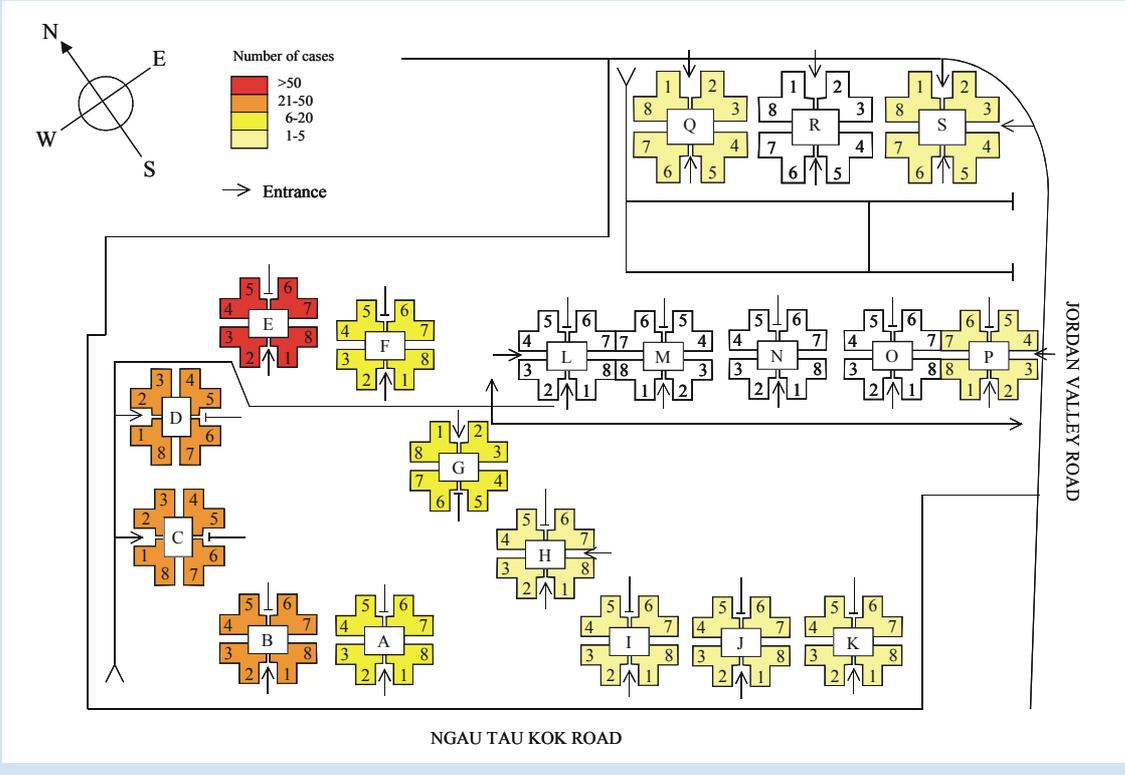
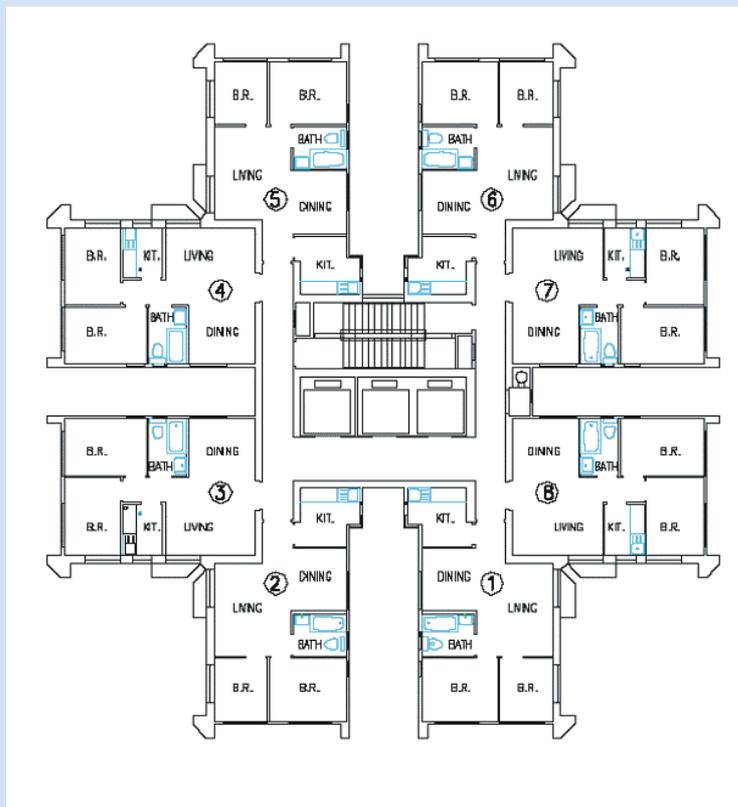


Figure 3.11 Typical Floor Plan of Housing Blocks in Amoy Gardens



26.3.03 Wednesday

3.71 On 26.3.03, DH's Kowloon Regional Office was notified by HA's United Christian Hospital that it had admitted 15 suspected SARS cases from 7 households, all of whom residing in Amoy Gardens. A DH medical team made a field visit to the housing estate on the same day. They interviewed 20 available units on 7 floors with suspected cases, all in Block E. It was found that the affected households did not know each other and were not involved in any common activities.

3.72 Apart from placing family members of suspected SARS cases under medical surveillance and initiating contact tracing, DH also distributed letters to other Block E residents advising them to watch out for symptoms. Pamphlets about SARS were further distributed to all residents in the housing estate. The building management was instructed to disinfect common areas of all blocks, starting with Block E.

3.73 In the afternoon, SHWF held the fifth meeting of the HWFB Task Force. DH reported the situation in Amoy Gardens. Key discussion points included the following –

- ◆ Transmission routes of SARS coronavirus were most compatible with droplets spread and through fomites, ie contaminated materials via body secretions. However, rare instances of aerosol transmission needed further examination

- ◆ Frequent hand washing and surface cleaning important
- ◆ The need to revise public health measures, detailed below, in view of the community outbreak
- ◆ Discharge protocol required for SARS patients
- ◆ Increased background pneumonia cases observed during the past week.

3.74 In response to SHWF's invitation at the meeting, the Director of Health recommended a basket of public health measures. These included adding SARS to the Quarantine and Prevention of Disease Ordinance (Chapter 141 of the Laws of Hong Kong) to make it a notifiable disease, requiring incoming visitors to Hong Kong to complete health declaration forms, temporarily suspending schools, setting up medical surveillance centres at designated locations to screen contacts of SARS patients, and designating Princess Margaret Hospital to receive new SARS cases referred by designated medical centres.

3.75 Later in the day, DH and HA provided information on the Amoy Gardens outbreak in the daily press briefing.

The Index case of the Amoy Gardens outbreak

The index case of the Amoy Gardens outbreak was identified as a 33-year-old man, YY, who works and lives in Shenzhen, China. Since 1987, he had developed end stage kidney disease due to an autoimmune disease and had been travelling to Prince of Wales Hospital twice a week for haemodialysis. When he came to Hong Kong, he would stay in his brother's flat in Amoy Gardens.

The chronology of the events was as follows –

- ◆ 14.3.03 YY stayed overnight at his brother's flat in Amoy Gardens. He had already developed fever and was having diarrhoea.
- ◆ 15.3.03 He had routine dialysis in ward 8C of Prince of Wales Hospital. He was unwell, and chest x-ray showed features of pneumonia. He was diagnosed as a suspected case of atypical pneumonia and was admitted and cohorted in ward 8A* for further management.
- ◆ 17.3.03 His condition improved after antibiotics and anti-flu treatment. His fever subsided and body temperature returned to normal.
- ◆ 18.3.03 Rapid test of his nasopharyngeal aspirate showed that he had **influenza A**.
- ◆ 19.3.03 YY remained afebrile, and with almost complete resolution of his chest x-ray changes, he was discharged from the hospital. He stayed overnight in his brother's flat in Amoy Gardens.
- ◆ 20.3.03 He returned to Shenzhen.
- ◆ 22.3.03 YY went to Prince of Wales Hospital for dialysis, but was admitted to ward 8D because of fever and shortness of breath. Chest x-ray was markedly different from the one on 19.3.03, with pneumonia changes on both lungs.
- ◆ 23.3.03 His clinical condition deteriorated rapidly and he was transferred to the intensive care unit where he was intubated the following day.

YY was diagnosed to have SARS on 27.3.03. He made an eventual recovery and was discharged on 2.6.03.

Viral genetic sequencing work in August subsequently showed that the virus isolated from YY is highly similar to the Prince of Wales Hospital strain and the Amoy Gardens strain. It is also noted that he had developed fever and diarrhoea before his first ward admission on 15.3.03. Retrospectively, he possibly had dual infections of both influenza A and SARS on his first admission. However, the diagnosis of SARS could not have been made before he was discharged on 19.3.03 because –

- ◆ The causative agent of SARS was not identified until 22.3.03
- ◆ A diagnosis of influenza A had been positively made
- ◆ His clinical condition had improved markedly with both resolution of fever and chest x-ray features of pneumonia.

In terms of close contacts, it was noted that both YY's brother and sister-in-law had become SARS cases with onset dates on 23.3.03 and 28.3.03 respectively. Two nurses who had attended to him during the kidney dialysis sessions on 22.3.03 had also become infected. All recovered eventually.

* *Prince of Wales Hospital turned ward 8A into a cohort ward for cases with suspected atypical pneumonia in the evening of 13.3.03, after transferring existing patients to the "SARS" (a later terminology) wards or the step-down wards.*

27.3.03 Thursday - 29.3.03 Saturday

3.76 Daily site inspections to Amoy Gardens were undertaken by DH to identify possible sources of the outbreak and conduct medical surveillance of affected households. A multi-disciplinary team, led by DH and consisting of the Police and other Government departments responsible for water services, environmental protection, electrical and mechanical services, food and environmental hygiene, and drainage services, undertook detailed inspections at Block E and the shopping mall. No major irregularities were detected at the time. Environmental swabs and water samples were taken. DH's medical team also conducted door-to-door interviews in the housing estate.

3.77 DH set up two medical stations at Block E, manned by the Auxiliary Medical Service, to take body temperature of residents and provide SARS-related information. A WHO team provided assistance to DH in conducting an epidemiological study, including a case control study.

3.78 On 27.3.03, the Government announced new control measures to manage the SARS outbreak. These were in line with the deliberations of the HWFB Task Force the day before, and were as follows –

- ◆ Adding SARS to the list of infectious diseases specified in First Schedule to the Quarantine and Prevention of Disease Ordinance (Chapter 141 of the Laws of Hong Kong) with immediate effect

Strengthening the legal base

The legislative framework for the prevention and control of infectious diseases in Hong Kong is provided by the Quarantine and Prevention of Disease Ordinance (Chapter 141 of the Laws of Hong Kong) and its subsidiary legislation. The Ordinance provides for various statutory powers relating to the prevention of import and spread of infectious diseases listed in the First Schedule to the Ordinance. Prior to the inclusion of SARS, 27 infectious diseases were listed. By adding SARS to the Ordinance on 27.3.03, the Director of Health had the legal power to mandate notification, surveillance, and isolation of people suspected of SARS as well as their contacts.

The inclusion of SARS in the Ordinance enabled a series of public health measures, including the following –

- ◆ Surveillance of close contacts at designated medical centres from 31.3.03 and later, home confinement of household contacts as of 10.4.03
- ◆ Health declaration by incoming visitors introduced on 29.3.03
- ◆ Isolation and later, evacuation of Amoy Gardens Block E residents on 1.4.03.

On 17.4.03, amendments to the legislation were gazetted in order to effect temperature checking of travellers and the barring of close contacts of SARS patients from leaving Hong Kong.

- ◆ Introduce health declaration for incoming visitors to Hong Kong effective from 29.3.03
- ◆ Require close contacts of SARS patients to report to designated medical centres from 31.3.03
- ◆ Suspension of classes in all schools from 29.3.03 to 6.4.03.

3.79 On 29.3.03, DH reported at its press briefing that most of the cases in the Amoy Gardens outbreak came from units 7 and 8 of Block E. It was further reiterated that available evidence still pointed to droplet transmission, and fomites spread. The general public was advised to observe personal and environmental hygiene.

Surveillance of contacts: a graduated enhancement

During the initial phase of the outbreak, all close contacts* of SARS patients were placed under DH's medical surveillance through telephone interactions. They were advised not to go to work or school for at least 7 days, with sick leave granted. Symptomatic contacts were referred to HA hospitals for further investigations.

On 31.3.03, DH set up four designated medical centres, one in each regional location. Close contacts had to report to a designated medical centre on a daily basis for a period of 10 days for medical surveillance. During this period, they were asked to remain at home and not venture outside other than to attend the designated medical centre. At the designated medical centres, the close contacts underwent health screening and temperature check and, if symptomatic, a chest x-ray. Those suspected of SARS were referred to HA hospitals.

Since 10.4.03, household contacts of SARS patients were ordered to undergo home confinement (quarantine) for 10 days, with no visitors allowed. Regular home visits were made by public health nurses during this period for medical surveillance. The Police also conducted spot checks to ensure compliance. At the same time, close contacts other than household contacts continued their attendance at the designated medical centres. From 25.4.03, medical surveillance and home confinement were extended to close contacts and household contacts of suspected SARS patients respectively.

The overwhelming majority of the contacts complied with the surveillance at the designated medical centres and home confinement orders. These measures were implemented smoothly, an indication of the wide acceptance by the general public, probably facilitated by the graduated enhancement approach. However, there were occasional problems. For example, the Committee had been told that at the height of the outbreak, close contacts had to wait in long queues at the designated medical centres for health screening. Concerns were expressed about placing individuals deemed to be at high risk of acquiring SARS in the same environment for a long duration. The Committee also learnt that during the isolation period of Block E residents, Owners' Committee of Amoy Gardens requested DH to set up medical posts at Amoy Gardens instead of requiring close contacts from other blocks to travel to the designated medical centres. The request was declined for operational reasons.

* Close contacts were initially defined as family members and selected contacts at workplace or school. By the end of March, DH started using WHO's definition for close contacts, which refers to contacts who had lived with, cared for, or had direct contact with respiratory secretions of the SARS patient.

Technology – a facilitating tool of outbreak management

During the initial phase of the outbreak, DH and HA had set up their own SARS databases for public health and clinical treatment purposes respectively. The two organisations were unable to access directly each other's databases because they operated two different information systems. As a consequence, they had to rely on email, faxes and phone calls for notification and exchange of case information.

Effective outbreak management requires that the flow of information must be timely. In this regard, SHWF instructed both DH and HA on 28.3.03 to develop an electronic database that would enable them to share and exchange information in real-time. This on-line database, with web access, was created from scratch drawing on the strengths of the HA's clinical management system. Named **e-SARS**, the database was launched on 8.4.03. This electronic database subsequently proved invaluable in providing timely information for prompt case investigation.

At about the same time in early April, the Police offered their sophisticated computer with geographical information system called the Major Incident Investigation and Disaster Support System (MIIDSS) to facilitate DH's work on contact tracing. MIIDSS allowed SARS investigators to validate addresses, map out the geographical distribution, reveal potential sources or routes of spread, and show the connectivity between cases and contacts.

The combination of e-SARS and MIIDSS contributed significantly to the control of the SARS outbreak by facilitating prompt case investigation and swift contact tracing, which led to effective isolation and quarantine. The information flow between the systems is illustrated graphically below –



Early case investigation
 Swift contact tracing
 Prompt isolation and quarantine

3.80 As cases in Amoy Gardens continued to rise at a rapid rate, residents panicked and many started moving out of the housing estate.

30.3.03 Sunday

3.81 By 30.3.03, there was a cumulative total of 190 suspected and confirmed SARS cases among Amoy Gardens' residents. Their distribution was as follows –

- ◆ Block E: 93 cases (49%)
- ◆ Block C: 24 cases (12.6%)
- ◆ Block B: 20 cases (10.5%)
- ◆ Block D: 15 cases (7.9%)
- ◆ The rest of the blocks: 38 cases (20%)

3.82 SHWF held the sixth meeting of the HWFB Task Force to discuss the Amoy Gardens outbreak. Key discussion points centred on the following –

- ◆ A prominent vertical stack of cases noted in Block E, with high concentration in units 8 and 7
- ◆ Field investigations by DH and its multi-disciplinary team had examined the possibilities of spreading through people movement, water supplies, garbage and elevators, sewerage system, vectors, and construction site next to the housing estate. No firm conclusion yet, and intensive investigations would continue as a matter of urgent priority. Staff of the Environment, Transport and Works Bureau would undertake additional studies on possible environmental factors
- ◆ Possibility that Block E residents had already formed an infected pool in view of the high number of cases.

3.83 Against the background of the continuing large increase in the number of cases in Block E, the HWFB Task Force also discussed the option of isolating the building to control the spread of the disease in the community. It was

considered that isolating Block E would protect the health of both the residents and the community as a whole, by preventing infected persons from spreading to other places. The other blocks would not require isolation at that stage because cases there were likely to have been infected by Block E residents, their case distribution pattern was different and there were much fewer affected households compared to Block E. The decision to issue an isolation order for Block E of Amoy Gardens was made by the Government in the evening of 30.3.03.

31.3.03 Monday

3.84 At 0600, DH served an order to isolate Block E for 10 days. Block E residents could neither come out of the block nor receive any visitors. During this period, they would be subject to medical surveillance and their daily needs would be catered for. Additionally, appeals were made to those residents who had moved out of the building prior to the isolation order to report to DH for medical surveillance.



Isolation of Amoy Gardens Block E

3.85 On the same day, DH put into operation the four designated medical centres and started a mandatory programme of medical surveillance of all close contacts of SARS patients (other than those Block E residents who had been isolated) for a period of 10 days. All contacts were further required to remain at home and not go to work, or school.

3.86 SHWF chaired the press briefing that day to explain the isolation order. It was announced that 213 residents had been admitted for suspected SARS with 107 (50.2%) coming from Block E, and that intensive investigations were underway to identify the reason for the vertical stacking of cases in Block E. He also expressed gratitude to the affected residents for their understanding and cooperation.

Fighting SARS: a concerted action

In response to the rapid escalation of the SARS outbreak, SHWF tasked his permanent secretary at HWFB to chair an Inter-departmental Action Co-ordinating Committee (IACC). The role of the IACC was to command and coordinate efforts and resources from various Government departments and public bodies to implement SARS control-related policy decisions and initiatives. Membership of the IACC comprised 4 policy/resource bureaux and more than 20 Government departments and statutory bodies.

During its operation from 27.3.03 to 20.5.03, the IACC had enhanced the capacity considerably in carrying out SARS-related public health measures. The input from members of the IACC had been key to ensuring success and smooth implementation of operations such as the isolation and evacuation of Amoy Gardens Block E, port health measures such as body temperature checking and health declaration of travellers, and the home confinement scheme.

Although IACC had been effective in mobilising resources and re-deploying manpower, some difficulties were experienced in its early operation. For example, an Owners' Committee of Amoy Gardens when providing information to the Committee mentioned that they had to shuttle among staff from different departments to gather information or ask for assistance during the evacuation exercise on 1.4.03. This was largely due to unclear site command, probably a result of the short time available for preparation.

Overall, it was considered that the IACC had met the challenge well and responded effectively to emergency situations, such as the chartering of a flight on 29.4.03 to escort home a group of Hong Kong tourists stranded in Taiwan after a child member was found to have fever, and the rescue on 4.5.03 of a Malaysian-registered vessel with suspected SARS-infected crew members on board.

A notable initiative of the IACC was the establishment of a Multi-disciplinary Response Team on 18.4.03 to undertake proactive environmental investigations and implement remedial actions in "hotspots" or buildings with SARS cases, in order that environmental contamination in these places could be proactively eliminated.

1.4.03 Tuesday

3.87 In the morning of 1.4.03, the Secretary for the Environment, Transport and Works contacted SHWF and informed him that her team of experts working with DH investigators had found preliminary evidence suggesting that the sewerage and drainage system might have been involved in the vertical spread of SARS cases in Block E. This emerging evidence was central to the decision later on during the day by the Government to evacuate Block E residents to another place for isolation. Preparations were immediately underway to carry out the evacuation exercise.

3.88 By early evening, logistics support to implement the evacuation was in place and DH announced that Block E residents would be transferred to three Government holiday camps under the removal order to continue the 10-day period of quarantine. Medical surveillance of these residents would be carried out on the camp sites. All their daily needs would also be catered for.

3.89 The evacuation exercise started after the announcement and continued through the early hours of the next day. Though stressful, all affected residents were compliant with the removal order and extended their full cooperation. At the end of the operation, a total of 247 Block E residents were evacuated.

SARS coronavirus and stool

Patients with SARS excrete the virus in their faeces. The WHO multi-centre collaborative network of laboratories showed that the SARS coronavirus could survive in normal faeces at room temperature for at least 1-2 days. However, the survival time of the virus was considerably longer, and could reach up to 4 days, in stool from patients with diarrhoea which has higher pH than normal stool. This observation raised the possibility of oral-faecal transmission of the disease. It was also of relevance to the Amoy Gardens outbreak in which the drainage and sewerage system was implicated in facilitating the spread of SARS. The index case of Amoy Gardens was noted to have diarrhoea at the time of illness on 14.3.03 when he was staying overnight at his brother's flat in Block E.

A notable clinical feature of the SARS patient from Amoy Gardens, as reported in the *Lancet**, was that 73% of them had watery diarrhoea. The maximum frequency was 6.3 times per day, with a mean duration of 3.9 days. This implied that a significant viral load could have been discharged into the sewerage system, facilitating the spread of the disease.

The study investigators noted, "*diarrhoea seemed more prominent (in these patients) than previously reported, and the severe watery diarrhoea in these patients presented a challenge to healthcare workers for infection control*". This observation might have contributed, to some extent, to the outbreak among healthcare workers in the Princess Margaret Hospital, which had taken in the majority of the SARS patients from Amoy Gardens.

* JSM Peiris et al., "Clinical Progression and Viral Load in a Community Outbreak of Coronavirus-associated SARS Pneumonia: A Prospective Study", *Lancet*, 9 May 2003.

2.4.03 Wednesday – 15.4.03 Tuesday

3.90 After Block E residents were evacuated, a multi-disciplinary team of experts proceeded to carry out in-depth investigations at Amoy Gardens. Households that moved out of Block E before imposition of the isolation order were again urged to contact DH for medical surveillance. By 4.4.03, with assistance from the Police, virtually all of them had been contacted for this purpose.

3.91 A thorough disinfection and pest control exercise was undertaken by the Food and Environmental Hygiene Department in Amoy Gardens and surrounding area, including Ngau Tau Kok Lower Estate, a public housing estate in the vicinity of Amoy Gardens. During this period, the Ngau Tau Kok Lower Estate was also experiencing an outbreak, albeit on a much smaller scale. With the cooperation of the Owners' Committee and residents concerned, all units and common areas of Amoy Gardens Block E were thoroughly cleansed and disinfected between 7.4.03 and 10.4.03. Guidelines and disinfectants were provided to residents of other Blocks in the housing estate to disinfect their flats. The importance of maintaining water seal at the U-traps of drainage outlet was also emphasised.

3.92 Under intense local and international media coverage of the Amoy Gardens outbreak, many residents from all blocks felt that they were being singled out and discriminated against. An exodus of Amoy Gardens residents continued. To diffuse the situation, the Owners' Committee urged the Government to release the names of other buildings with SARS cases. At the same time, there were also calls from the community for DH to disclose the location of infections. The Government was eventually swayed by public opinion and DH started releasing the names of buildings with SARS cases on 12.4.03 on its website. The intention was to help alert residents of the affected buildings to further strengthen appropriate precautionary disinfection measures and enhance personal hygiene. The listing of affected buildings was extended to those with suspected SARS cases on 25.4.03.

3.93 The isolation order for Block E expired at midnight on 9.4.03. On 10.4.03, the residents started to return home.

3.94 It was observed that between 1.4.03 and 15.4.03, there were 5 SARS patients from Block E of Amoy Gardens, with onset dates as follows –

- ◆ 1.4.03 – 2 cases; all were household contacts of previous SARS cases
 - ◆ 2.4.03 – 1 case; history of travel to Shenzhen from 28.3.03 to 3.4.03
 - ◆ 3.4.03 – 1 case; household contact of a previous SARS case
 - ◆ 15.4.03 – 1 case; identified while in hospital.
- After 15.4.03, no more SARS patient was identified from Block E.

The puzzle of the vertical spread

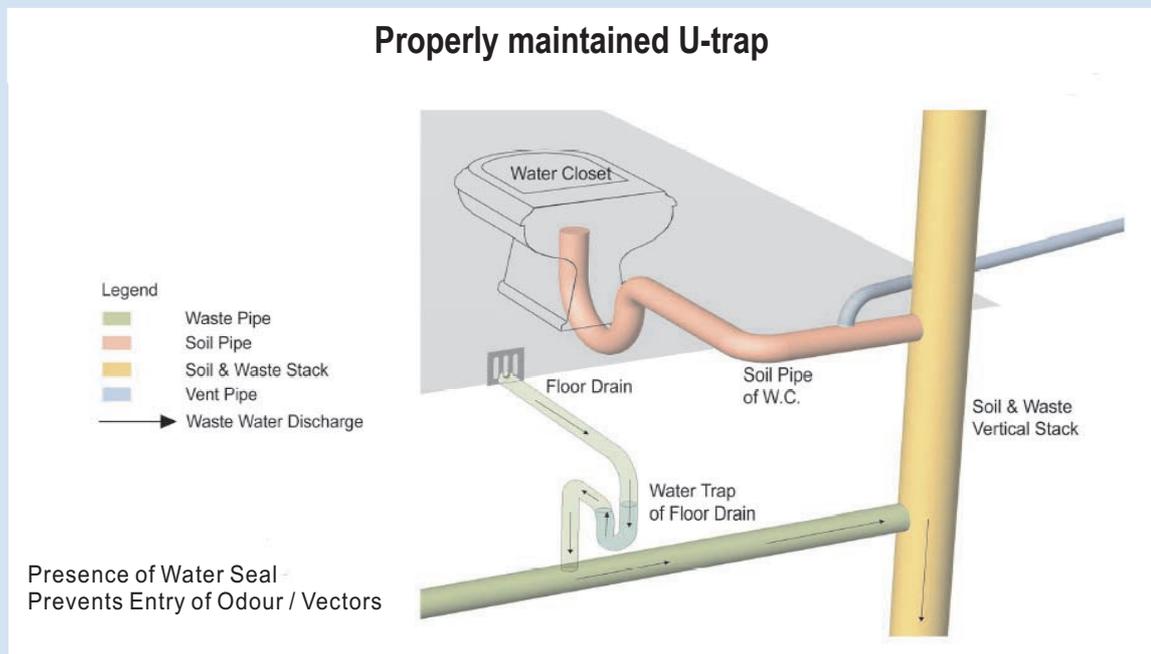
On 17.4.03, the Government released its investigation findings in respect of the Amoy Gardens outbreak. The vertical spread of SARS in Block E was attributed to a combination of dried-up U-traps, contaminated sewage, and updraft in the lightwell, that facilitated droplet spread. The findings were later corroborated by a report released on 16.5.03 by an expert environmental health team of WHO, who had carried out an independent investigation on the community outbreak. Both reports were posted on the website www.info.gov.hk/info/sars/e_report.htm.

The studies highlighted the following –

- ◆ At the time of the outbreak, the U-traps of the bathroom floor drains in most apartments had been dry for long periods, losing their sealing function to the soil stack. In the case of a running exhaust fan and a closed bathroom door, droplets would have been drawn from the soil stack into the bathroom through the dry U-trap, thus contaminating the bathroom
- ◆ A break of a flush-water pipe serving all unit 8 apartments of Block E on 21.3.03 led to an overnight shutdown of the flush-water system. This event most likely decreased the flow, but increased the generation and movement of droplets, in the soil stack. In addition, bucket flushing would have increased the generation of droplets in the bathroom
- ◆ The running exhaust fan served to transport into the lightwell contaminated droplets present or generated in the bathroom. Due to the natural current within the lightwell, these droplets had the tendency to move up and could enter an apartment several floors away from the source through an open window.

In the light of these findings, DH and other relevant Government departments had embarked on an extensive public education on household disinfection, proper care of U-traps, and maintenance of sewer piping systems. The message of environmental hygiene was emphasised, together with that of personal hygiene.

The puzzle of the vertical spread (continued)



Notwithstanding the findings, other investigators continued to offer alternative hypotheses. For example, a private investigator had put forward a rat vector hypothesis in the August issue of the *Lancet* and to the Committee. Also submitted to the Committee was a study report on sewage system prepared by a local university. The study showed that varying pressure inside the soil stack, affected by a host of pipe conditions, such as length and size, could cause an upward movement of air and droplets through the pipe.