Investigation Report on the Incident of Unpleasant Odour in Drinking Water in Kwai Chung and Tsuen Wan

January 2018

Contents

Chapter 1 Introduction

The Incident

1.1 The Water Supplies Department (WSD) received complaints from residents in some areas of Kwai Chung and Tsuen Wan starting from the night of 18 November 2017 (Saturday) to the late afternoon of 20 November 2017 (Monday) regarding unpleasant odour[1] in drinking water.

1.2 Upon receiving the complaints, the WSD deployed the standby teams to follow up the case by flushing the water mains in the water supply network of the affected areas through fire hydrants in accordance with the established procedures with a view to restoring the quality of drinking water supply to the customers as soon as possible.

1.3 When more and more complaints on unpleasant odour in drinking water were received, it was suspected that the cause was at the source of the drinking water supply to the affected areas i.e. the Tsuen Wan Fresh Water Service Reservoir (TWFWSR). The WSD therefore arranged to change the source of drinking water supply for the affected areas from TWFWSR to Tsuen Wan No. 2 Fresh Water Service Reservoir, Tsuen Wan West Low Level Fresh Water Service Reservoir and Lai Chi Kok Fresh Water Service Reservoir by opening / closing valves in the water supply network. The change of drinking water supply source to the affected areas was completed at around 8pm on the evening of 19 November 2017. However, flushing of the water mains in the water supply network of the affected areas had to be continued in order to remove the residual water in the water mains from the previous source. By noon of 20 November 2017, no more unpleasant odour was detected in the drinking water in the water supply network.

1.4 However, it was still necessary to drain away the residual water from the previous source in the inside services of the affected housing estates / buildings and clean their sump and roof water tanks. The WSD proactively offered technical support to the related management offices of the affected housing estates /

[1] The residents complained that there was cleaning agents, thinners and varnishes-like smell in the drinking water.

buildings in draining away the residual water and cleansing of their tanks. With the residual water being drained away, no further complaint on unpleasant odour in drinking water from the affected areas was received by the WSD since the late afternoon of 20 November 2017. The WSD also deployed water wagons and/or water tanks since the night of 19 November 2017 to provide drinking water to the affected residents until they were no longer required.

1.5 **Figure 1** shows the affected housing estates / buildings from which complaints on unpleasant odour in drinking water were received. The WSD estimated that there were about 60 000 residents affected by the incident.

1.6 On the evening of 20 November 2017, the WSD issued a press release to give an account of the latest development of the incident and the findings of its initial investigation into the incident **(Annex A)**.

1.7 On the morning of 21 November 2017, Mr CHAN Chung-kun, the Assistant Director (New Territories) of the WSD, gave an account of the incident including the WSD's follow-up actions in two radio phone-in programmes. The WSD also uploaded the latest information regarding the incident onto the webpage on the same day **(Annex B)**.

1.8 The WSD took water samples from the outlet pipe of the TWFWSR, the water supply network and the inside services of the affected estates / buildings from 20 to 23 November 2017 for rapid toxicity tests[2]. The water samples were also tested for the 15 health-related volatile organic compounds (VOC) parameters[3] in the World Health Organization *Guidelines for Drinking-water Quality* (WHO Guidelines). All water samples had negative toxicity test results and their VOC contents complied with the requirements of WHO Guidelines as shown in the water sampling test results at **Annex C**.

[2] The rapid toxicity test is an internationally well-recognised technique based on the bioluminescent technology (light-emitting bacteria) that is able to accurately screen over 1,000 harmful substances.

[3] The 15 VOC parameters include benzene, carbon tetrachloride, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane, 1,2-dichloroethene, dichloromethane, ethylbenzene, hexachlorobutadiene, styrene, tetrachloroethene, trichloroethene, toluene, vinyl chloride and xylenes.

The Investigation Team

1.9 On 21 November 2017, the Director of Water Supplies set up an independent Investigation Team headed by the then Assistant Director of Water Supplies (Mechanical and Electrical), Mr. WONG Man Ching, with team members comprising Assistant Director (Urban), Mr. LAM Ching Man and Chief Chemist (Acting), Mr. LI Lun Ho Joseph who were all independent from the Supply and Distribution (New Territories) Branch responsible for the water supply system in the affected areas and had not been involved in the incident.

1.10 The terms of reference of the Investigation Team are as follows:

(i) To look into the cause(s) of the incident; and
(ii) To recommend improvement measures to prevent recurrence of similar incidents in future.

1.11 This Report will present the investigation conducted by the Investigation Team and the identified cause of the incident as well as other observations in **Chapter 2** and its conclusion in **Chapter 3**. The recommendations of the Investigation Team to prevent recurrence of similar incidents in future will be presented in **Chapter 4.**

Chapter 2 Investigation and Findings

2.1 This Chapter gives a detailed account of the investigation conducted by the Investigation Team and their findings in identification of the cause of the unpleasant odour in drinking water and the safety of the drinking water during the incident as well as their other observations of the incident.

2.2 The Investigation

2.2.1 Upon switching the drinking water supply source for the affected areas from the TWFWSR to other fresh water service reservoirs on the evening of 19 November 2017 and after flushing the residual water in the water mains of the water supply network from the TWFWSR, no unpleasant odour was detected in the drinking water in the water supply network. Therefore, it was likely that the incident was related to the source of the affected areas, viz. the TWFWSR. The Investigation Team noted that there were maintenance works being carried out at the TWFWSR during the incident and therefore conducted detailed investigation of the cause of the incident along this direction.

2.2.2 The Investigation Team conducted site inspections at the TWFWSR, examined the test results of the water samples taken during the incident and the materials used in the maintenance works, reviewed the related documents and records, and met the maintenance contractor and relevant staff of the WSD.

2.3 Identification of the cause of unpleasant odour in drinking water

(I) Internal design of the TWFWSR

2.3.1 The TWFWSR is a service reservoir built in 1957 with two compartments, which are separated by a concrete division wall. Such design is conventional which allows one compartment to be in operation to supply water while maintenance works are being carried out at the other compartment in order to maintain the reliability of the water supply system. As the division wall is about 2.5 metres lower than the ceiling of the service reservoir, there is a gap between the top of the division wall and

the ceiling of the service reservoir. Plastic curtains for air insulation have been installed to seal off the gap.

2.3.2 However, the 60-year old TWFWSR is of an old layout design with two access manholes with cat ladders on the top of the division wall to allow access to the service reservoir for carrying out maintenance works. As a result, the gap on top of the division wall at the locations of the access manholes / cat ladders has not been completely sealed off with plastic curtains for air insulation.

2.3.3 **Figure 2** shows the general layout of the service reservoir.

(II) Use of protective coating material

2.3.4 Maintenance works were carried out at the eastern compartment of the TWFWSR starting in early October 2017 to maintain its durability and water-tightness. The compartment was drained down on 2 October 2017 while the western compartment continued to be in operation for supplying water. The repair works in the eastern compartment, commenced on 7 October 2017, were first to repair the worn-out walls and floor joints by applying epoxy coating (MasterProtect 180) and joint sealant (Polyseal PS) and no complaint on unpleasant odour of drinking water had been received during this period. In the final stage of the maintenance works, a protective coating was to be applied to the worn-out part of the floor slab (about 250 square metres, 16% of the total floor slab area) of the eastern compartment. **Figure 3** shows the schematic arrangement of the maintenance works to the floor slab in the eastern compartment.

2.3.5 The protective coating for applying to the worn-out part of the floor slab of the eastern compartment was SPUA-406. It is a polyurea-based material and is an approved product under the United Kingdom Water Regulations Advisory Scheme (WRAS). The cured protective coating contains no harmful substance to human and complies with the BS6920 for use in potable water installation works. A copy of the approval document is at **Annex D**. Moreover, the product is anti-skid.[4] The raw

[4] The usual epoxy repair material is slippery.

materials of the SPUA-406 contain VOCs which give unpleasant odour as they evaporate during the curing of the protective coating. The VOCs will totally evaporate after the protective coating has been completely cured and no further odour will be released.

2.3.6 Maintenance works are not usually required for the floor slab of service reservoirs. However, as the TWFWSR has been put into use for many years, there were worn-out parts on the floor slab in the eastern compartment which required application of protective coating. In view of the anti-skid property of SPUA-406, it was used as protective coating for the floor slab to prevent the WSD staff / workers from slippery when they are working inside the service reservoir thus meeting occupational safety and health requirements. It was the first time that the product was used in one compartment of a service reservoir while the other compartment was in operation to supply water.

(III) Construction procedures

2.3.7 The maintenance works for application of the protective coating to the floor slab of the eastern compartment commenced on the morning of 18 November 2017. The works were carried out until 3:30 pm on that day. With the evaporation of the VOCs from the protective coating during its curing, the eastern compartment was filled with odour.

2.3.8 The investigation revealed that the contractor did not seal off the two openings without plastic curtains for air insulation at the locations of the access manholes / cat ladders. Instead, the contractor arranged to extract the air from inside of the service reservoir to the outside by means of blower fans, i.e. forced ventilation at the two access manholes.

2.3.9 The forced ventilation was however not effective. Since the air blowers were located at the access manholes on top of the division wall to extract air from the service reservoir, the VOC fumes from the corner of the eastern compartment flew in the direction to the western compartment. The VOC fumes in the eastern compartment were not totally extracted from the service reservoir and some of the VOC fumes got into the western compartment through the two openings and dissolved into the

drinking water. After the forced ventilation stopped at 5:30 pm on 18 November 2017, about 2 hours after the maintenance works had been finished on that day, the VOC fumes in the eastern compartment continued to diffuse into the western compartment through the two openings and dissolved in the drinking water in it. **Figure 4** illustrates how the VOC fumes from the eastern compartment got into the western compartment and dissolved in the drinking water.

2.3.10 The drinking water with dissolved VOCs were distributed from the western compartment of the TWFWSR through water mains to the customers. As a result, when the drinking water was drawn from the water taps by the customers, the VOCs were released from the drinking water thus causing odour problems to the customers. The VOCs have such a low odour threshold that even a very low concentration in the drinking water could be perceivable by the customers. To confirm this point, an odour testing panel was set up to verify the odour threshold of xylene[5] in water (the major VOC constituent of the protective coating raw materials). All panel members detected odour at a concentration well below the guideline value for xylene in the WHO Guidelines. Please refer to **Annex E** for details of the results of the testing panel.

(IV) Benchtop Study to confirm the identified cause

2.3.11 In order to confirm the cause of the incident as identified above, the Investigation Team made reference to an overseas research[6] and conducted a benchtop study to confirm the cause as identified above. Two glass tanks were used to simulate the operating condition of the two compartments of the TWFWSR during the incident, i.e. one compartment being emptied (for maintenance works) while the other one being filled with water (in operation), with openings provided to simulate incomplete separation of the two compartments. Details of the experiment are given in **Annex F.** The result of the experiment showed that odour released from the protective coating material applied in the empty glass tank could diffuse through a narrow tubing

[5] In this report, "xylene" refers to a mixture of isomers including *ortho*-, *meta*- and *para*-xylenes which often co-exist in commercial products.

[6] M.G. Mahmoodlu et al, 2017, Dissolution kinetics of volatile organic compound vapors in water: An integrated experimental and computational study, Journal of Contaminant Hydrology 196 (2017) 43-51.

connected to the other glass tank and caused odour in the water. The result of the experiment supported the validity of the cause of the incident as identified above.

2.4 Possibility of accidental spillage of the protective coating material into the compartment in operation during delivery

2.4.1 The Investigation Team noted that the protective coating material had been delivered manually to the eastern compartment through the access manholes above the division wall. The Investigation Team therefore also explored whether the incident could have been caused by accidental spillage of the protective coating material into the drinking water in the western compartment during its delivery into the eastern compartment.

2.4.2 The Investigation Team arranged draining down the western compartment and conducted a detailed inspection of the compartment. The Investigation Team did not find any sign of residual protective coating material on the walls and floor slabs of the compartment particularly in the vicinity of the access manholes. Photos showing the condition of the western compartment after it was drained down are shown in **Annex G.**

2.4.3 The Investigation Team therefore considered that the incident should not have been caused by accidental spillage of the protective coating material into the western compartment.

2.5 Drinking water safety during the incident

2.5.1 There were concerns regarding the safety of the drinking water with the unpleasant odour supplied to the customers during the incident. The Investigation Team noted that the WSD staff had been engaged in flushing the water mains as well as the subsequent operation of the valves in the water supply network to switch the drinking water supply source for the affected areas during the incident. The WSD staff had not taken water samples from the taps of the customers before the switching of the supply source. Nevertheless, the WSD took a water sample from the outlet pipe of the western compartment of the TWFWSR on the following morning of 20 November 2017 for water quality testing [Note: the water supply from the western

compartment of the TWFWSR was suspended since the evening of 19 November 2017]. The Investigation Team considered that the water sample should have adequately reflected the quality of the drinking water with an unpleasant odour supplied to the customers during the incident as the TWFWSR was the source of drinking water supply to the affected areas during the incident and the outlet pipe was an enclosed conduit through which the VOCs in the drinking water could not evaporate and hence there should be no reduction in the VOC content in the drinking water at the time the water sample was collected.

2.5.2 The water sample taken at the outlet pipe of the western compartment on the morning of 20 November 2017 had an unpleasant odour. The rapid toxicity test result of the water sample was negative, i.e. non-toxic. The water sample was also tested for the contents of the 15 health-related VOC parameters in the WHO Guidelines and all results complied with the requirements of the WHO Guidelines. The water sample test results are at item 10 of **Annex C.** Based on the test results of the water sample, the drinking water, though with an unpleasant odour, should not cause any health hazard. As explained in paragraph 2.3.10 above, due to the low odour detection threshold, a very low VOC concentration in the drinking water would still be perceivable by the customers despite the fact that the VOC concentration in the drinking water was compliant with the requirements of the WHO Guidelines.

2.5.3 After switching the drinking water supply source to the affected areas and draining away the residual water from the previous source in the water supply network and inside services, the WSD took water samples from the water supply network and the inside services of the affected estates / buildings from 20 to 23 November 2017 for rapid toxicity test and test for VOC contents. The water samples all had negative toxicity test results and their VOC contents complied with the requirements of WHO Guidelines which confirmed that the drinking water after the switch of source is also safe. Details of the water sample test results are shown in **Annex C**.

2.6 Other observations

2.6.1 Since the western compartment of the service reservoir continued to supply drinking water when maintenance works in the eastern compartment was in progress, the contractor should have the responsibility to adopt appropriate measures to effectively and completely separate the two compartments to prevent the drinking water in the western compartment from being affected. The contractor however had not properly discharged his responsibility by sealing off the two openings present at the access manholes / cat ladders that had not been covered up with plastic curtains for air insulation. He only relied on forced ventilation to extract the VOCs released from the application of the protective coating to the floor slab in the eastern compartment. The forced ventilation was ineffective and some of the VOC fumes got into the western compartment through the two openings and dissolved into the drinking water therein. Moreover, the forced ventilation stopped at around 5:30 pm after the maintenance works had been finished for two hours and the VOC fumes in the eastern compartment continued to diffuse into the western compartment through the two openings and dissolved in the drinking water.

2.6.2 The maintenance works to the floor slab of the eastern compartment were under the WSD's supervision and the material and methodology proposed by the contractor had been reviewed by the WSD staff. The site work was supervised by a Works Supervisor II of the WSD. Both the staff responsible for reviewing the material and methodology proposed by the contractor and the staff supervising the work had underestimated the possibility that the VOCs released from the protective coating material in the eastern compartment could get into in the western compartment in operation through the two openings and dissolve in the drinking water. It reflects that they lacked awareness of the possible impact of the maintenance works on drinking water quality.

2.6.3 In handling the incident, the WSD switched the drinking water supply source as soon as they suspected that the service reservoir could be the cause of the incident and deployed water wagons and tanks to mitigate the impact on the customers during the incident. In addition, the WSD issued a press release on 20 November 2017 and gave an account of the incident in radio phone-in programmes and uploaded related information

on its website on 21 November 2017.

2.6.4 In spite of the above effort made, the Investigation Team considered that there was still room for improvement in respect of management of the incident in several aspects. Although a water sample was taken from the outlet pipe of the western compartment of the TWFWSR on the morning of 20 November 2017 for water quality testing and the water sample should have adequately reflected the quality of the drinking water with an unpleasant odour supplied to the customers during the incident, the Investigation Team considered that in future, it would be a better arrangement to collect water samples from the supply network and consumer taps at the onset / early stage of the incident so that the water sampling test results could be released earlier to alleviate the concern of the affected customers over the quality of the drinking water supplied to them during the incident. Moreover, the Investigation Team opined that press release or updated information should be issued earlier to keep the affected customers and the media informed of the situation and the measures being taken by the WSD to tackle the incident. Furthermore, the Investigation Team considered that it would be helpful if the WSD would provide relevant guidelines for reference of the property management companies to facilitate them to take prompt and appropriate contingency measures including draining away the water of substandard quality, cleansing of their inside services etc. in response to water quality incidents.

Chapter 3 Conclusion

3.1 The Investigation Team has the following conclusion:

(i) The unpleasant odour in the drinking water in some of the areas in Kwai Chung and Tsuen Wan was caused by the VOCs released from the application of protective coating to the floor slab in the eastern compartment of the TWFWSR, that got into the western compartment in operation through the two openings above the division wall (at the locations of the access manholes / cat ladders which had not been sealed off by plastic curtains for air insulation) and dissolved in the drinking water in the western compartment which was then distributed to the customers.

(ii) The drinking water supplied to the customers during the incident, though with an unpleasant odour, should not cause any health hazard. As the VOCs have a low odour detection threshold, a very low VOC concentration in the drinking water would still be perceivable by the customers despite the fact that the VOC concentration in the drinking water was compliant with the requirements of the WHO Guidelines.

Chapter 4 Recommendations

4.1 To prevent recurrence of similar incidents, the Investigation Team recommends the following short- and long-term improvement measures:

Short-term measures

(i) For maintenance works carried out in one compartment of a service reservoir with another compartment in operation for supplying water, all openings between the ceiling of the service reservoir and the division wall should be completely sealed off;

(ii) The use of materials with high VOC contents (including those in the raw materials) for maintenance works inside service reservoirs under condition (i) above should be stopped immediately;

(iii) Contractors should be required to conduct a Water Quality Impact Assessment (WQIA) by relevant professionals before carrying out construction or maintenance works that may affect drinking water quality, including assessing the risk of impacts of the works on drinking water quality, determining the level of supervision required, formulating corresponding preventive measures and establishing a monitoring system which includes regular inspection and water sampling tests. The WQIA should be duly vetted and approved by senior professionals of the WSD;

(iv) Regular training for front-line staff to enhance their awareness of the possible risk on drinking water quality posed by construction and maintenance works should be strengthened;

The Investigation Team noted that the above short term measures have already been implemented by the WSD.

Long-term measures

(v) The arrangements for handling water quality incidents,

which include the collection of water samples for testing and the release of information to the affected customers and the media, should be reviewed and further enhanced; and

(vi) Guidelines should be provided to property management companies to assist them to take prompt and appropriate contingency measures in response to water quality incidents.

- End -

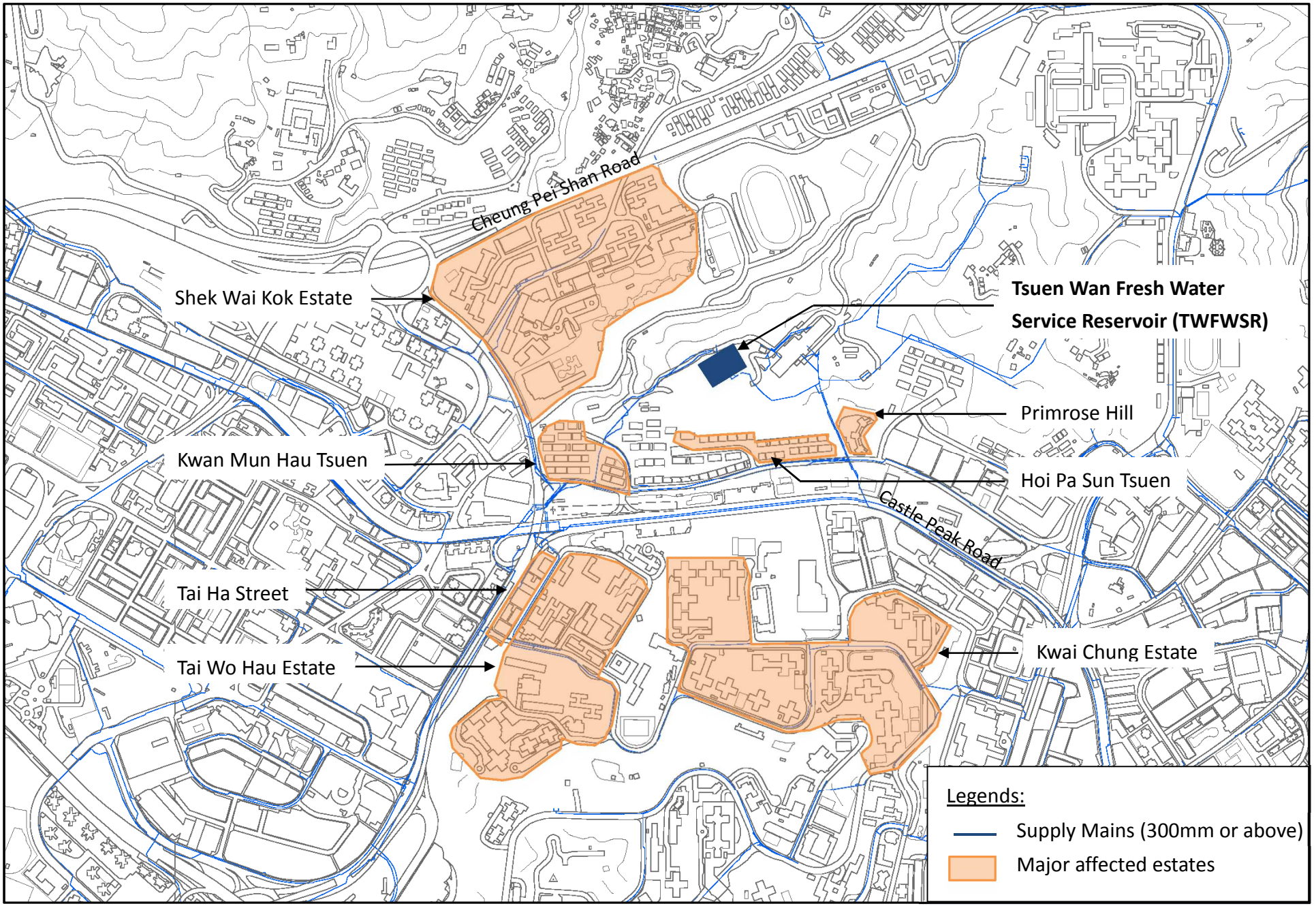

Figure 1 - Affected housing estates / buildings from which complaints on unpleasant odour in drinking water were received.

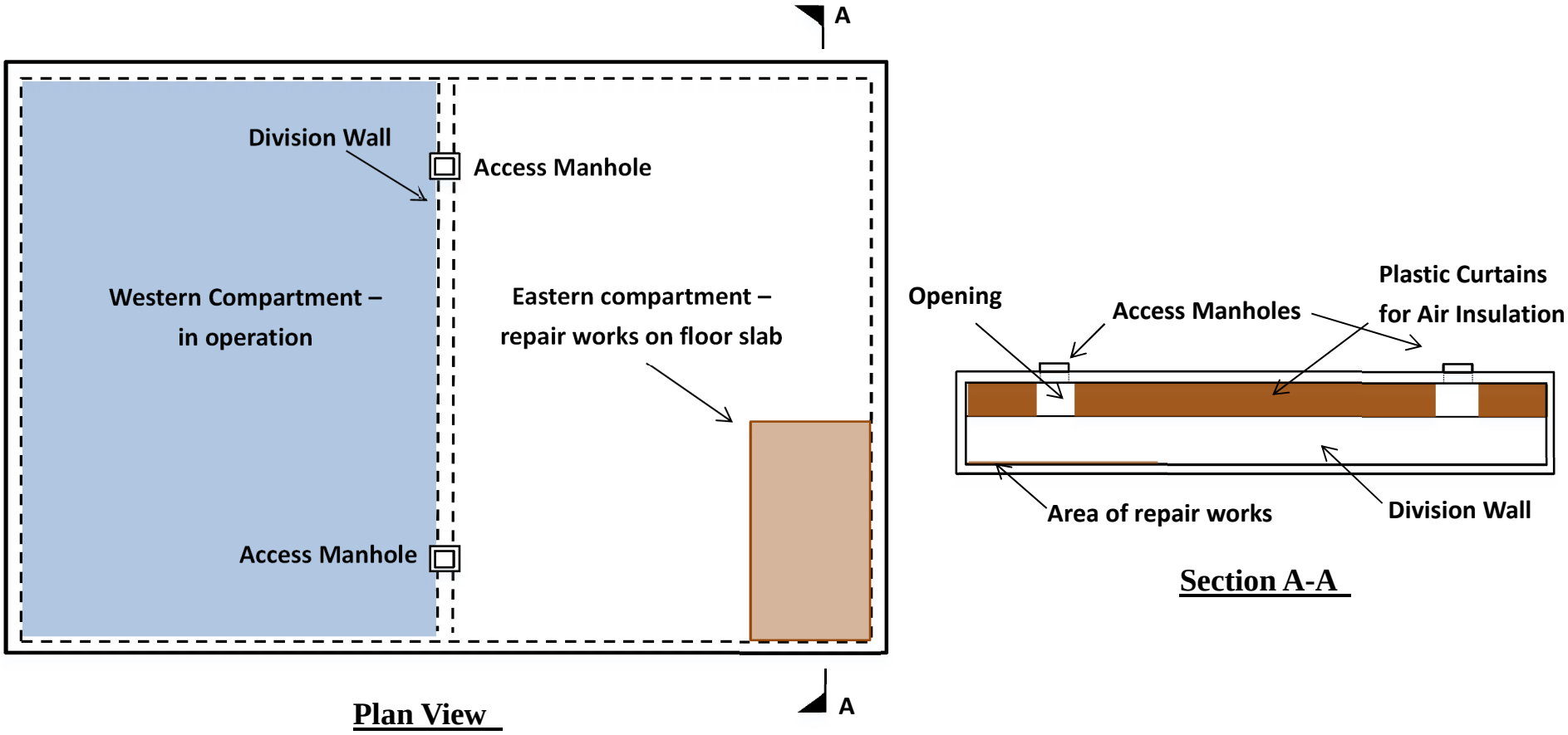

Figure 2 – General layout of Tsuen Wan Fresh Water Service Reservoir

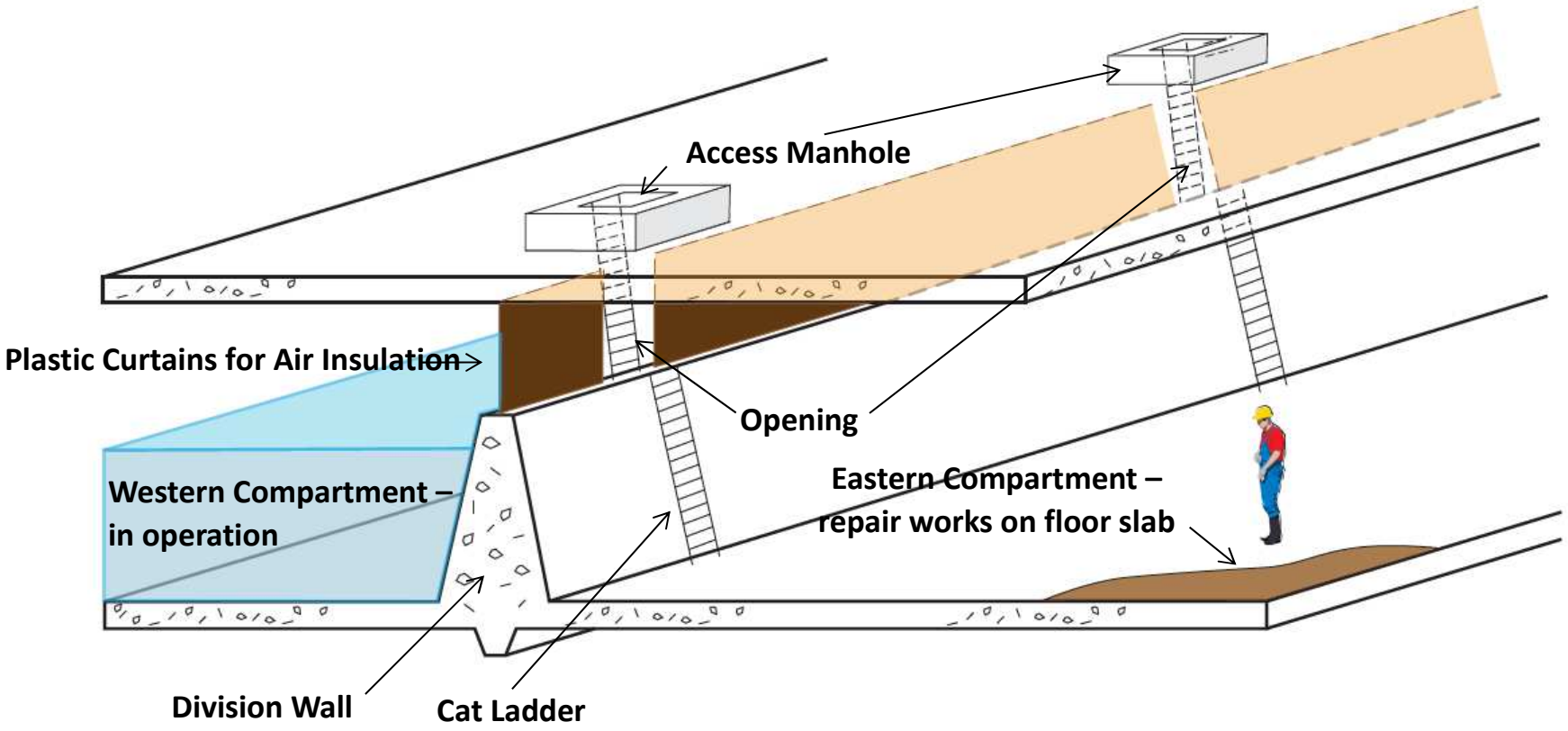

Figure 3 - Schematic arrangement of floor slab repairing works

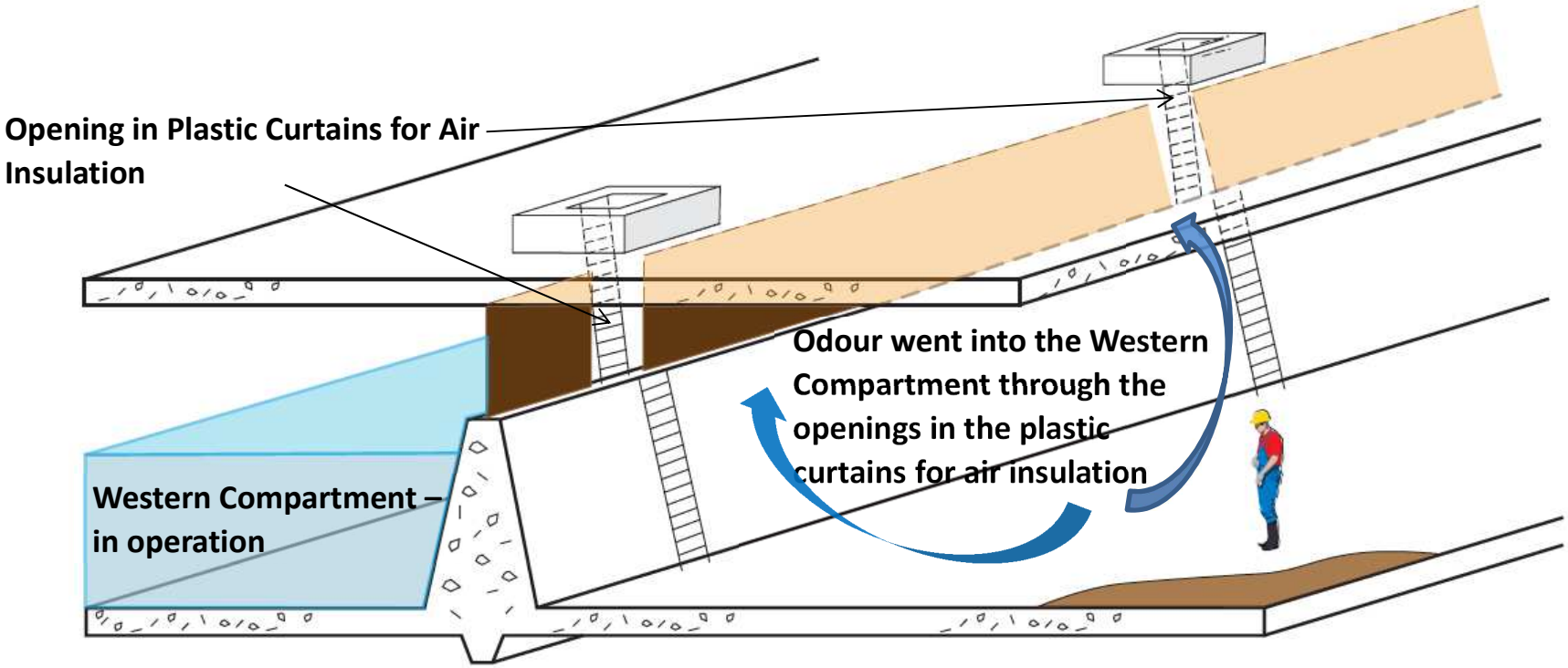

Figure 4 Odour went from eastern compartment to western compartment of the service reservoir

Annex A

WSD responds to media enquiries on drinking water quality in Kwai Tsing District and Tsuen Wan District[7]

In response to media enquiries on the drinking water quality in Kwai Tsing District and Tsuen Wan District, a spokesman for the Water Supplies Department (WSD) said today (November 20):

After receiving a number of enquiries from residents of Kwai Tsing District and Tsuen Wan District about an unpleasant odour in drinking water yesterday (November 19), the WSD immediately followed up, including flushing through fire hydrants near the affected areas and providing drinking water supply to the affected districts from another supply network last night.

The WSD has been proactively liaising with the management offices of the affected housing estates to provide technical support to help them to drain away the drinking water stored in the sump and roof drinking water tanks and clean the water tanks. In addition, the WSD has deployed water wagons and/or water tanks in Kwai Tsing and Tsuen Wan Districts to provide drinking water to residents in need during the cleaning of water tanks.

WSD's initial investigation reveals that the unpleasant odour in the drinking water in the above-mentioned districts may be related to the maintenance work at the Tsuen Wan Fresh Water Service Reservoir and the WSD is carrying out further investigations. The WSD suspended the supply of drinking water from the service reservoir last night and has taken water samples for testing. Initial results show that there was no substance in the water samples that was harmful to

[7] Press release dated 20 November 2017: http://www.info.gov.hk/gia/general/201711/20/P2017112000963.htm?fontSize=1

humans.

The WSD will continue to closely monitor the quality of water supply to ensure the safety of drinking water quality.

Ends/Monday, November 20, 2017
Issued at HKT 21:13

Annex B
(Chinese only)

有關葵青及荃灣區食水出現異味事件[8]

市民查詢及即時跟進

水務署於11月18日(星期六)傍晚至11月19日(星期日)期間接獲多宗葵青及荃灣區居民表示食水出現異味的查詢。署方隨即派員跟進，並按一般程序於受影響地區附近的消防栓沖水，以排走有異味的食水。然而，我們發現問題持續，遂估計屬區域性供水事件，因此當晚調動供水網絡將水源轉至荃灣二號食水配水庫、荃灣西低地食水配水庫及荔枝角食水配水庫，並繼續於受影響地區附近的消防栓沖水，直到11月20日(星期一)中午，供水網絡的食水已没有異味。

水務署同時積極聯絡受影響屋苑的管理處，以提供技術支援，協助他們排走貯存在天台及地下食水貯水缸內的食水和清洗貯水缸，並在受影響屋苑安排水車及／或水箱，為有需要的居民提供食水。

初步調查

水務署初步估計上述地區食水出現異味可能與荃灣食水配水庫的維修工程有關。有關工程屬於定期維修保養工程，主要在配水庫地台加上保護層，以維持配水庫混凝土結構的耐用性和防水效能。保護層的物料完全符合相關標準，並適用於食水中，承建商亦已提交相關證書。配水庫一般在中央設置混凝土牆，把水庫分為兩個間隔，以便維修工程在其中一邊進行時，另一邊仍可維持正常供水。由於混凝土牆頂部與配水庫上蓋之間存有空隙，在進行上述維修工程前，承建商需使用隔氣膠簾把空隙密封，令工地與配水庫另一邊的供水部分完全分隔。我們初步估計今次事件的成因是修補物料產生的氣味可能透過隔氣膠簾的空隙揮發至配水庫的供水部分，令食水出現異味。

跟進工作

水務署於11月19日晚已停止從荃灣食水配水庫供水，並於該配水庫抽取食水樣本化驗，初步結果顯示，食水樣本並無含有對人體有害的物質。有關化驗包括國際慣用的快速毒性檢測，利用生物發光技術(發

[8] The WSD uploaded the latest information regarding the incident on the webpage : http://www.wsd.gov.hk/tc/media-corner/hot-topics/water-smell-in-kwai-tsing-tsuen-wan/index.html

光菌)能快速、準確地測試超過 1,000 種有害物質，結果食水並無含有對人體有害的物質。同時，署方亦對食水樣本進行了有機化合物測試，結果符合世衛標準。

另外，調動供水網絡後，水務署於 11 月 20 日進一步在供水網絡及大廈的內部供水系統抽取食水樣本進行快速毒性檢測，結果顯示調動供水網絡後供應的食水並無含有對人體有害的物質。署方亦正為食水樣本進行有機化合物測試，並會繼續密切監察供水水質的情況，確保食水安全。

水務署會深入調查事件，並盡快完成調查報告。及後會作出跟進工作，包括審視承建商的責任，以及檢討和改善有關工作流程，以避免同類事件再次發生。

Water sampling test results

Annex C

No.	Date	Time	Location			Volatile Organic Compounds (VOC)														
				Rapid Toxicity Test	Odour	Benzene (μg/L) (WHO GV: 10 μg/L)	Carbon tetrachloride (μg/L) (WHO GV: 4 μg/L)	1,2-Dichlorobenzene (μg/L) (WHO GV: 1000 μg/L)	1,4-Dichlorobenzene (μg/L) (WHO GV: 300 μg/L)	1,2-Dichloroethane (μg/L) (WHO GV: 30 μg/L)	1,2-Dichloroethene (μg/L) (WHO GV: 50 μg/L)	Dichloromethane (μg/L) (WHO GV: 20 μg/L)	Ethylbenzene (μg/L) (WHO GV: 300 μg/L)	Hexachlorobutadiene (μg/L) (WHO GV: 0.6 μg/L)	Styrene (μg/L) (WHO GV: 20 μg/L)	Tetrachloroethene (μg/L) (WHO GV: 40 μg/L)	Trichloroethene (μg/L) (WHO PGV: 20 μg/L)	Toluene (μg/L) (WHO GV: 700 μg/L)	Vinyl chloride (μg/L) (WHO GV: 0.3 μg/L)	Xylenes (μg/L) (WHO GV: 500 μg/L)
1	20/11/2017	6:00	Fire hydrant PH5446, Kwok Shui Road, Tsuen Wan	Negative	Pungent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	20/11/2017	6:00	Fire hydrant PH1673, Kwong Fai Circuit, Tsuen Wan*	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	20/11/2017	6:00	Fire hydrant PH5451, Tai Ha Street, Tsuen Wan	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	20/11/2017	6:00	Fire hydrant PH4095, Tai Ha Street, Tsuen Wan	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	20/11/2017	6:00	Fire hydrant PH4075, Shek Wai Kwok Estate	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	20/11/2017	6:00	Fire hydrant PH280, Kwai Chung Estate, Kwai Chung	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	20/11/2017	11:02	Kwai Chung Estate Mall	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	20/11/2017	11:37	Fire hydrant PH540, Kwai Hop Street*	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	20/11/2017	12:34	Fire hydrant PH843, Shing Fong Street*	Negative	No Odour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	20/11/2017	11:45	Tsuen Wan FW SR outlet pipe	Negative	Pungent	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
11	20/11/2017	12:30	Tsuen Wan West FW Low Level SR*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
12	20/11/2017	13:05	Yau Kom Tau FW SR No.1*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
13	20/11/2017	13:30	Yau Kom Tau FW SR No.2*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
14	20/11/2017	20:05	Fire hydrant PH4076, near Shek Wai Kok Road	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
15	20/11/2017	20:09	Male Toilet, Shek Fong House, Shek Wai Kok Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
16	20/11/2017	20:27	Management Office, Fu Kwai House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
17	20/11/2017	20:35	Fire hydrant PH5446, near Ting Kwok Street	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
18	20/11/2017	20:54	Management Office, Ha Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
19	20/11/2017	20:55	Fire hydrant PH4095, near Tai Ha Street	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
20	20/11/2017	21:03	Management Office, Luk Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
21	20/11/2017	21:07	Fire hydrant PH5451, near Tai Ha Street	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
22	20/11/2017	21:20	Male Toilet, Fu Pik House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
23	20/11/2017	21:26	Fire hydrant PH820, near Tai Wo Hau Road	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
24	20/11/2017	21:44	Male Toilet, Kwai Fong Terrace Shopping Centre*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
25	20/11/2017	21:48	Fire hydrant PH1673, near Kwong Fai Circuit*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
26	21/11/2017	14:10	Tower 6, Tieera Verde, Phase I, Tsing Yi*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
27	22/11/2017	15:00	Fu Wah House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
28	23/11/2017	11:16	Sump Tank, Chau Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
29	23/11/2017	11:20	Roof Tank, Chau Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
30	23/11/2017	11:40	Sump Tank, Yan Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
31	23/11/2017	11:40	Roof Tank, Yan Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
32	23/11/2017	11:55	Sump Tank, Block 1, Kwai Fong Terrace*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
33	23/11/2017	12:00	Sump Tank, Block 7, City Point, Tsuen Wan*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
34	23/11/2017	12:10	Roof Tank, Block 1, Kwai Fong Terrace*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
35	23/11/2017	12:11	Sump Tank, Tsz Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
36	23/11/2017	12:12	Roof Tank, Tsz Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
37	23/11/2017	12:20	Roof Tank, Block 7, City Point, Tsuen Wan*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
38	23/11/2017	12:29	Sump Tank, Ying Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
39	23/11/2017	12:32	Roof Tank, Ying Kwai House, Kwai Chung Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
40	23/11/2017	13:00	Sump Tank, Block C, New Kwai Fong Garden*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
41	23/11/2017	13:15	Roof Tank, Block C, New Kwai Fong Garden*	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
42	23/11/2017	13:20	Sump Tank, Fu Ping House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
43	23/11/2017	13:20	Roof Tank, Fu Ping House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
44	23/11/2017	13:45	Sump Tank, Fu Man House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
45	23/11/2017	13:45	Roof Tank, Fu Man House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
46	23/11/2017	14:20	Sump Tank, Fu Wah House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
47	23/11/2017	14:20	Roof Tank, Fu Wah House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
48	23/11/2017	14:32	Sump Tank, Shek Lin House, Shek Wai Kok Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
49	23/11/2017	14:35	Sump Tank, Fu Kwok House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
50	23/11/2017	14:35	Roof Tank, Fu Kwok House, Tai Wo Hau Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
51	23/11/2017	14:43	Roof Tank, Shek Lin House, Shek Wai Kok Estate	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
52	23/11/2017	15:30	Sump Tank, Block 1, Primrose Hill, Tsuen Wan	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125
53	23/11/2017	15:48	Roof Tank, Block 1, Primrose Hill, Tsuen Wan	Negative	No Odour	< 2.5	< 0.5	< 250	< 75	< 7.5	< 12	< 5	< 75	< 0.15	< 5	< 10	< 18	< 175	< 0.2	< 125

* denotes location outside the supply zone of the TWFWSR

Annex D

Copy of the WRAS Certificate of the protective coating of SPUA-406

Approval Number: 1501522
Test Report: MA5168/V

Water Regulations Advisory Scheme Ltd.
Unit 13,
Willow Road,
Pen y Fan Industrial Estate,
Crumlin,
Gwent,
NP11 4EG

29th January 2015

Marine Chemical Research Institute Co. Ltd.
No. 4 Jinhu Road,
Shinan District,
Qingdao,
China

WATER REGULATIONS ADVISORY SCHEME LTD. (WRAS)
MATERIAL APPROVAL

The material referred to in this letter is suitable for contact with wholesome water for domestic purposes having met the requirements of BS6920-1:2000 and/or 2014 'Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water'.

The reference relates solely to its effect on the quality of the water with which it may come into contact and does not signify the approval of its mechanical or physical properties for any use.

COATINGS, PAINTS & LININGS - FACTORY APPLIED PIPE & FITTINGS COATINGS. **5030**

SPUA-406. Factory applied, yellow coloured, two component PU coating. Mix the two components in a 1:1 volume ratio. Cure for 7 days@25°C. For use with water up to 23°C. This material is only approved for the curing conditions that appear on the approval. If the cure conditions are varied from those specified on the approval then the material is not covered by the scope of the approval.

APPROVAL NUMBER: 1501522
APPROVAL HOLDER: MARINE CHEMICAL RESEARCH INSTITUTE CO. LTD.

The Scheme reserves the right to review approval.
Approval 1501522 is valid between January 2015 and January 2020

An entry, as above, will accordingly be included in the Water Fittings Directory on-line under the section headed, "Materials which have passed full tests of effect on water quality".

The Directory may be found at: www.wras.co.uk/directory

Yours faithfully

Jason Furnival
Approvals & Enquiries Manager
Water Regulations Advisory Scheme

Annex E

Odour Testing Panel for Xylene in Water

1. According to the supplier's information of SPUA-406, the major volatile organic compounds (VOCs) constituent of the protective coating raw materials is xylene, with guideline value (GV) of 500 µg/L in the WHO Guidelines. Xylene has a strong, thinner-like odour that is unpleasant.

2. To assess the amount of xylene present in water that can lead to unpleasant odour, an odour testing panel was formed by 8 laboratory staff of the Water Supplies Department to study the concentration at which xylene in water became sensually detectable.

3. The testers were given of a series of water samples containing different concentrations of xylene and asked to describe the odour intensity of each sample. The intensity descriptions ranged from "No Smell" to "Very Mild", "Mild", "Strong", "Very Strong" and "Pungent".

4. The detection level of xylene varied among the testers but the odour was detectable by all testers at 30 µg/L. (see table below)

Xylene (µg/L)	Detection by the testers (%)
10	80
20	80
30	100
50	100

5. The results indicated that xylene would be detectable by customers at a concentration much lower than the guideline value of 500 µg/L of the WHO Guidelines due to its very low odour threshold.

Annex F

Benchtop Study on the Diffusion of Odour in Compartments of Service Reservoirs

1. Introduction

1.1 As part of the investigation of the water quality incident at Tsuen Wan Fresh Water Service Reservoir (TWFWSR) in November 2017, a benchtop study was conducted to investigate if the odour released during application of the protective coating materials in one SR compartment could impart sufficient amount of volatile organic compounds (VOCs) in water in the adjacent compartment to cause odour problem in drinking water.

2. Procedure

1.1 The proposed procedures of the benchtop study have made reference to an overseas research.[9] It is noted that the two compartments of the TWFWSR are segregated by a division wall with plastic curtains for air insulation on top but the curtains were incomplete with openings at the two access manholes / cat ladders of the SR. Besides, the SR has air vents on its rooftop.

1.2 In the benchtop study, a pair of glass tanks were used to simulate the two compartments. The tanks were covered and holes of about 0.5 cm in diameter were drilled on the cover at the four corners of both tanks to simulate the air vents. One tank was filled with tap water while a layer of protective coating material was spread on the bottom of the other as thinly as possible (Figure F1). While the tanks were covered, they were interconnected by a metal tubing simulating the openings in the plastic curtains. Details of the set-up of the glass tanks and the SR compartments are indicated in Table F1.

[9] M.G. Mahmoodlu et al, 2017, Dissolution kinetics of volatile organic compound vapors in water: An integrated experimental and computational study, Journal of Contaminant Hydrology 196 (2017) 43-51.

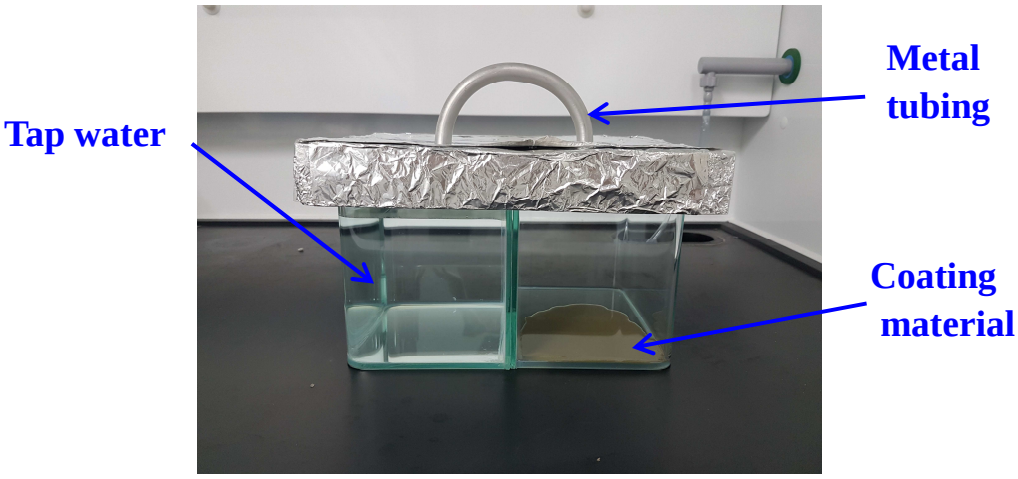

Figure F1

	Glass Tank	SR Compartment
Length	17 cm	47 m
Width	12 cm	35 m
Height	14 cm	6 m
Length/Width	1.4	1.3
Water depth	11 cm	4 m
Water volume	2.2 L	6580 m^3
Opening	0.5 cm^2 (a)	7 m^2 (b)
Weight of top coat	8 g	~170 kg

Notes:

(a) Cross sectional area of the metal tubing bore.

(b) Total surface area of the plastic curtain openings under the two manholes.

Table F1

1.3 The tanks were covered as soon as the protective coating material was applied and the set-up was left in a fume-cupboard overnight at about 17°C with the sash down and extraction fan turned off. To simulate flowing water in the SR, the water in the tank was gently agitated by a magnetic stirrer bar. A control was also set up in which an identical tank was similarly filled with tap water and covered but not connected to any VOC sources.

1.4 Water samples were extracted after 15 hours from the set-up for VOC analysis. Water sample was also extracted after 15 hours from the control.

2. Results and Discussion

2.1 According to the supplier's information, the major VOC constituent of the protective coating raw materials is xylene, which is a VOC of health significance in drinking water with a guideline value of 500 µg/L in the WHO Guidelines.

2.2 The general properties of xylene and experimental results are summarised in Table F2 and Table F3 respectively.

Xylene[(a)] properties	**Value[(b)]**
Melting point (°C)	-48 – 13
Boiling point (°C)	138 – 144
Density(kg/L)	0.86 – 0.88
Water solubility (mg/L)	175 – 198
Guideline value in WHO Guidelines (µg/L)	500[(c)]

Notes:

(a) "Xylene" refers to a mixture isomers including *ortho*-, *meta*- and *para*-xylenes

(b) Source of information (except Guideline value in WHO Guidelines): WHO, 2003, *Xylenes in Drinking-water*

(c) For the combined isomers of *ortho*-, *meta*- and *para*-xylenes. Source of information: WHO, 2017, *Guidelines for Drinking-water Quality 4th Edition Incorporating the 1st Addendum*

Table F2

		Xylenes in water (µg/L)
1	**Experiment**	414
2	**Control**	Not detected

Table F3

2.3 The experimental results showed that a detectable level of xylene in water was caused by diffusion of VOCs from one glass tank to the other through the narrow metal tubing. It thus demonstrated that application of protective coating material in an SR compartment could lead to odour in the drinking water in the adjacent compartment due to diffusion of VOCs.

2.4 However, it must be stressed that the experimental results were for qualitative indication only as the water volume, weight of protective coating material used and other conditions of the SR were different from those of the benchtop study.

3. Conclusion

3.1 The benchtop study demonstrates that the odour in the drinking water in the operating western compartment of the TWFWSR was caused by the VOCs released during the application of the protective coating material in the adjacent eastern compartment if there were openings in the plastic curtains above the division wall.

Annex G

Condition of the Western Compartment after Draining Down

Location: Area near the access manhole close to the inlet of the western compartment

Observation: There is no sign of residual protective coating material found on the walls and floor slabs. The white sediments are residues of limes which are one of the ingredients in the water treatment process.

Location: Outlet of the western compartment

Observation: There is no sign of residual protective coating material found on walls and floor slabs.