香港特別行政區政府渠務署
Drainage Services Department
Government of the Hong Kong SAR

RESEARCH & DEVELOPMENT REPORT NO. RD 2076

Determination of Hydrogen Sulfide Capacity of Different Activated Carbon Types at Various Operating Conditions

(Final Report)

Research and Development Section
Electrical & Mechanical Projects Division
Drainage Services Department

Apr 2016

Final Report endorsed by R&D Steering Committee Meeting No. 2-2016 (E&M Part) on 1 Apr 2016

R&D Report No.	RD 2076
Title of R&D Item	Determination of Hydrogen Sulfide Capacity of Different Activated Carbon Types at Various Operating Conditions
Title of Report (if different from title of R&D item)	Provision of Carbon Testing Unit to Determine Hydrogen Sulfide Adsorption Capacity of Different Activated Carbon Types at Various Operating Conditions
Version (for draft reports)	
Month and year of issue	1/4/2016

	Name	Post	Signature	Date
Prepared by	Dr. T.K. LAU	Chemist/P4/R&D		8/4/2016
Verified by	Ir. Sussana LAI	SE/P4/R&D		8/4/2016
Approved by	Ir. Ricky LI	CE/E&MP		22.4.2016

DRAINAGE SERVICES DEPARTMENT

EVALUATION REPORT

PROVISION OF CARBON TESTING UNIT TO DETERMINE HYDROGEN SULFIDE ADSORPTION CAPACITY OF DIFFERENT ACTIVATED CARBON TYPES AT VARIOUS OPERATING CONDITIONS

(Final Version)

(CONTRACT NO.: DEMP/2013/06)

(HKPC REF: M:\emd\4103\Water_Team\PROJECTS\40179572\FinalReport\DEMP1306)

Prepared by

Environmental Management Division
Hong Kong Productivity Council

1st April 2016

Executive Summary

This summary is abridged. Names of brand and model of activated carbon tested have been removed..

1. Background

1.1 Activated carbon filter technology is an adsorption process which can be used in deodorizing. Hydrogen sulfide (H_2S) generated from sewage treatment facilities is a common source of malodour, which can be adsorbed by activated carbon. In order to eliminate the malodor, it is valuable for Drainage Service Department (DSD) to study H_2S adsorption by activated carbon.

1.2 The objectives of the study are:

(i) To design and deliver a carbon testing unit that allows concurrent evaluation of H_2S adsorption capacities of multiple activated carbons;

(ii) To evaluate the effects of varied operating conditions (that is, high and low relative humidity) on H_2S capacities of different carbons in laboratory tests and field tests to ascertain the effect of relative humidity on H_2S capacity as this information is not available from the manufacturers;

(iii) To evaluate the effect of water wash regeneration of exhausted carbons on H_2S capacities of the two catalytic activated carbons (CAC) in laboratory tests.

2. Carbon Testing Unit

2.1 DSD has commissioned HKPC to supply a carbon testing unit, a mobile system which can be moved to sewage treatment plants for investigations on genuine foul air, and to carry out the laboratory study to compare the H_2S adsorption capacity of different carbon at different relative humidity (%RH). The system was first set up and fabricated in a well-ventilated workshop in HKPC for laboratory study. Then it was moved to the Stonecutters Island Sewage Treatment Works (SCISTW) for the field test.

2.2 The carbon testing unit in this study was composed of 7 main parts, including the Foul air stream intake system w/ H_2S gas cylinder, the Humidification system, the Dehumidification system, the Cylindrical plastic AC filters, the Supporting framework, the Humidity and H_2S Gas detection system, and the Activated carbon scrubber.

2.3 The carbon testing unit in this study is capable of:

(i) Simulating different conditions of relative humidity (<50%, 60–70%, 70–80%, 80–90%,

90-99% and 100% with water condensation);

(ii) Maintaining a steady gas stream to attain the designed face velocity and empty bed retention time (EBRT);

(iii) Providing a steady feed of H_2S to maintain an average of 90 ppmv H_2S for four AC filters.

2.4 After completing the laboratory and field tests, it can be concluded that the carbon testing unit can allow concurrent evaluation of H_2S adsorption capacities of multiple activated carbons. The designed conditions of face velocity at 0.3 m/s, EBRT 1–2 sec and inlet H_2S at 90 ppmv can be met and kept steady with a little fluctuation throughout each set of test. Besides, the carbon testing unit is also capable of producing air of a specified %RH range. The %RH can be controlled within the preset range most of the time in each set of test. A breakthrough time of 8–20 days for the carbon with the highest capacity was observed in each set of test.

2.5 During the laboratory tests, the carbon testing unit was modified to allow *in-situ* water regeneration. The regeneration conditions were tested according to manufacturer's recommendations and confirmed effective.

2.6 Compared with the ASTM D6646 accelerated test with 10,000 ppmv inlet H_2S and other laboratory studies found in literature, the designed conditions of this carbon testing unit is closer to typical design of AC filters (0.3 m/s face velocity, EBRT 2–3 sec, inlet H_2S around or below 10 ppmv). Therefore, the results are expected to simulate the real applications better. The breakthrough time is not excessively long for practical evaluation.

3. Types of Activated Carbons

3.1 Four types of carbons were selected by DSD in this study. The first activated carbon is (CG) which is a kind of virgin activated carbon (VAC) without impregnation. The second type of carbon tested is (IK) which is a caustic-impregnated activated carbon (IAC) in use by DSD. The remaining two carbons are (UN) and (CA) which are catalytic activated carbons (CAC). The two CAC carbons selected are the two major commercially available CAC which can be regenerated with water-wash.

4. Study Programme

4.1 The study consisted of the laboratory tests and field tests.

4.2 The laboratory tests were separated into two rounds. In Round 1, four activated carbons packed in the four AC filters were tested under the relative humidity conditions of %RH <50%, 60–70%, 70–80%, 80–90%, 90–99% and 100% with water condensation.

4.3 In one test of Round 2, the AC filters broken through at %RH=100% in Test 6 of round 1 were air dried without any water-wash to examine the performance of reviving process of wet spent carbon.

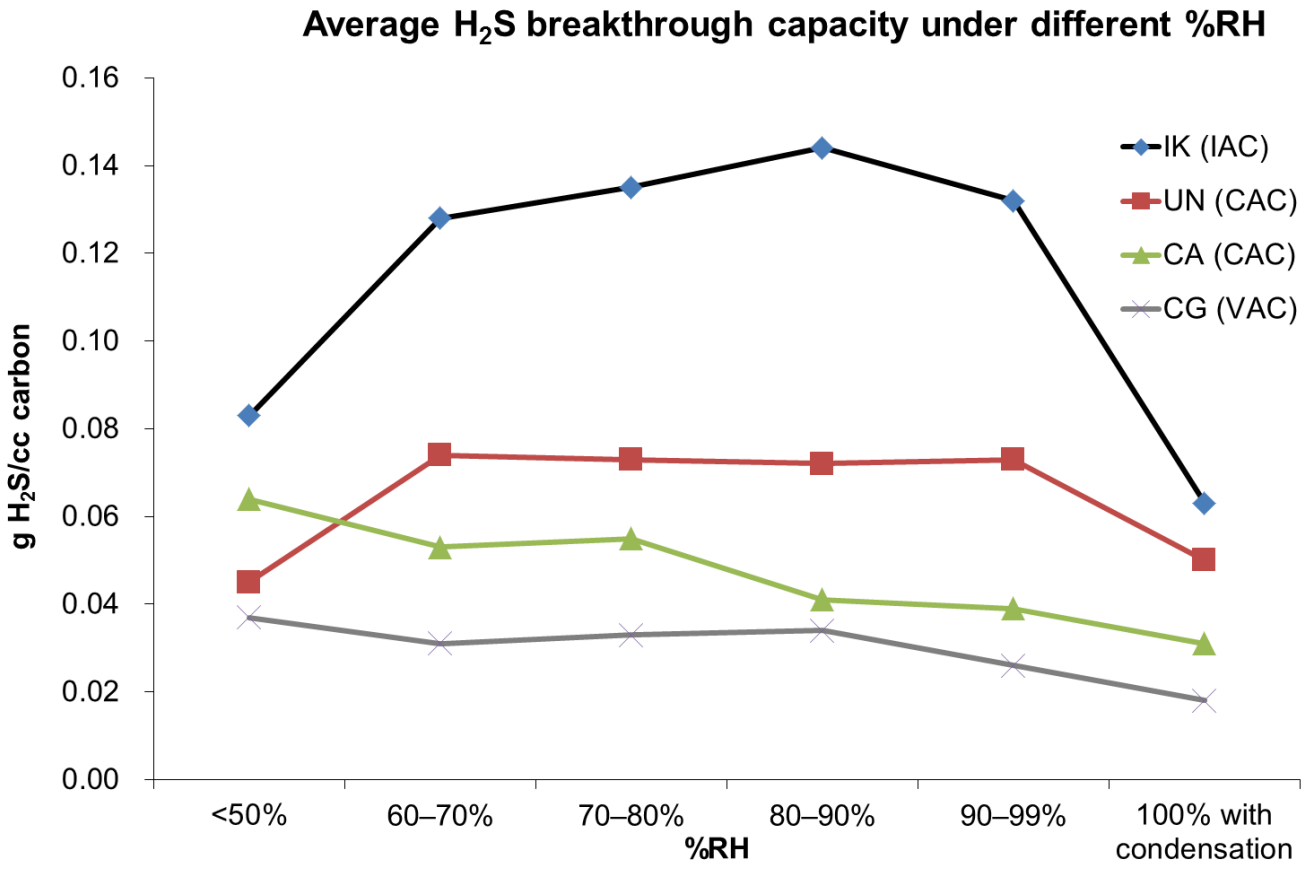
4.4 In other tests of Round 2, the two CAC were regenerated by water wash and the regeneration efficiency were evaluated by comparing the H_2S adsorption capacities of fresh carbon, carbon regenerated once and regenerated twice respectively.

4.5 Four sets of *field* tests in Round 3 were conducted at the selected site in the SCISTW of DSD to ascertain the performance of the Carbon testing unit in field conditions. To investigate the effect at the driest and most common moderate %RH conditions, four %RH conditions of <50%, 70–80%, 80–90% and 90–99% were selected in the field test.

5. H_2S adsorption on four activated carbons in Carbon Testing Unit

5.1 The H_2S breakthrough capacity of each carbon in the Round 1 laboratory tests and the Round 3 field tests under different relative humidity was averaged and shown in the figure below.

Figure: Average H_2S adsorption capacities of four carbons in Round 1 and 3 tests



5.2 From the above figure, it can be observed that the four carbons are useable between %RH of 60%–99% (non-condensing). The order of H_2S capacities are in the order of IK>UN>CA>CG. It was also observed that the H_2S adsorption capacities of IK and UN dropped significantly at a dry condition of %RH <50%.

5.3 The adsorption capacity dropped significantly when the %RH increased from 90-99% to 100% (with condensation) in all four types of carbons, showing that condensing conditions is detrimental to H_2S adsorption.

5.4 The H_2S adsorption capacities of the four carbons were compared with the claimed value provided by the supplier. The highest H_2S adsorption capacity of IK was determined to be close to the claimed value while that of the CAC (UN and CA) were far below their claimed values.

6. Comparison with ASTM D6646 result

6.1 The H_2S adsorption capacities of the four carbons determined in this study were also compared with the ASTM D6646 results from a commercial laboratory. It is fair to assume that the results from this study is closer to practical carbon filter application in full scale when compared to 1% v/v (10,000 ppmv) H_2S inlet concentration in the ASTM D6646 method. The capacities of the IK and UN carbons are a little higher than the ASTM D6646 results, while that of the CA carbon is a little lower. In contrast, the capacity of the CG carbon is higher than the ASTM D6646 results and the difference is huge.

7. Regeneration of AC filters in carbon testing unit

7.1 The two types of catalytic activated carbon (CAC), UN and CA carbons are claimed to be regenerable and one can recover their H_2S adsorption capacities by simple water wash process. A standard *in-situ* regeneration procedure including a water-washing step and air-drying step was developed in the laboratory test based on the procedures recommended by the suppliers. Both CACs could be regenerated. H_2S capacity of the fresh carbon and the regenerated carbon were compared in the laboratory tests with two regeneration cycles.

7.2 The regeneration efficiency of CA was higher than that of UN. The recovery of 88–100% in CA and 73–85% in UN were determined from the first two regenerations of their spent carbon respectively.

8. Revival of AC filters in carbon testing unit

8.1 The H_2S capacities was hindered in the presence of water condensation, nevertheless, true capacity are not depleted and the carbons can be revived by air drying without water wash. The H_2S adsorption performance of the four revived carbons was evaluated in Test 7 laboratory test after the air-drying process. The adsorption capacities of the UN, CG, and CA carbons were fully recovered after the reviving process while large reduction was observed for IK.

9. Selection of Activated Carbon for full-scale AC filters

9.1 It will be cost effective to use the IAC carbon for H_2S removal due to its high adsorption capacity and low price. However, the CAC carbons were demonstrated to be regenerable to recover their H_2S adsorption capacity assuming 85–88% recovery after each regeneration. The ultimate H_2S adsorption capacity of UN and CA after regeneration were determined to be higher than that of IAC and the unit cost of these two CACs per g H_2S adsorbed is about 80% higher than that of IAC if CAC are regenerated 6 times before replacement (within 10 times recommended by manufacturer and 6 times would be practical).

9.2 Among the four activated carbons, unit costs by weight are in order CG<IK<CA<UN. Results on cost effectiveness (in terms of gH_2S/cc carbon) showed that IAC is the recommended carbon type and CG is about twice the material cost. However, if bed fire safety issue is a great concern and system suspension for regeneration of CAC is acceptable, CAC is also suggested.

9.3 It is important to stress that the above discussions and recommendations are based on the results from the four selected carbon only. It is uncertain if other members of the same type will behave the same.