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# Remote controlled helicopters: a tool for air sampling in difficult situations

Ken Li[a], Eric Dainty[b], Mervin F. Fingas[a], Jacqueline M.R. Bélanger[a], J.R. Jocelyn Paré[a,*]

[a] *Environment Canada, Emergencies Science Division, Environmental Technology Centre, Ottawa, ON, Canada K1A 0H3*

[b] *Natural Resources Canada, Bells Corners Complex, Nepean, ON, Canada K1A 0G1*

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**Abstract**

Remote-controlled (RC) sampling helicopters were designed and constructed for use as air sampling platforms. These units employed hobby-kits as a basic chassis. Sampling instruments mounted included sampling pumps with sorption of indicator tubes, detection instrumentation and evacuated gas sampling canisters. Example of system usage is given, along with the description of the X-Cell, the third generation of RC helicopter developed by the Emergencies Science Division (ESD). Also reported here are data on Volatile Organic Compounds (VOCs) as collected in the smoke plume of the Newfoundland Offshore Burn Experiment (NOBE).

*Keywords:* Remote controlled helicopters; Air sampling tools; Sampling instruments; Volatile analysis; Oil burning

## 1. Introduction

Sample collection at a spill site is not always easy to perform. These difficulties can be the result of the remoteness of the site itself, or of the geographical position of the contaminated area, making it inaccessible to emergency personnel. Also to be taken into consideration, is how close to the disaster area can the responders get to without endangering their lives or be unduly exposed to health hazards. In order to alleviate some of these difficulties, the Emergencies Science Division (ESD) of Environment Canada (the Federal Department of the Environment of Canada) develops tools for sample collection and analysis during emergency situations directly at spill sites, or for special projects. One of these tools is remote-controlled helicopters. There are few reports on the use of low cost miniature remote-controlled airborne aircrafts for

* Corresponding address: Chief, MAP Unit, 3439 River Road, Ottawa, ON, Canada K1A 0H3. Tel.: 613-990-9122. Fax: 613-991-9485.


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environmental sampling and monitoring [1]. The use of remotely operated aircraft, mainly for military, law enforcement and telemetry applications has been reported. These aircraft, however, are expensive and costly to develop.

ESD has pioneered the use of remote-controlled helicopters to sample and monitor vapour clouds over highly toxic spills. In hazardous toxic spills, the airborne platforms equipped with sensing/sampling equipment, can be flown over the spill site for rapid assessment of the situation. The mobile nature of these sampling platforms also enables plume movements to be tracked easily. If a situation requires it, instantaneous or composite samples can be taken using on-board collection devices such as conventional particulate filters or sorbent tubes.

This paper reports on the use of remote-controlled helicopters to collect Volatile Organic Compounds (VOCs) using summa canisters mounted on the helicopters. Although not reported here, these helicopters can also be used to monitor Polyaromatic hydrocarbons (PAHs) levels at spill sites, by collecting samples from either polymeric XAD tubes attached to pumps mounted on the helicopters or from the soot collected by wiping the blades upon return of the helicopter to the ground when there is smoke present. A brief history of the construction of the helicopters is also given, along with typical experimental data demonstrating the usefulness and the advantages that such a technology can offer.

## 2. Historical background

The development of remote-controlled helicopters as sampling tools is now in its third generation in ESD [2]. The initial prototype consisted of a custom-built helicopter, since commercially available hobby helicopter kits did not meet the 10 kg payload requirement. Among the sampling devices carried by this first generation helicopter were: a photo-ionization-based gas detector, a Gilian high flow sampler and an on-board video camera with a data telemetry system transmitting real-time imagery and gas detection data to the ground. The major disadvantage of this helicopter was its heavy weight (about 6.5 kg) that made it difficult to fly. Another problem was the maintenance, since parts were non-stock items.

The second generation consisted of helicopters constructed largely from the commercially available GMP 60 Legend units using mostly off-the-shelf components. With emphasis on low development costs and ease of operation, the video positioning/data telemetry systems were omitted. Sampling equipment were a Gilian sampler using conventional particulate filters and sorbent cartridges. Air samples were drawn through a stainless steel probe protruding about 45 cm beyond the nose of the helicopter.

In anticipation of an offshore oil burn experiment [3], the third generation of remote-controlled helicopters was constructed for over water operations. These helicopters, of which a total of four were built, were primarily based on 60-size X-Cell helicopter kits (Miniature Aircraft, Orlando, FL) and custom modified with flotation devices, as can be seen in Fig. 1. Detailed specifications of the helicopters are described in Table 1. Of special interest are the flotation devices that were painted in bright

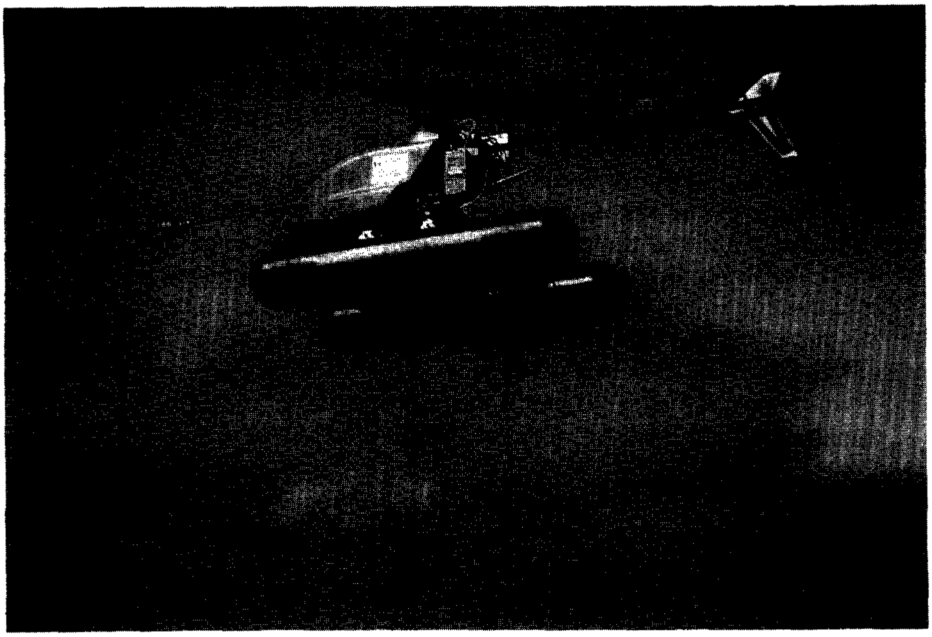

Fig. 1. The X-Cell helicopter as used in this study. Note the Gilian pump on the side of the device.

Table 1
Specifications of the third generation; The X-Cell helicopter

| | |
|---|---|
| Airframe: | Miniature/X-Cell modified with a set of glass-fibre floats for over water operation |
| Radio: | JR C-347 7-channel digital proportional RC system |
| Gyro: | JR rated gyro |
| Fuel: | 12% nitro/methanol |
| Engine: | OS Max SF, 0.61 cu in (10 cc); cruising power, 3 hp |
| Dimension: | 24 in (61 cm) high, 52 in (132 cm) long; rotary span 58 in (145 cm) |
| Weight: | 18 lbs (8 kg) all-up weight |
| Payload: | 8 lbs (3 kg) |

colours to improve visibility. These were very useful to avoid loosing sight of the helicopters as they were flown into the smoke plume to collect samples essential to this experiment.

## 3. Experimental

### 3.1. Materials and methods

#### 3.1.1 Sampling equipment on-board the RC X-Cell helicopters

The RC X-Cell helicopters had servo-activated switch on a distinct channel which was employed to turn samplers off and on. The sample probe which consisted of a 1.25 cm diameter aluminum tubing was mounted on the right side of the helicopter and protruded by approximately 45 cm in front of the nose to clear the rotary blades (see Fig. 1). Air samples were drawn through a Teflon filter to screen out particulate and through a concentric 0.6 cm diameter Teflon tubing. The smoke/soot sampling was done using Gilian LFS-113 low-flow sampler at a nominal sampling rate of $1\,l\,min^{-1}$. The sampling media were one 37 mm Teflon filter and a 6 × 70 mm XAD sorbent tube to collect PAH samples (these results were reported in Ref. [2]). Inert gas and VOCs sampling were done using 1- or 2-litre evacuated summa canisters equipped with a restricted orifice drawing at a nominal flow rate of $50\,cc\,min^{-1}$.

A custom-designed solenoid latching valve driver was constructed and installed on each of the X-Cells so that the sampling device could be remotely activated. To improve the survivability in case of a crash or forced landing on water, a pair of floats were fitted to each X-Cell helicopter in lieu of the normal landing skids. The design and construction of these floats are described in more detail in the literature [2].

*3.1.2. Sampling train set-up procedure for RC helicopter sampling*

The following outline is a general sampling preparation procedure for deploying the RC helicopter, assuming two types of sampling runs are to be carried out. Summa canister runs are to collect whole air grab sampling using 1- or 2 l size evacuated canisters. Gilian runs are for soot and smoke sampling, using conventional filters/sorbent tubes.

As a first step, the helicopters were fully tested out to ensure that there were no vibration and that their engines were running smoothly. A slightly rich fuel mixture setting was used. The aluminium sampling probe was extended so that the tip protruded beyond the diameter of the rotary blade disc, thus clearing the propeller wash.

*Summa run.* The following is the step-by-step procedure used to install the summa canisters on the RC helicopters before a run. The installation of these devices is easy, once personnel is properly trained.

1. Installation of a pair of new 9 volts batteries in the switch box.
2. Construction of the sampling train as follows:
   - assemble the filter cartridge (2 μm × 37 mm TPFE filter in a cassette), cap the intake end of the cassette;
   - run a $\frac{1}{8}$ in Teflon line through the sample probe;
   - attach the filter cassette to the Teflon line with an appropriate size tubing sleeve, secure the tip of sampling probe with a tubing sleeve;
   - attach the other end of the Teflon line to the solenoid valve in-port;
   - attach a calibrated restrictor to the solenoid valve out-port;
   - attach a restrictor to a summa canister cradled in the black plastic support between the struts of the floats; and
   - secure all loose fittings, loose wiring to avoid all metal to metal contact because of radio interference. Isolate with duct tape if necessary.
3. Check-out of sampling trains:
   - switch on the radio transmitter and receiver;
   - turn on the arming switch at the bottom of switch box; and

– switch on the selected channel ("7" for this device – a clicking noise from solenoid valve can then be heard). Open the value on the summa and remove the cap from filter cassette at the tip of the sampling probe – there should be a slight suction because of the evacuated canister trying to draw air in. The Gilian pump should also be running (the on/off switch on the pump was left off all the time with a piece of tubing connecting the in- and out-port in a recirculating mode), shut off summa at the end of flow testing.

4. Open the valve on summa manually before lift-off.
5. After the run, shut off valve manually on summa.
6. Remove canister from cradle, cap with brass nut and de-grease the exterior of summa by wiping down with a general purpose cleaning agent. If possible, check the vacuum of summa. No or very little vacuum was left if the sampling run was successful.
7. Install a new summa for another run. The filter cartridge can be left on the tip of the sampling probe (this is to prevent particulate from plugging the restrictor).

*Gilian run.* Experimental results from Gilian sampling have been reported elsewhere [2–5]. However, a procedure for their operation is reported for the sake of completeness and to further demonstrate the versatility of these RC sampling tools, during emergency response situations:

1. Assemble a filter cartridge (one pre-weighed 37 mm TFPE filter, 2 μm), attach to small XAD (150 mg) tube with appropriate size tubing.
2. Connect the entire assembly to the Teflon sampling line, secure to the front end of the aluminum probe with a tubing sleeve.
3. Disconnect the other end of Teflon sampling line from solenoid in-port. Cap the port with a brass nut to prevent contamination. Remove the summa restrictor.
4. Connect to the Gilian pump in-port with a piece of tubing.
5. Ensure that the arming switch is off. Check the sampling train operation by switching on the appropriate channel ("7" for this device), the Gilian pump should run (on/off switch on pump should be left off all the time as in Summa runs) and there is suction at the intake port of the filter/XAD package. Cap with a plastic cone to prevent contamination during standby.
6. Remove the plastic cone prior to lift-off.
7. After sample collection, remove the filter/sorbent cartridge; cap all ends to exclude air and wrap them in aluminium foil. Keep the cartridges cool during shipping.
8. If the helicopter has gone through a smoke plume, additional soot/sample can be recovered by wiping down the blades with an acetone-moistened filter paper (pre-weighed first). The high rotational speed of the blades makes them good impactor samplers for fine soot. The weight of soot is calculated by difference in weight of the wipe paper.

## 4. Results and discussion

Until recently, this form of sampling technology had been used mainly to sample smoke from oil burn experiments over land [5]. In anticipation of the Newfoundland

Offshore Burn Experiment (NOBE), the X-Cells had been constructed for over water operations. The most significant improvement for emergencies response was the addition of mini-summa canisters. The inclusion of these whole air sampling devices enables the responder to get an instantaneous snap shot of the air at a spill site.

During the NOBE experiment, about 40 000 l of crude oil were spilled at sea (about 40 km east of the coast of St-John's, Newfoundland, Canada). This crude oil was contained within a fire-resistant boom. Upon ignition, the smoke plume was sampled by a variety of samplers positioned in the air as well as at sea level on an array of ship-mounted stations [3]. Fig. 2 shows the RC helicopter taking off from a floating helipad during this experiment. The summa canister can be seen between the floats.

A number of operational requirements were observed in order to ensure the efficient collection of reliable data with these remote-controlled air sampling devices. A brief description of such requirements, along with our on-site experience follows.

### *4.1. Operational requirements for deployment*

*A Spotter.* Normal deployment of the helicopter calls for a team of two: the pilot and his assistant – titled the "spotter". The spotter's primary role is to enhance the visual capacity of the pilot. He can act as a coordinator between the ground control and the pilot, warning the pilot of any obstacles or disturbances that could come in

Fig. 2. A X-Cell helicopter lifting off from the helipad during the Newfoundland Offshore Burn Experiment (NOBE). Note the summa canister visible between the floats of the device.

conflict with the planned flight path. If properly trained in flying the RC helicopters, he can also serve as a backup for the pilot. Under particular circumstances, the spotter might also have to control the crowd so that the pilot's concentration is not affected. During the NOBE experiment, the spotter was an experienced scientist that would indicate to the pilot where to send the helicopter in the plume in order to collect specific samples (i.e. samples that had been planned according to a stringent protocol). Upon return of the helicopter to the landing platform, this individual was also in charge of changing the sampling devices on board the helicopter before it was sent out again to collect more samples.

*Flight/sampling logging.* In order to make subsequent data interpretation meaningful, the spotter was also in charge of recording the flight/sampling log. Details of the sampling conditions such as atmospheric conditions, the relative position of the helicopter to the suspected release point, etc., were entered in a log book to ensure that verification can be effected at a later stage.

To an untrained eye, distance and especially vertical heights are very hard to judge. We have conducted tests assessing the ability of the pilots to see how close they could hover over a designated spot 30 m high at various distances. The following is a summary of these observations: (i) pilots can generally navigate quite well (within a 3 m radius) to the designated point when they are 75 m away, but the navigation deteriorates rapidly to $\pm$ 7.5 m when they are 150 m away; (ii) without any point of reference, as for example in the case of a cloudless sky, even proficient pilots found it difficult to limit the drift. In that regard, a video camera with a running time log is of value to mark precisely the spatial and temporal relation of the helicopter with respect to the hot zone.

*Canister sample handling.* To minimize the handling difficulties, the canister was positioned as near to the centre of lift as possible. Mounting and dismounting was reasonably convenient. In the present configuration, the canister hangs beneath the air frame in a special mounting bracket. Since quick access to the canister is essential in cases where multiple samples are required, the canister, together with the solenoid valve, are not enclosed and thus exposed to the exhaust of the helicopter. To minimize accidental contamination while removing the summa samples, the threaded area of the summa valve and the restrictor were degreased by spraying them with a general purpose cleaner to remove any grime from the exhaust. The summa valve was protected from the exhaust by covering it with Parafilm. It must be noted that aluminium foil was not used because metal to metal contacts could cause radio interferences.

It is also essential to check the integrity of the sample at the end of the run by a vacuum gauge. Depending on the diameter of the restrictor and the duration of the run, there should be very little residual vacuum. We have used a $50 \times 0.5$ mm i.d. length PEEK tubing as a restrictor. This allowed a leak rate of 100 ml min$^{-1}$ into the canister. The sampling duration was 10 m to fill a 1 l summa canister. The sampling rate is only nominal because of the small summa size, the leakage rate is very high initially and falls off rapidly after 5 minutes. A 2-L summa with which we also experimented, allowed a more uniform sampling rate but has the disadvantage of being heavier. A still-evacuated canister indicated that the solenoid valve had not opened or that the restrictor was plugged.

Table 2
Comparison of VOC profiles from NOBE samples collected with RC helicopters with the ones from a refinery and Canadian cities (weight% normalized to ethylbenzene)

| Compounds | Refinery | Cities | RC Boat | | | Helicopter 1 | | | Helicopter 2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Evap | Burn | Bkgrd | Evap | Front | Under | Bkgrd | Under | Under |
| Propane | 13.7 | 3.8 | 2.81 | 1.74 | 0.89 | 1.18 | 0.00 | 23.50 | 0.69 | 2.06 | 0.22 |
| Butane | 27.2 | 7.8 | 1.57 | 5.00 | 2.41 | 7.41 | 3.82 | 97.14 | 0.79 | 5.56 | 1.22 |
| 2-Methyl butane | 10.9 | 7.4 | 1.97 | 7.00 | 5.82 | 13.34 | 3.68 | 98.13 | 1.65 | 6.05 | 1.30 |
| Pentane | 6.8 | 4.2 | 2.00 | 4.04 | 2.99 | 7.68 | 4.65 | 100.49 | 1.13 | 5.81 | 1.36 |
| Benzene | 3.7 | 2.6 | 0.46 | 0.78 | 3.24 | 1.05 | 0.41 | 2.44 | 0.61 | 0.58 | 0.36 |
| Toluene | 6.4 | 6.3 | 3.61 | 3.13 | 4.04 | 3.66 | 4.29 | 4.68 | 4.77 | 12.41 | 13.32 |
| *m/p*-Xylene | 3.4 | 3.4 | 4.28 | 3.91 | 3.34 | 3.08 | 3.79 | 3.35 | 3.25 | 3.17 | 3.27 |
| *o*-Xylene | 1.5 | 1.1 | 1.47 | 1.26 | 1.08 | 1.00 | 1.26 | 0.97 | 1.15 | 1.12 | 1.16 |
| Ethylbenzene | 1 | 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

*Notes:* (1) Helicopter 1: Closest to fire, front is in front of fire, "under" is under the smoke plume in burn experiment # 1; (2) Helicopter 2: About 150 meters from fire, both runs under the plume in burn experiment # 1.

### *4.2. VOC data analysis*

Tables of raw data from field trials have been reported in detail in earlier reports [2, 4]. The NOBE experiment generated a multitude of data that cannot all be reported here. Only data related to the analysis of summa canisters that could not have been obtained without the use of the RC helicopters, are presented.

Preliminary analysis on the summa VOCs data from the helicopter runs were conducted to see if the profile of the burn samples did match the ones of existing data base profiles. Table 2 is a compilation of VOCs profiles of NOBE samples as compared with results obtained from air sampling at refineries and within major Canadian cities [6]. The ratio of a few representative alkanes and aromatics to ethylbenzene are tabulated in that table. The ratio shows that the background and the evaporation samples are similar, whereas during the burn, the alkane ratio goes up for samples that were collected under the smoke plume. The second helicopter, located at about 150 m downwind from the fire has a profile similar to that of the Canadian urban atmosphere. The aromatic ratio remains fairly constant for all helicopter runs and is similar to the samples collected by radio-controlled boats during the same experiment [7]. These RC boats were located at a distance of about 50 and 100 m from the fire. Apart from the under the plume runs which might have some smoke entrained in the summa sample, the profile analysis suggests that the impact of VOCs at elevated altitudes, even at points very close to the fire is similar to that from the vicinity of a refinery. The small sample set, though not definitive, at least attests to the unique capability of the RC helicopters to sample the VOC levels around the smoke plume.

### *4.3. Future developments and improvements of the equipment on board*

These types of sampling devices can be maintained at the forefront of the technology, as they are easily modified to include new, state-of-the-art instrumentation as it becomes available, such as pocket-portable gas sensors which can monitor, on a continuous basis, spot concentration of toxic and combustible gases. Their sensors are generally electrochemical or catalytic and some have data-logging capability. A review of these solid state sensors is given in reference [8]. For example, the Personal Monitor MAT 5100 (Matheson) is a single channel gas detection unit that can be supplied for more than 140 gases and ranges. This unit weighs less than one pound and is rugged, thus making it suitable for this purpose.

Furthermore, video cameras are now available in sizes similar to a package of cigarettes (Supercircuits, TX). Once imposing a heavy weight penalty and bearing a high price tag, these new versions of video-on-a-board plus a UHF transmitter kit are relatively inexpensive and light weight. This can bring back the video positioning/surveillance capability. On-board visual aids would eliminate the visual sighting limitations. Also, by providing the responder a "from the cockpit out" perspective similar to real helicopters, this could simplify flying and allow sampling to be carried out more precisely.

## 5. Conclusion

This paper reported on the usefulness of RC helicopters in emergency response situations. The versatility of these sampling tools is almost limitless, and depends largely on the availability of sampling equipment which can be mounted on-board. The single most important impediment in using RC helicopters remains the high level of skills required to pilot them. This can be overcome by having access to pools of skilled pilots from local communities.

The following is a synopsis of the advantages that the RC helicopters offer by comparison with other airborne platforms:

(i) they can carry a reasonable payload given the size of the craft (compared with lighter-than-air crafts);

(ii) they have the ability to hover over the spill site with no or little ground speed;

(iii) they can take off and land in confined areas (compared to fixed wing aircraft);

(iv) they are not as sensitive to high wind conditions and thus they can take off anywhere upwind from the suspected site, and the operator does not have to be in the downwind area of the spill zone, thus minimizing any health risks;

(v) these helicopters, once their blades are folded back, are transportable in a fairly small package and are easy to deploy;

(vi) the components for these devices are readily available using hobby-style helicopters; and

(vii) when using whole air samplers such as evacuated summa canisters or tedlar bags, a quick grab sample can be taken and multiple analysis can be performed.

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