INTRODUCTION TO ADVANCED BACK CALCULATION® (ABC)

A SAFER Systems Patented Technology

May 2009

Author:
Dr. Shah Khajehnajafi
Vice President and Manager of R&D
SAFER Systems

SAFER SYSTEMS
The right response to a chemical emergency.

SAFER Systems LLC
5284 Adolfo Road, Suite 100
Camarillo, CA 93012
800-621-7237 / 805-383-9711
www.safersystem.com

Introduction to Advanced Back Calculation® (ABC)

Table of Contents

Introduction to Advanced Back Calculation® (ABC)

The Problem

What comes to mind when there is a toxic chemical release? The most obvious responses involve evacuation or shelter in place of the people in the path of the plume. To predict the path, area, and severity of a plume impact, you need a dispersion model. The basic information required to initiate a dispersion model is weather data, identification of the chemical, and the rate of the chemical release. However, the Achilles' heel of this information is the release rate specification: "How big is the hole?"

The Idea

SAFER Systems has developed and patented a unique scheme for estimating the release rate. The algorithm to implement the scheme is called **Advanced Back Calculation® (ABC)**[1]. The idea basically involves "reverse engineering" a dispersion model. While we usually input the release rate to the dispersion model and obtain the concentration field for the plume-impacted area, in ABC we utilize the concentration field data to estimate the release rate.

Implementation of the Idea

Upon release of a chemical, fixed sensors will pick up the concentration. To deploy portable sensors, a wind corridor, which is an angle depicted on a GIS map, will aid in the positioning of those sensors. The angle origin is placed at the release point, and its width is based on atmospheric stability. Sensors residing on the edge of the plume show strong concentration fluctuation due to plume meandering, which may produce undesired effects. Therefore, those sensors residing on the edge of the plume will be filtered or excluded from the release rate estimation module.

Consider the dispersion of an accidental release of a chemical as depicted in **Figure 1**. The impact of the plume on each sensor differs due to its travel time and/or wind shift with respect to the position of each sensor. Therefore, some sensors may not detect a gas concentration until later in an event while other sensors may be impacted early on. In addition, some sensors may be unusable if they become saturated or reach the maximum upper limit of their reading range.

[1] Advanced Back Calculation® (ABC), U.S. Patent No. 6,772,071.

Introduction to Advanced Back Calculation® (ABC)

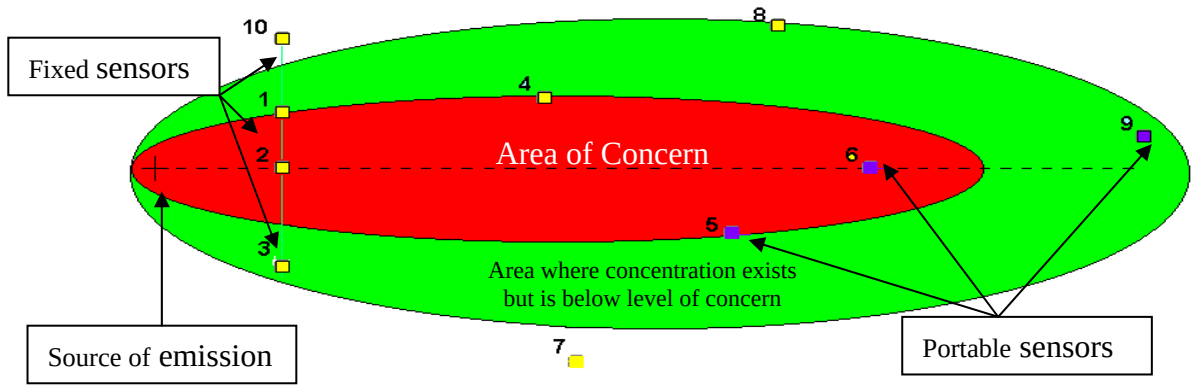

Figure 1- A typical plume with fixed and portable sensors

Assume the following hypothetical situation for the first few moments of a release. The inner area represents the lowest level we will model, but not necessarily the lowest level that can be measured. The outer area represents the area where some level of the cloud may be monitored at a range below the level of concern. Assume sensors 1, 2, 3 and 10 are fixed and sensors 4, 5, 6, 7, 8 and 9 are portable ones.

Fixed sensors, along with the deployed portable sensors, start transmitting their data to the Advanced Back Calculation module. The portable sensors are equipped with GPS, so their position will be known and visible on the SAFER GIS. The following data in **Table 1** shows typical information received through SAFER data acquisition to the ABC module:

Sensor ID	Location	Concentration (ppm)	Time	Saturation (ppm)
1	X1, Y1, Z1	C1	t1	C_{1limit}
2	X2, Y2, Z2	C2	t2	C_{2limit}
.	…	…	…	…
N	Xn, Yn, Zn	Cn	tn	C_{nlimit}

Table 1- Typical data passed from data acquisition to ABC module

The continuous measurement of the concentration at each sensor will be sampled at 1 Hz and averaged over one minute. **Figure 2** shows a typical sensor response to a plume impact. The averaged one-minute values are used by ABC to create a profile as close to the measurement profile as possible within a tolerance level. The convergence is over time and concentration for each point.

Introduction to Advanced Back Calculation® (ABC)

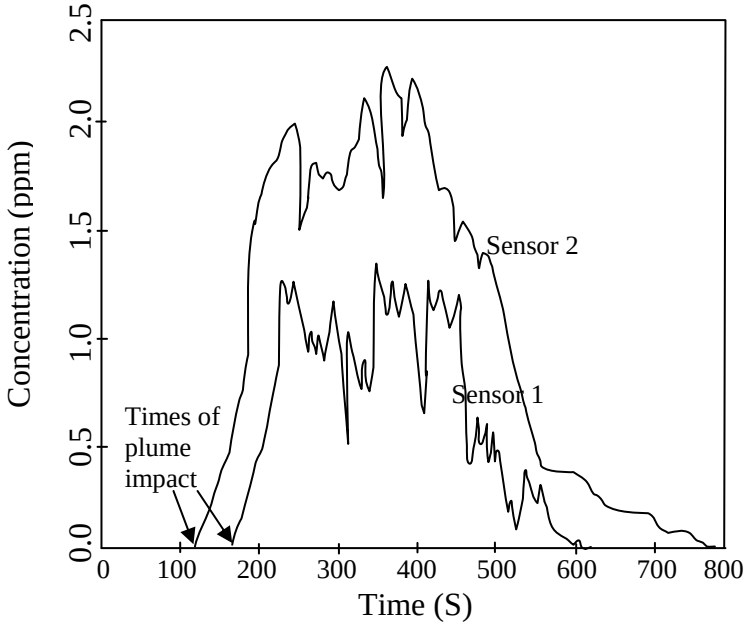

Figure 2- Typical sensor response to plume concentration

The following diagram depicts the process (**Figure 3**).

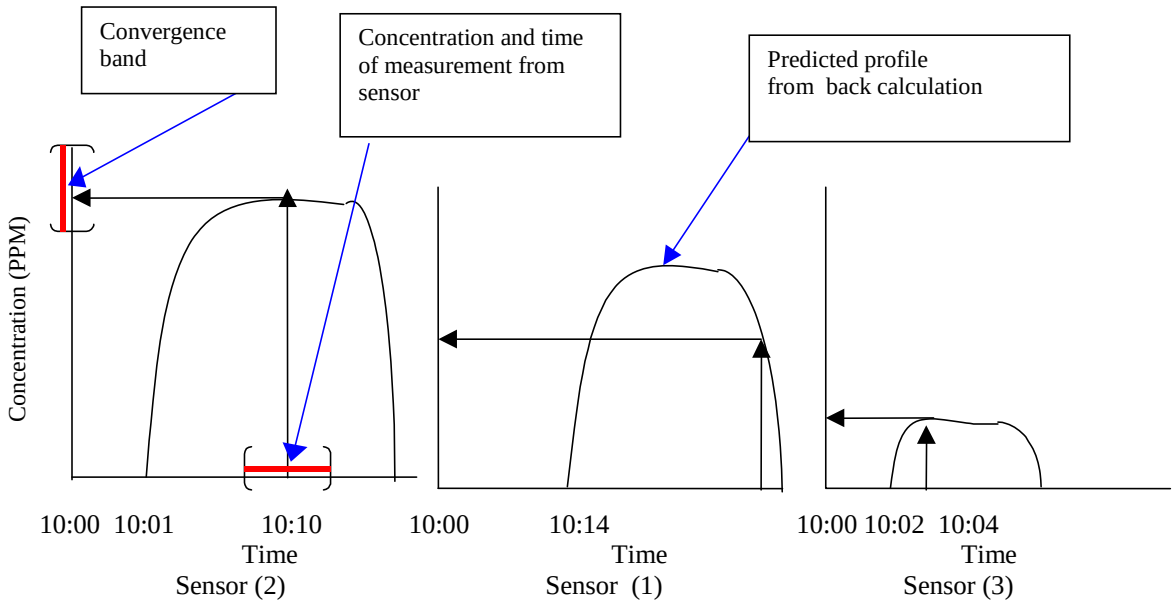

Figure 3- Comparison of model predictions against sensor measurements

Introduction to Advanced Back Calculation® (ABC)

The complex problem of plume meander due to atmospheric turbulence and the wind direction and speed changes over concentration measuring devices requires that not only the concentration but also its time of measurement at each recording location be relayed to ABC. The ABC module, with its sophisticated mathematical algorithm, hunts for the optimum release rate to match the concentration/time profile at all measuring stations within a reasonable tolerance level, enabling the dynamic prediction of release rates for constant or variable flow sources.

When all the measured concentrations and times are within the specified tolerance for all sensors, the trial release rate will be recorded to be utilized for dispersion simulation.

The whole process is very simple yet powerful. The SAFER data acquisition will automatically poll data from the meteorological tower and sensors. The GPS-enabled portable sensors report their positions as they are being moved around during the event. The portable sensors use radio frequencies to transmit the data to the SAFER data acquisition program. The data is run through the Advanced Back Calculation algorithm to calculate the release rate, run the dispersion model, plot the results on the GIS map, and calculate the impact on the affected areas and receptors (see **Figure 4**).

Introduction to Advanced Back Calculation® (ABC)

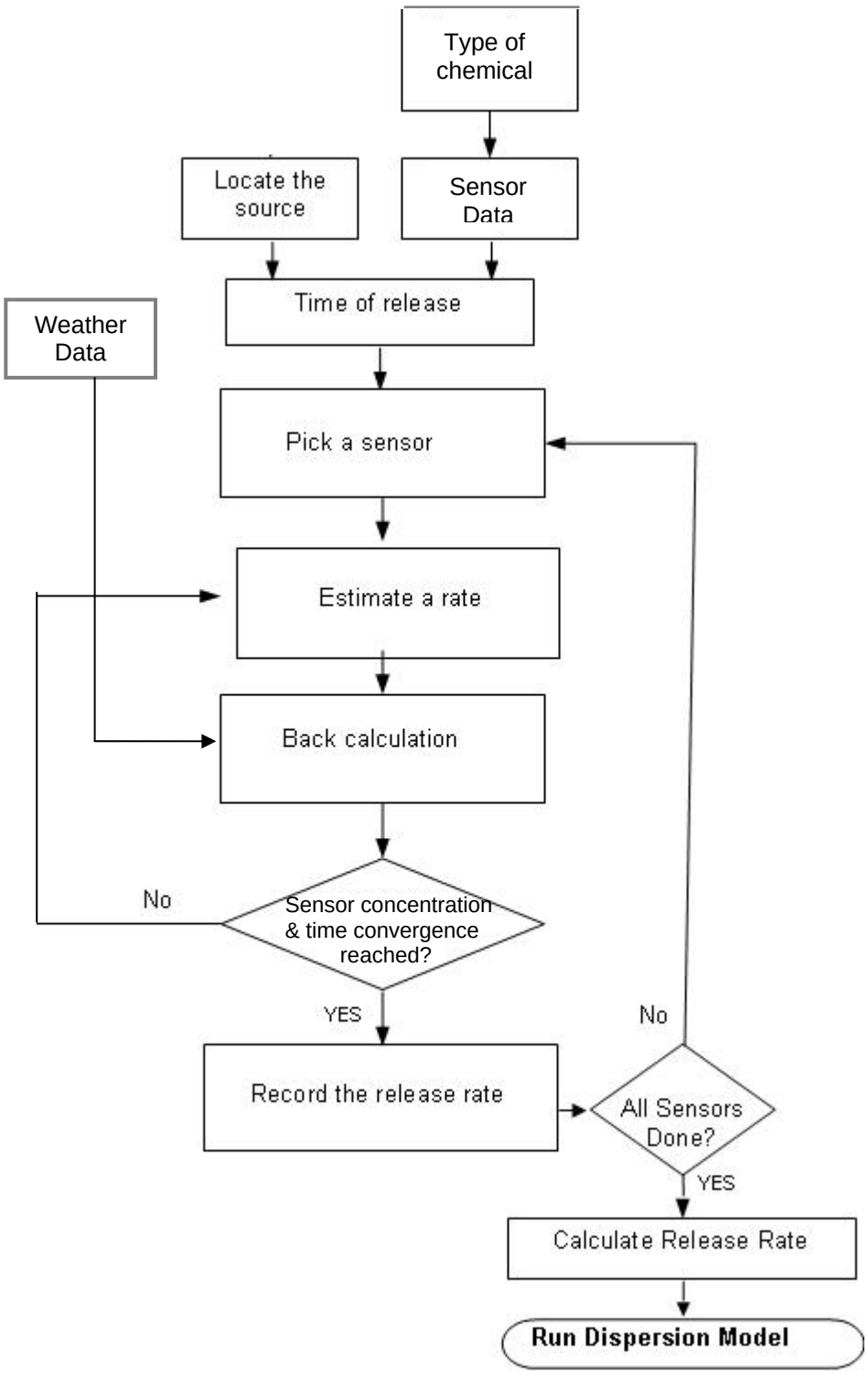

Figure 4- Advanced Back Calculation Algorithm

Introduction to Advanced Back Calculation® (ABC)

A Total Industrial Solution

ABC provides the emergency responder with the best scientifically defendable picture into an event that is useful both during the event and for post-event analysis. With this ability, SAFER Systems has created a powerful alliance with two industry leaders in the areas of sensors (RAE Systems-San Jose, CA) and meteorological instrumentation (Coastal Environmental Systems-Seattle, WA) to offer a turnkey and completely integrated solution. RAE Systems is a leading global developer and manufacturer of rapidly deployable, multi-sensor chemical detection monitors. Coastal Environmental Systems is a leader in wireless solid-state weather monitoring equipment. SAFER Systems, the leader in chemical emergency response solutions, provides the plume measurement software (ABC).

A Rapid Deployment Kit (RDK) with a military-grade case includes four wireless AreaRAE monitors with in-case charging and a host controller for monitoring from a command center up to two miles away. The unit is very easy to transport and easy to deploy (**Figure 5**).

Figure 5 - Rapid Deployment Kit

When deployed, the AreaRAEs and a Coastal WeatherPak unit will establish a connection to a RAELink2 by radio signal. The RAELink2 provides data to the ProRAE Remote Host application. The distance between an AreaRAE and the RAELink2 can be up to two miles. The ProRAE, in turn, relays the data to the SAFER Data Acquisition Server (DAS). Data can be provided to the SAFER DAS either locally or through TCP/IP over the Internet. The ABC plume measurement software will utilize the sensors and weather data to estimate the release rate and provide an accurate assessment of the impact of the chemical plume, as illustrated in **Figure 6**.

Introduction to Advanced Back Calculation® (ABC)

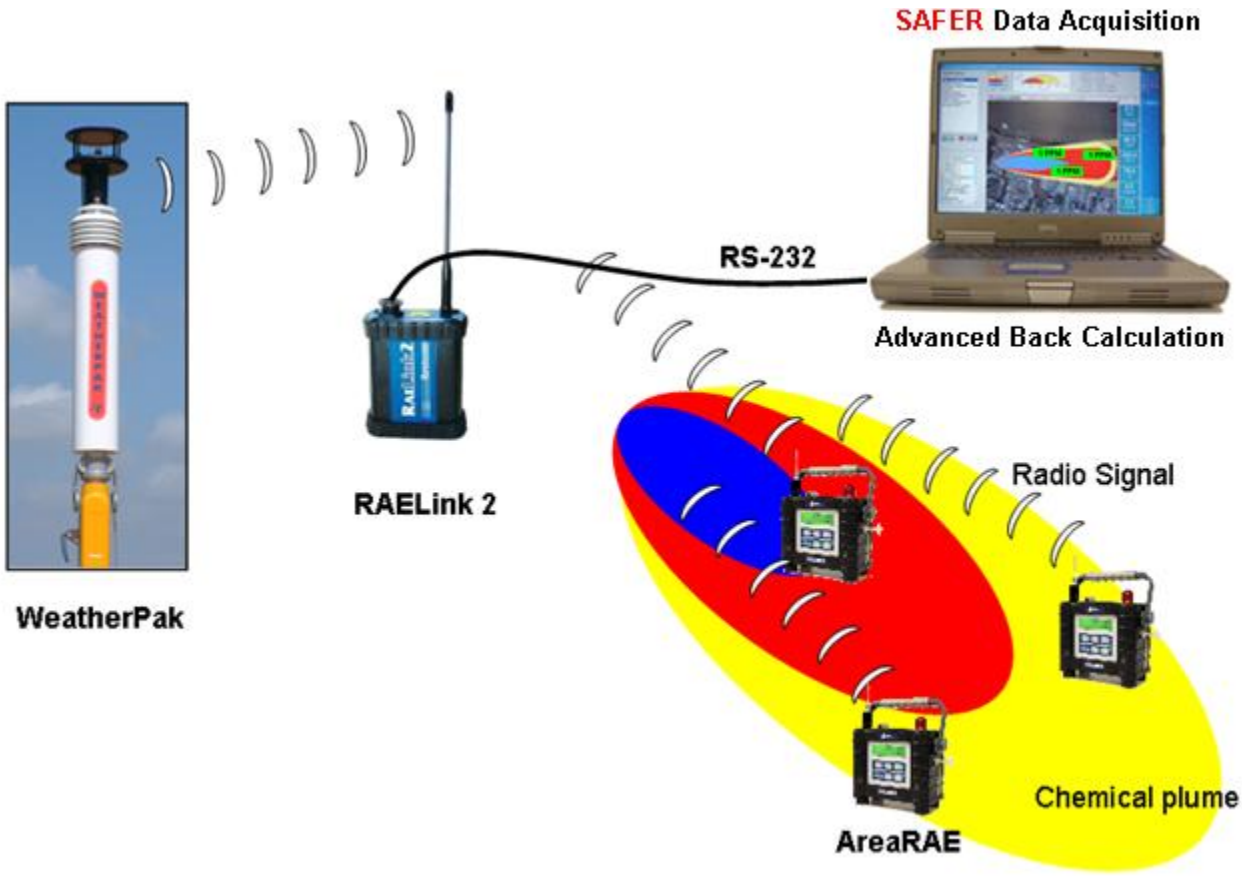

Figure 6- Schematic diagram for a rapid deployment emergency system

Benefits

Based on this scheme, the Advanced Back Calculation software provides the following unique benefits:

1. Answers the question of how much chemical is being released.
2. Creates a scientifically defendable method for release rate estimation, helping first responders make critical decisions regarding emergency management procedures.
3. Through complementary technology, offers a complete solution for emergency response.
4. Helps responders understand where to position the portable sensors.
5. May be loaded, along with RAE Remote software, on a laptop for an industrial solution for plume measurement. The laptop, four AreaRAE monitors, and a RAELink are packed into military-grade cases called a Rapid Deployment Kit (RDK), for quick deployment.

Introduction to Advanced Back Calculation® (ABC)

About SAFER Systems

Founded in 1978, SAFER Systems is the global technology leader in chemical emergency management solutions, with advanced chemical plume measurement and monitoring products that integrate real-time weather and sensor data. The company's scalable state-of-the-art solutions, which incorporate patented technologies, are designed to detect and accurately predict in real-time the dispersion of accidental or terrorist related releases of toxic chemical agents.

Using SAFER Systems products, organizations worldwide can better estimate the associated risks, thoroughly prepare for the possibility of a chemical release, and quickly determine the best ways to mitigate those risks when responding to an actual emergency. The company's international customer base includes *Fortune 500* chemical and petroleum companies, all Class 1 railroads in North America, and many government HazMat/First Responders, including teams located in U.S. cities and states and Canadian provinces, as well as the Civil Defense agencies of Singapore and Luxembourg. Other customers and applications for SAFER Systems' products include pharmaceutical manufacturers; nuclear reprocessing facilities; smelters; oil and gas pipelines; pulp and paper plants; chemical storage and transporters; engineering and consulting firms involved in plant construction/expansion, safety or environmental health; and seaports and airports around the world.

Headquartered in Camarillo, California, SAFER Systems maintains regional sales and support offices in the United States, Canada and Europe, and supports a network of authorized sales and service agents throughout the world. For more information, visit http://www.safersystemv10.com.

SAFER Systems
World Headquarters
Camarillo, CA, USA

SAFER Systems
Global Sales Office
Katy, TX, USA

SAFER Systems North America
Southern Regional Office
The Woodlands, TX, USA

SAFER Systems North America
Northern Regional Office
Edmonton, Alberta, Canada

SAFER Systems Intl.
European Office
Barcelona, Spain