ABSTRACT. This paper concerns the design and actual construction of practical chemical sensor arrays that are intended for field applications. That is, the direct technical approach to selecting sensors and sensor array systems, that can both contain the needed information as well as be able to provide this information to the user, in order to solve an existing and specific analytical problem. I have been working on the concept of chemical sensor arrays for about 12 years, and have been using sensor arrays to accomplish the elusive goal of providing a practical field instrument for simultaneous chemical identification and quantification. Much has been learnt about the various aspects of building and operating sensor arrays. Prior work has demonstrated clearly that the information content of the signals from sensor arrays is significantly greater than that from single sensor systems. This paper is not a comprehensive review, but rather a discussion of important factors and relationships in developing practical chemical sensor arrays. References are given to provide examples of the concepts and techniques that are used. The reader is encouraged to use these examples as a starting point for further work rather than as the last word on the subject. This manuscript is unavoidably slanted toward my own work because I know this the best.

1. Chemical Sensor Arrays in General

Sensor arrays have significant analytical potential and can address the qualitative and quantitative analysis problem simultaneously. Large sophisticated analytical instruments use the concept of arrays and multidimensional data to increase both the sensitivity and the selectivity of a variety of analytical methods. But we are not addressing these approaches herein. If the array is small and portable, it can be taken to the field and perform analyses “on-the-spot” like the human nose. So we are really addressing the concept of “microchemical sensor arrays” or “miniature-low-power-chemical sensor arrays” here. The definition of the sensor array discussed in this work is:

"a chemical sensor array that must be low-power, portable and small enough to be used in a field application like the human nose for the identification and quantitation of chemical gases, vapours and mixtures without requiring a large and expensive instrumental support system to perform quantitative and qualitative analysis".

Since it was the consideration of a real-world problem that led us to the concept of sensor arrays for chemical analysis, it is important to consider the application before proceeding to construct any practical sensor array.

2. The Application

We started work on our first sensor array around the beginning of 1980 to address the problem of the identification and quantitation of compounds for emergency response personnel in field situations. The US Coast Guard was responsible for spills of hazardous chemicals in waterways and on land (because the US Coast Guard is part of the US Department of Transportation). This meant that these people were responding to the scene of chemical spills that had occurred during the shipment, storage, and use of chemicals in trade and commerce. Chemicals are often shipped in bulk by rail as well as in small quantities such that analysis was required in many diverse situations and environments. The chemicals of concern ranged from petrochemicals for plastics and fuels to those used in agriculture and pharmacological processes. The list of compounds to which the Coast Guard was called to respond numbered well over 1,000 different compounds and complex mixtures. To design and build a small instrument to identify and quantify these compounds "on-the-spot" and "in-the-field" is truly a prodigious problem, even for modern technology. So, our first goal was to "define the analytical problem in a solvable manner".

In order to get a clear objective for our work, we took the computer record of emergency responses to all the chemical spills that occurred over a two year period (1979 and 1980) in the USA and prioritized it according to the frequency of the spilled chemical or mixture, the quantity spilled, the injury to human health, the environmental damage, and the toxicity of the chemical (acute, chronic, carcinogenic). With this prioritized list, we could account for more than 90% of the spills and most of the responses of the Emergency Response Units (or Coast Guard Strike Teams as they were called) with about 10% of the more than 1,000 chemicals listed [1]. However, this list of compounds still represented more than 30 different classes of chemicals. Further, about 140 of these priority chemicals were responsible for most of the damage to human health and the environment.