Industrial and Economic Aspects of Sarin:

Why poor quality is not an indicator of non-state manufacture

By Dan Kaszeta (dan@kaszeta.org) 6 November 2013

Introduction:

To use Sarin in any reasonable quantity, an industrial operation is needed. The Syrian incident in August of this year is of a size and scale that a large production effort was needed to accomplish it. But even a large-scale effort can produce an inferior quality product. The alleged poor quality of the Sarin used in Ghouta should not be taken as evidence that the Syrian government did not make it.

A number of blogs and articles have been advancing, either explicitly or implicitly, a thesis that I would term the "Sarin Quality argument." Roughly stated, the argument goes as follows: "The Sarin used in Damascus was obviously low quality. Therefore it must not have been made by a national level production program." The implication, therefore, is that the Sarin in use on 21 August 2013 must not have been made by the Assad regime. The purpose of this paper is to refute that argument. First, I will make a few general observations. Second, I will address in detail several points made by various bloggers and activists that are advanced in support of the "Quality" argument. Third, I will advance my own argument, which I would describe as a "Sarin Quantity and Economics Argument".

General Observations on Sarin Production and Quality Control

Production of Sarin is actually very difficult, particularly if you want to get more than a few spoonfuls. Various commentators have commented on the chemistry of Sarin production, but merely listing the chemical reactions required does not fully address the chemical engineering requirements. None of the observers other than myself seems to seriously address the Sarin production issue from an industrial perspective. A reasonable publically available document produced by the now defunct US Office of Technology Assessment [1] describes many of the engineering hurdles required for production of Sarin. Sarin is not a substance that easily lends itself to home-brew or clandestine "drug-lab" type manufacture, principally due to the requirements to handle highly dangerous corrosive gases at high temperature. I address some of these issues in summary form in my Bloomberg View op-ed column[2], but there is a deep well of information available if you are willing to research the history of the German nerve agent production facilities and the history and US production efforts at Rocky Mountain Arsenal, the facility in Colorado where the USA's "unitary" Sarin was produced between 1953 an 1957.

One principle problem faced by anyone producing Sarin is that the last step of the Sarin process actually leaves you with a cocktail of Sarin and acids. You get one mol of HF (hydrogen fluoride) or HCl (hydrogen chloride) for each mol of Sarin you produce. Most of the production pathways will end with HF in the Sarin. The US worked out a so-called di-di process (very hard to pull off, I may add) that ends up with HCl. Worked out in weight equivalents, if you make 1 kg of Sarin, it is going to be mixed with 140 g of HF. This residual HF is nasty stuff, to say the least. The residual acid, regardless of whether it is HF or HCl, is going to cause a number of problems. First, the product will be corrosive to whatever container or munition that it is in, degrading the shelf life of the container or munition and eventually posing safety and handling problems from leakage. Second, acidity causes degradation of the Sarin. Third, HF vapor can defeat many types of protective clothing and equipment. The acidic nature of the mix reduces the effective shelf life of the Sarin from decades to months. [3]

The US, the Soviet Union, and to the best of my knowledge, the UK and Tito-era Yugoslavia had developed the ability to refine the residual acid out of Sarin as a final refining step. I am not sure if anyone else was. My initial research has not been able to indicate whether the original German Nazi-era production facility surmounted this problem. Even the very large US production facility at Rocky Mountain Arsenal devoted many PhDs and millions of dollars to this effort and did not perfect the distillation process until well after production started. Earlier batches were re-distilled once the distillation method was perfected. The distillation of the residual acid was, and continues to be, a deeply protected dark art. Some of the general information about the process, but not the details, is described in the engineering history of Rocky Mountain Arsenal.[4] It is my belief that the UK mastered this process at their facility in Nancekuke, Cornwall and that the USSR did so similarly in its production facilities. The existence of long shelf-life Sarin in the Soviet-era stockpile is de facto evidence of this. I have spoken to several people involved in Tito-era Yugoslavian chemical weapons and they have indicated to me that Yugoslavia was able to remove the acid. Saddam Hussein's Iraq did not perfect the acid removal step of the process. Chinese, Swedish, North Korean, and French Sarin efforts remain an enigma to me.

If you are planning to store your Sarin for a long time, you need to remove the residual acid. However, this is not a terrible barrier if one is planning to use the Sarin quickly. The Iraqi military used a "just in time" approach to Sarin production and made every effort during the Iran-Iraq war to use the Sarin that they produced quickly. The Iraq Sarin production efforts are indicative that a nation state can produce the industrial infrastructure for Sarin but not have the acid removal step, either because they couldn't do it or because it was too expensive to do.

The best way I can summarize the production issues in brief form is as follows:

- A bench-top or home-style setup is very dangerous. Some lab scale production facilities using modern technology and techniques can create teaspoon-type quantities.
- To get any reasonable quantity of Sarin you need a factory-type setup. Even a very expensive factory gets you only a moderate grade of Sarin. The US OTA study estimated that you needed at least $10 million in 1993 USD to get a basic

setup going, not accounting for effectively dealing with waste or safety issues or the refining process.[5]

- To get a high quality, acid-free, long-shelf life product, you need a lot more money and effort than just a base-level production facility. Iraq wasn't able to pull it off. But if you don't need shelf life, you needn't bother with acid removal.
- The Iraq experience shows that a large, multimillion dollar chemical weapons production effort can still produce a mediocre product.

Salient points of the "Quality Argument"

In the various blogs and documents I have seen, the crux of the "Quality Argument" can be distilled down to four points.

Point 1: The UN report found multiple chemical impurities, indicating a deficient Sarin production. This obviously means that it wasn't produced by a state-level manufacturing program.

The Iraqi example shows us that a large and sophisticated chemical weapons production infrastructure can produce Sarin with significant impurities in it. The presence of impurities is testament to how hard it is to remove them, not any kind of evidence of non-state manufacture.

Point 2: Numerous odors were reported. High quality Sarin is odorless

Indeed. But this argument serves no great point one way or the other to tell who made it. Pure Sarin is odorless. But lower quality Sarin, which can be produced by a large state-run operation, will have impurities and decomposition products. The residual acids will react to whatever the impure Sarin has been stored in. If a binary device was used (see below), much of what may be smelled is precursors or byproducts rather than the Sarin itself. Yes, there are many reasons why lower quality Sarin can smell funny. But none of those reasons can be any kind of evidence to state that the Assad regime didn't manufacture it.

Point 3: No "stabilizers" were found in the Sarin residue. Serious military grade Sarin has stabilizers

The purpose of so-called "stabilizers" in Sarin is to prevent corrosion during long-term storage. In the US Sarin program in the 1950s, the additives were tributylamine and a chemical called N,N'-Diisopropylcarbodimide. These chemicals were added to prevent corrosion of steel and aluminum. If you don't care about long term storage, you don't need to add specialty additives. If your Sarin is produced from binary components (see below), there is not any absolute requirement to add additives, particularly as shelf life is patently not a concern after mixing the two components.

Point 4: Syria has admitted to a serious CW production program. Such a program can't make deficient Sarin.

This is simply not true. The US and USSR made Sarin in poor to mediocre condition for years before perfecting the process. Iraq devoted a large effort to manufacturing nerve agents and did so in large quantities during the Iran-Iraq war. The size, expense, and scope of the Iraqi industrial program is well documented by UNSCOM and UNMOVIC, and appears to be larger than the Syrian program. Yet it made an inferior grade of Sarin, largely due to the lack of an acid distillation step in the process. I think that taking Syria's admission of a nerve agent production facility as some sort of evidence that *someone else* made the Sarin in question is a truly epic feat of Orwellian doublethink.

A quick tutorial on Binary Sarin

Many of the issues surrounding the continuing mysteries of the Ghouta attacks can possibly resolved if the Sarin used in the attacks was binary in nature. I am increasingly of the belief that 8/21 involved a binary chemical warfare agent. Chemical agents can be made in binary form – by combining two or more non-warfare agent precursor chemicals to create the warfare agent. This is done for many reasons, to include safety and security. To date, it appears that at least four different nerve agents (GB, GD, GF, and VX) can be made in a binary fashion.[6] Iraq experimented with binary Mustard but could not make it into a tactically and economically viable weapon due to the low concentration of Mustard in the mix that was produced.[7]

In the case of Sarin, a chemical known as DF (methylphosphonic difluoride) is mixed with isopropyl alcohol. This chemical reaction results in Sarin and hydrogen fluoride (HF). It is my understanding that this reaction is a bit violent, and the resulting HF in vapor form is in itself a highly toxic and corrosive substance. For this reason, US binary Sarin weapons included a quantity of isopropylamine to react with the surplus acid[8].

It would appear, both from the OPCW[9] and various media activity that the Syrian CW program's nerve agents are actually binary in nature, wherein Syria stores the binary components of Sarin and VX. The OPCW states that Syria declared approximately 1230 unfilled munitions. This fact implies that the mode of employment is to fill munitions prior to use, rather than manufacture and store filled munitions.

In my experience, there are three theoretical ways to effectively field binary Sarin:

1. **In-flight mixing**. One could put the separate components into the weapon system and have the mixing occur in flight on the way to the enemy. This is much harder to do in practice than in theory. The US spent a lot of time and money into getting the mixing in flight correct. Even so, the project was plagued with errors and I am not convinced that the US ever fully resolved the in-flight mixing issues before the programs were cancelled. Iraq used binary Sarin.[10]

2. **Mixing at the launch point**. Theoretically, the products can be mixed immediately prior to pouring into the munition. This is an abysmally bad idea with Sarin. This is very dangerous for the handler who has to do it and the reaction produced by combining the components is a very dangerous one. While it can be safely handled in a reactor vessel or inside a steel artillery shell, doing this in a bucket on the side of the road may kill the handler and damage vital equipment due to the corrosive nature of the HF. This may be a more viable approach with VX, though, as that reaction creates fewer acute problems.

3. **Mixing in the factory prior to shipping**. One viable concept of operations is to do the mixing in a factory setting with proper engineering controls to contain the reaction and the concomitant HF. The munitions could be filled in the factory and sent straight to the field for use. The OPCW's reference to mixing and filling equipment could be taken as evidence that this is the approach in use in Syria.

The proper employment of binary Sarin requires effective mixing and cannot be done without creating excess HF vapor. A poorly executed binary mix will result in a cocktail of chemicals: some Sarin, some unmixed precursors, some byproducts – including HF. This could go a long way towards explaining the mix of casualties and odors during the 8/21 attack. The precursors and byproducts are more in the category of general irritants than specific neurological poisons (as Sarin is) and are more likely to have strong odors.

The Sarin Quantity Argument

<u>The amount of Sarin that appears to have been used is a strong indicator of a national-level production program</u>.

People often make assumptions about the efficiency of Sarin as a battlefield weapon. There is a wide gulf between theoretical toxicity of Sarin in the laboratory environment and actual practical toxicity on the battlefield. To make a very long story short, a lot more Sarin is needed to create death and injury than the layman usually thinks. Even though Sarin is very toxic, a large number of casualties over a wide area will require a lot of chemical agent.

In my recent article in CBRNe World magazine[11], I use old military chemical target analysis methods to attempt to figure out how much Sarin may have been used. These methods are too lengthy and obtuse to recite here. Indeed, I had to summarize for the CBRNe World article due to a 2000 word article limit. Basically, as a thought exercise, I pretended that I was Assad's chemical officer and using old US charts and tables. I had to make many assumptions and guesses, as some raw data was simply unavailable to me. I came up with an order of magnitude estimate that the amount of Sarin for an attack of this nature would have been somewhere in the range of 370 kg to 4400 kg. As is often the case, I believe that there are strong reasons why neither the bottom end or the top end of the range of estimates is likely to be the case. My own instinct tells me we are looking at something roughly around a metric ton of Sarin.

A metric ton (-ish) of Sarin is not something that anyone is going to cook up without a factory. Who is more likely to have done this? An unnamed non-state actor or the state who has admitted to having the factory? As previously stated, a significant amount of engineering is required to produce Sarin, even in small quantities. It should be noted that the Aum Shinrikyo production facility, the only significant example of non-state Sarin manufacture, is an interesting comparison point. It cost a lot of money, was a large and custom-built three story building, was staffed by engineers and chemists, and used a front company to buy chemicals legally.[12] Despite this level of effort, the Aum Shinrikyo facility was only able to manage a modest production level of single batches of 2 gallons of Sarin.

To make ton-level quantities of Sarin an industrial-scale factory is needed. The level of difficult and the scale of the operation simply don't permit it to be done in less than a factory setting. Based on the German experience at their factory in Dyhernfurth, a ton of Sarin required about 8 tons of precursor raw materials. Due to principles of conservation of mass, about 7 tons of waste material, much of it very dangerous, would be produced.

The scale of the operation required to produce tons of Sarin, or indeed tons of DF (the critical precursor binary component) raises an interesting issue of economics. Given the industrial difficulties, Sarin is extremely expensive in comparison to conventional alternatives, unless you run your Sarin plant for years and amortize the cost over the course of thousands of tons of product. The expense, in terms of equipment and skilled labor, of such an effort means that one has to seriously question whether this is time, labor, and money well spent in pursuance of tactical military objectives. One has to seriously question whether a cash-strapped insurgency is going to squander their resources on such an endeavor when that amount of money, tens of millions of dollars at a minimum, could be used for a lot of other purposes to greater effect. Thirty million dollars buys a lot of conventional equipment that is much more immediately useful than a few tons of Sarin. So, from an industrial and economic standpoint, the culprit looks to be the regime more than anyone else.

Notes and Disclaimers:

1. This paper represents my personal opinion and does not represent any position or opinion of any previous employer.
2. I've used US spelling conventions and a US paper size instead of UK conventions. I had to pick one or the other. Criticisms on this point will be ignored.
3. Information current as of 6 November 2013 was used for this paper. I have done rather a lot of research on chemical warfare agents over the years. Some of the documents I have consulted are not generally available online. They are in these quaint things called libraries. Others are government documents that you might have to go to a special reading room to find or to request by Freedom of Information means. If you can't find a document I cite online, please don't blame me. The internet has a lot, but it doesn't have everything.
4. I firmly believe that Sarin, as a product trade name, should be capitalized. I often lose this argument, but I continue to insist on this point.

About the author: Dan Kaszeta is the author of "CBRN and Hazmat Incidents at Major Public Events: Planning and Response" (Wiley, 2012) as well as a number of magazine articles and conference papers. He has 22 years of experience in CBRN, having served as an officer in the US Army Chemical Corps, as CBRN advisor for the White House Military Office, and as a specialist in the US Secret Service. He now runs Strongpoint Security, a London-based CBRN and antiterrorism consultancy and is also a Senior Research Fellow with the International Institute of Nonproliferation Studies.

[1] Office of Technology Assessment (OTA), US Congress. Technologies Underlying Weapons of Mass Destruction. December 1993. OTA-BP-ISC-115.
[2] http://www.bloomberg.com/news/2013-10-10/no-you-can-t-make-sarin-in-your-kitchen.html
[3] Ibid, p. 26.
[4] Hess, Jeffrey A.. Historic American Engineering Record for Rocky Mountain Arsenal. US Department of the Interior, 1984. Possibly available through US DOI reading room.
[5] OTA, p. 27.
[6] http://emedicine.medscape.com/article/831901-overview
[7] http://www.un.org/depts/unmovic/new/documents/compendium/Chapter_III.pdf
[8] http://www.opcw.org/about-chemical-weapons/types-of-chemical-agent/nerve-agents/
[9] https://www.opcw.org/index.php?eID=dam_frontend_push&docID=16847
[10] UNMOVIC, op .cit.
[11] http://www.cbrneworld.com/_uploads/download_magazines/Managing_the_deficit.pdf
[12] See Amy Smithson's *Ataxia* - http://www.stimson.org/books-reports/ataxia-the-chemical-and-biological-terrorism-threat-and-the-us-response/