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Syria's Past, Secret Nuclear Program Poses Proliferation Risks

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In early January 2013 the *Financial Times* reported on unusual activities taking place at the alleged, former Syrian nuclear facility near Marj as Sulṭān located in the eastern suburbs of Damascus. According to Western sources, this site was a possible, small, secret uranium conversion facility. The International Atomic Energy Agency (IAEA), according to senior officials close to the IAEA, linked this facility to making reactor fuel for the Al Kibār reactor that was destroyed by an Israeli air strike in September 2007.

The *Financial Times* article raised concerns about the security of about 50 tonnes of natural uranium alleged to still be in Syria, which would have been intended for use in fuel for the Al Kibār reactor, and whether the civil war had put this stock at risk of theft or diversion. There is concern that this uranium stock could end up in the hands of those who may wish to sell it on the black market or otherwise seek to use it to extract concessions or cause damage. This material may also end up in undeclared programs of other states. The *Financial Times* in particular raised the concern that Syria could provide Iran with this uranium stock. For several years, Iran reportedly tried to obtain covertly high-quality natural uranium on the international market. Although Iran mines its own natural uranium, it could prefer a secret stock of purified natural uranium for a parallel centrifuge based uranium enrichment program. Fifty tonnes of natural uranium would be enough, if enriched to weapon-grade, for 3-5 nuclear weapons, depending on centrifuge efficiency and cascade operations.

The *Financial Times* did not link this uranium stock to the suspicious activities at the Marj as Sulṭān site at the time of its reporting, or have evidence that the uranium was at the site then. In fact, this site, located adjacent to a military depot, witnessed fighting between government and rebel forces in late fall of 2012 and was subsequently abandoned by the government, according to an informed government official. It was reportedly in rebel-controlled territory since late 2012 or early 2013 although in recent months the government offensive in Eastern Ghouta has made major inroads into rebel held areas of Marj as Sulṭān.[1] Moreover, this site is within a few kilometers of the areas which the Syrian regime attacked with chemical weapons on August 21, 2013, killing hundreds of civilians. The January *Financial Times* article raises wider concerns about the security of all of Syria's nuclear assets, including those that were part of its past, undeclared nuclear program.

[1] "Syrian Army Advances, Controls Strategic Region in Reef Damascus", Fars News Agency, August 12, 2013.

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In February 2013, Syrian rebels also seized the Al Kibār reactor site based on videos posted on Armscontrolwonk.org.[2] This seizure marked another case of undeclared nuclear sites falling outside the control of the Syrian government. Moreover, the rebels reportedly invited the IAEA to inspect the grounds, if they satisfied some unspecified conditions. The IAEA did not take up this offer, and it would have had no authority to do so, since its safeguards agreement is with the Syrian government. The United Nations would need to provide the IAEA with authority, and adequate protection, to inspect this site independent of the Syrian government. In June 2013, because of security concerns, the IAEA decided not to conduct an annual inspection of Syria's small Miniature Neutron Source Reactor (MNSR).[3]

This report seeks to assess the situation at Marj as Sulṭān, the characteristics of a secret stock of natural uranium in Syria, and other nuclear assets reported to have been located at the Marj as Sulṭān site. Syria is not believed to have an active, secret nuclear program at this time, but Syria is believed to be actively hiding assets associated with this past undeclared nuclear reactor effort.

It should be noted that any known or suspected nuclear materials inside Syria are not nearly as dangerous as Syria's chemical weapons stockpile or biological weapons since the nuclear material in this case cannot be used directly to make nuclear weapons. Syria also has radioactive sources and wastes, which could be at risk of seizure, and these could cause greater radioactive harm than natural uranium.

Nonetheless, this large stock of natural uranium metal poses nuclear proliferation risks. It could be obtained by organizations such as Hezbollah or Al Qaeda or undeclared nuclear programs of states such as Iran. The U.S. government and its allies, in consultation with the International Atomic Energy Agency, should continue closely monitoring for Syria's nuclear capabilities. Russia's proposal to place Syria's chemical weapons under international monitoring should be broadened to include establishing international control over Syria's nuclear assets, particularly those that were part of its undeclared nuclear efforts.

The United Nations Security Council should pass a resolution that creates the mechanisms and authorities to verifiably characterize, locate, and dismantle Syria's chemical and biological weapons of mass destruction programs and to assess the scope, past and current status, and fate of Syria's undeclared nuclear programs. This resolution must allow for the securing, destruction, and removal of assets to the extent that they that pose a proliferation risk. A special team reporting directly to the Director General of the IAEA and the UN Security Council would be a logical choice to take responsibility for the nuclear portfolio. The team would also be responsible for verifiably determining that these programs and their assets are fully understood, rendered harmless, and dismantled. It could also ensure that Syria's declared nuclear facilities and activities are safeguarded.

Commercial Satellite Imagery of Marj as Sulṭān

Commercial satellite images from November and December 2012 and February 2013 confirm the report by the *Financial Times* that suspicious activity occurred at the Marj as Sulṭān site. Images from November 29 and December 10, 2012 show that the trees of the orchard were cleared within the compound of the suspected processing facility (figures 1a, 1b, 1c, and 2.)[4] The changes took place mostly in mid-to-late November 2012 (see figures 1a and 1c). There are signs that an adjacent military facility was subject to a military attack. What appear to be defensive trenches, likely against mortars or artillery, have been dug within the grounds of this facility; one of the perimeter vehicle sheds has been partially destroyed spreading debris into the nearby residential compound. Debris and remnants of equipment can be seen in the courtyard of the facility that was

[2] Jeffrey Lewis, "FSA Overruns Al Kibar," Armscontrolwonk.com, February 25, 2013 http://lewis.armscontrolwonk.com/archive/6309/fsa-overruns-al-kibar

[3] Director General IAEA, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, GOV/2013/41, August 28, 2013.

[4] ISIS would like to thank DigitalGlobe's Analysis Center for their assistance in understanding several DigitalGlobe images.

previously used as a depot for military vehicles and equipment (compare figures 1 and 4). The February 4, 2013 image shows a small amount of additional vegetation clearing on the grounds of the military facility as well as at an unidentified compound adjacent to the suspected uranium processing facility (figure 3).

In late November of 2012, Syrian rebels seized, and for a short period held, the Marj as Sulṭān military helicopter base less than three kilometers from this area, increasing the likelihood that the Marj as Sulṭān site did in fact see fighting in late October or early November.[5] The stark difference between the satellite images from 2012 and 2013 as compared to imagery from 2008 (figure 4) lends further support to the notion that fighting occurred in the area.

It is unclear why the vegetation near the suspected processing facilities was cleared; one possibility is that it was done in order to improve the defensive capabilities of the facility by removing cover for possible attackers. Some observers have suggested that the wood from this orchard could have been simply used as firewood and although weather was unusually cold in the region between December and January, the average temperature in the area in late November was 12°C/54°F. The February 2013 imagery, in addition to later imagery, shows only minor additional removal of vegetation, despite the unexpected cold snap in late December and January. Thus, the assessment that vegetation was removed in November/early December 2012 to obtain firewood appears doubtful. An assessment that the vegetation was cleared for defensive purposes remains possible but unconfirmed.

According to several informed government officials, the site was subsequently abandoned by the Syrian government. This is consistent with several unofficial internet sources, which compile information about the Syrian conflict, that show this site in rebel-controlled territory in early 2013.[6]

Uranium Processing at the Marj as Sulṭān Site

The IAEA learned of the Marj as Sulṭān site relatively soon after the 2008 public revelations about the Al Kibār reactor, as the possible location of one of three sites functionally related to the reactor, according to senior officials close to the IAEA. Since then, it has repeatedly called on Syria to cooperate fully with the IAEA in connection with unresolved issues related to this reactor and associated locations, including the Marj as Sulṭān site.[7] According to the IAEA, Syria has yet to respond to these calls.

In a February 2011 ISIS report, supported by information shared by the *Süddeutsche Zeitung,* the site was publicly identified as a likely uranium processing facility that could have been involved in fuel manufacturing for the destroyed reactor. ISIS also learned from the *Süddeutsche Zeitung* that the equipment inside the two main buildings included a scrubber and two cyclone separators in the larger building, and large diameter pipes (30-50cm across), a manifold, reaction vessels apparently made from stainless steel, and storage tanks in the smaller building. Also mentioned was a large vertical metal column with windows that was described as equipment for the cleaning or purification of solutions.

Images made available to ISIS by a Western source allegedly show equipment inside the two major buildings at the Marj as Sulṭān site prior to the 2007 bombing of the Al Kibār site. The equipment correlates exactly with the descriptions given to ISIS by the *Süddeutsche Zeitung* in 2011 of a scrubber, cyclone separator, manifold, and purification column (figures 5-8). Analysis of the internal layout of the buildings in these images shows that it appears to match the external structure of the two main buildings at the site as observed in satellite imagery. Based on an assessment of these images by an ISIS technical expert, the facility was not yet

[5] "Syria rebels seize Marj al-Sultan base near Damascus," BBC News, November 26, 2012.

[6] http://en.wikipedia.org/wiki/File:Rif_Dimashq_offensive_%28March_2013%29.svg

[7] *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, August 28, 2013, op. cit.

operational when the photos were taken. The equipment looks clean, tools are present, and some of the piping or wiring does not look fully connected.

This equipment is consistent with what would be expected to be present at a small uranium conversion facility. According to the Western source, the images were taken in 2005. So, it cannot be excluded that the site operated prior to September 2007, when the reactor was bombed and the program likely halted.

However, as noted in the earlier ISIS report and by the *Süddeutsche Zeitung*, missing in the images is uranium metal production equipment and fuel fabrication capabilities essential to making fuel for the type of reactor Syria is alleged to have built with the assistance of North Korea. There are, however, other buildings at the site that could have held additional equipment beyond that in the images, or equipment could have been located at another site. Alternatively, given its relatively small size compared to conventional fuel manufacturing facilities, the site could also be a research and pilot fuel production center or part of a network of facilities involved in developing or producing reactor fuel.

The IAEA expressed suspicion that Syria was building a small uranium conversion and fabrication facility in about 2005. In 2006, the head of the Syrian Atomic Energy Agency, Ibrahim Othman, approached the IAEA about building such a facility, according to a former senior official close to the IAEA. However, after the IAEA responded that the facility would need to be a stand-alone, safeguarded facility, Othman dropped the matter. A senior UN official close to the IAEA said that his educated guess was that this facility was likely already being planned or constructed along with the Al Kibār reactor and the Syrians became nervous about declaring such a facility.

Natural Uranium Associated with the Al Kibār Reactor

Since the Syrian reactor at Al Kibār was reportedly close to completion before it was destroyed by the Israeli strike, U.S. and Israeli governmental analysts assessed that Syria was likely already in possession of the fuel necessary to start the reactor. Little information is available about this fuel.

The fuel type and amount are related to the type of reactor that was being built at Al Kibār. According to information released by the U.S. government, the Al Kibār reactor was modeled on a North Korean gas-graphite reactor, which uses a relatively large core of natural uranium metal fuel.[8] The Syrian reactor is estimated to be similar in size to the reactor at the Yongbyon nuclear center in North Korea. The Yongbyon reactor is typically referred to by its electrical rating of 5 megawatts-electric and its thermal power is estimated at about 20-25 megawatts-thermal. This reactor has a core of about 50 tonnes of natural uranium in about 8,000 fuel rods, which are placed in a total of 812 fuel channels.[9] The Syrian reactor should have a similarly sized core of natural uranium. Based on the information available to the IAEA, the inspectors estimated that the reactor core had 843 fuel channels, or slightly more than the North Korean reactor.[10] Depending on the heat transfer characteristics of the fuel, according to the IAEA, the reactor may have had a thermal power of 25 megawatts-thermal or higher.[11]

Syria is unlikely to have produced 50 tonnes of natural uranium by itself, which is the equivalent of about 59 tonnes of uranium yellowcake. Syria produces uranium as a byproduct in its phosphate purification process

[8] Background Briefing with Senior U.S. Officials on Syria' s Covert Nuclear Reactor and North Korea's Involvement, April 24, 2008. www.fas.org/irp/news/2008/04/odni042408.pdf

[9] Albright and Kevin O'Neill, *Solving the North Korean Nuclear Puzzle* (ISIS Press, Washington, D.C., 2000). The mass of 50 tonnes is the uranium mass only.

[10] IAEA Director General, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, GOV/2011/30, May 24, 2011. http://isis-online.org/uploads/isis-reports/documents/Syria_24May2011.pdf

[11] *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, May 24, 2011, op. cit.

facilities.[12] According to the IAEA, in a visit during July 2004, inspectors observed some hundreds of kilograms of yellowcake at Syria's main such plant at Homs.[13] Commissioned in 1997, the Homs plant does not appear to be capable of producing the many tens of tonnes of yellowcake needed for the first core of the Al Kibār reactor, let alone subsequent cores.

Alternately, North Korea could have provided sufficient fresh, finished fuel for the first and possibly subsequent cores. And it could have provided Syria with yellowcake and the wherewithal to convert the yellowcake into finished fuel. North Korea has extensive stocks of natural uranium. In the early- to mid-2000s, particularly after the failure of the U.S./North Korean Agreed Framework in late 2002, it had the means to make both uranium metal and fuel in secret. Moreover, it could have assisted Syria in obtaining the wherewithal to chemically convert uranium yellowcake into uranium metal and produce the fuel for the reactor.

A North Korean expert in fuel fabrication is alleged to have helped Syria. Chou Ji Bu, who was the chief engineer of the Yongbyon fuel fabrication plant, is standing next to Othman in a picture released by the U.S. government in 2008.[14] The picture appears to have been taken in Syria prior to 2007. Chou Ji Bu is suspected to have prominently contributed to Syria's effort to procure or make fuel for the Al Kibār reactor.

If Syria were going to operate this reactor for several decades, it would likely have wanted to establish a domestic capability to make the fuel itself, even if it imported one or two core loads of fuel initially from North Korea. Syria may have processed some uranium at the Marj as Sulṭān site as part of developing a capability to convert uranium. As indicated previously, the relatively small size of the facility suggests that it could not have produced all the fuel for the Al Kibār reactor. Since the IAEA was never granted access to the site and calls for special inspections, a measure of last resort available to the IAEA, were never demanded, the IAEA has not finished evaluating the role of the Marj as Sulṭān facility or the fate of any uranium stocks stored or processed there.

In any case, the evidence implies that the Al Kibār reactor would have used fuel similar to the Yongbyon 5 megawatt-electric reactor. Among the images made available by the Western source is an image taken in 2005 allegedly showing uranium metal rods located in Syria that are similar to uranium rods prepared for the Yongbyon reactor (figure 9). The rods in the image would be in an intermediate state between being removed from a mold and "canning," which means to put on the fuel cladding, in this case likely a magnesium alloy used as cladding for gas-graphite reactor fuel.

ISIS asked an expert with decades of experience with reactors using natural uranium metal fuel to assess the image to evaluate whether the rods appear to be uranium metal. The expert said that the rods in the picture could be uranium metal, although the expert could not be certain from only a visual inspection of the photo. The rods show a bluish-black sheen from potential surface oxidation that occurs quickly in the case of uranium metal. The expert also pointed out that some of the rods had ridges on them, implying that they had not yet been finished after removal from a mold. Three rods also had golden tips, which the expert thought could represent recent sampling that laid bare fresh metal. He did not think that the golden areas represented sleeves over the rods.

[12] There has been or was some cooperation between Syrian and Egyptian scientists; the latter were developing capabilities to extract uranium from phosphate deposits in the Sinai. However, the known installations at the Nuclear Material Authority of Egypt appear to be of a small scale not able to produce the quantities of uranium needed for the Al Kibār reactor.

[13] IAEA Director General, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, GOV/2010/11, February 18, 2010.

[14] The picture can be found in the video *Syria's Covert Nuclear Reactor at Al Kibar* at http://www.youtube.com/watch?v=4ah6RmcewUM. The relevant part begins at about 5:20.

ISIS compared the rods to known images of Yongbyon fuel rods. A comparison of the uranium rods in figure 9 with fuel rods for the Yongbyon reactor shown in the 1992 video (11:00 mark) of the IAEA visit to North Korea appear to show similarities (see figure 10). Both sets of rods have a similar color and surface texture, which, according to the ISIS expert, is consistent with un-machined, unclad natural uranium fuel rods.

ISIS could not determine the dimensions of the rods in figure 9 due to the lack of any measurable reference point. However, an estimate of the ratio of the diameter to the length of several rods shown in figure 9 matched to within three or four percent the ratio derived from data about uranium slugs for the Yongbyon 5 megawatt-electric reactor.[15] Although the match was not 100 percent the same, it is very close, particularly given that the nature of the picture prohibited measuring the length and diameter of any one rod.

On balance, we could not confirm if the rods in figure 9 were inside Syria or if they were made for the Al Kibār reactor. However, it is reasonable to conclude that they appear to be un-machined natural uranium metal rods that are similar to those made for the 5 megawatt-electric reactor at Yongbyon. If U.S. and Israeli assessments of the Al Kibār reactor are correct, uranium slugs for this reactor should look similar to the ones in figure 9.

Uranium may also be in a more finished fuel form. For example, the uranium rods could be fully clad by a magnesium-zirconium alloy. In this case, the cladding of the fuel would appear silvery and have some additional physical structure. Figure 11 shows clad fuel rods from the Yongbyon 5 megawatt-electric reactor in the cooling pond next to the reactor after irradiation in the core.

Rudimentary Information on Plutonium Separation

There is little information about any Syrian effort to process irradiated fuel with the goal of separating plutonium. One possible indication of construction of a plutonium separation facility was reported by the IAEA. It stated:

> Large quantities of barite [mineral containing barium sulfate] were purchased by the AECS [Syrian Atomic Energy Agency] between 2002 and 2006. Syria has stated that the material was to be used for shielded radiation therapy rooms at hospitals, without providing any supporting information. However, the end use of the barite as stated in the actual shipping documentation indicates that the material was intended for acid filtration. Additionally, the delivery of the barite was stopped at the request of the AECS after the destruction of the building at the Dair Alzour [Al Kibār reactor] site and the remaining quantity was left undelivered. Given that barite is frequently used to improve radiation shielding properties of concrete, and the inconsistency concerning the end use of the barite and the involvement of the AECS in its procurement, the Agency cannot exclude the possibility that barite may have been intended for use in the construction of shielded spaces for purposes linked to nuclear fuel cycle related facilities.[16]

One type of shielded space is a hot cell involved in the initial steps of separating plutonium from highly radioactive irradiated fuel. ISIS did not identify the company that obtained the barite beyond it being in Hong Kong. In addition, the Syrian Atomic Energy Agency had contracted with this Hong Kong company for the barite which in turn acquired it in China. When the Syrian Atomic Energy Agency suspended the contract in 2008, the Hong Kong company sued since it had already bought all of the required quantity in China.

[15] The dimensions of North Korean uranium slugs are in *Solving the North Korean Nuclear Puzzle*, op. cit., table VIII.4. The diameter is 2.9 cm and the length is 52 cm. The mass is 6.242 kg.
[16] IAEA, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, GOV/2011/30, May 24, 2011.

In the case of North Korea, its plutonium separation plant emerged a few years after the 5 megawatt-electric reactor started to operate in 1986. So, the absence of evidence of a plutonium separation plant in Syria is not surprising. Nonetheless, there is a gap in knowledge about what exactly Syria intended to do with irradiated magnesium-clad metal fuel, which is notoriously difficult to store and typically is processed and the plutonium separated.

Finding Nuclear Assets

A priority is determining the location of any uranium linked to the Al Kibār reactor, in addition to the equipment associated with this reactor, the manufacture of fuel, and the chemical processing of irradiated fuel.

The most widely accepted assessment is that the reactor had not yet been loaded with fuel when the 2007 air strike took place. Some uranium fuel was likely at the site, but the core itself had not yet been loaded with fuel.

However, it cannot be discounted that uranium fuel may remain entombed in the buried ruins of the Al Kibār reactor. According to officials from a Western intelligence agency, the 2007 military strike did not use bunker busters and thus the core remained relatively intact. In this case, Syria may have buried the core with the fuel left inside. At some point, the core could be uncovered and checked for any fuel inside it. Likewise, it could be determined if the huge pile of graphite is there.

However, there is evidence to conclude that Syria could have subsequently removed any fuel that had been in the core at the time of the attack. According to an April 24, 2008 briefing by U.S. intelligence officials:

> Immediately after the building was destroyed, the Syrians began taking additional measures to limit potential observation of the reactor and their activities including covering the exposed reactor vessel with tarpaulins; erecting structures to prevent satellite observation of their activities; and opening holes in the building, probably to remove heavy reactor-related equipment.[17]

Thus, after limiting the chances of being observed, Syrians had the opportunity to remove fresh fuel from the reactor core and move it to a secret storage site. Two such possibilities are the salt mine of Al Tibni, which Syria had foreseen as a site for storing radioactive waste, or the near-by agricultural research and development facility at Al Kibār.

If either of the latter two cases are true, where might the uranium be located today? There are few solid leads.

It is natural to ask whether after the bombing the uranium could have been stored at the Marj as Sulṭān site or at one of the other two sites allegedly linked to the Al Kibār site. However, these sites would have initially been poor choices due to the IAEA's interest in visiting them. For example, satellite imagery from July 2008 published in the February 2011 ISIS report showed what was suspected to be sanitization activities at the Marj

[17] Background Briefing with Senior U.S. Officials on Syria' s Covert Nuclear Reactor and North Korea's Involvement, April 24, 2008, op. cit. The briefing continued:

> Syria destroyed the remainder of the reactor building with a massive controlled demolition on October 10th, 2007, as part of an ongoing effort to remove all evidence of the reactor's existence. Demolition of the building, however, revealed key nuclear-related interior structures that remain because they were made of heavily reinforced concrete. These corresponded in configuration and location to key gas-cooled reactor features of our photography-based computer model, including the concrete reactor vessel, the shielded heat-exchanger rooms, and the probably spent fuel storage pool area.

as Sulṭān site following a May 2008 IAEA request to inspect the site. Any uranium stocks or uranium conversion equipment that would have been present at the site in 2008 would likely have been moved during the suspected sanitization activities following the IAEA's request for access.

As the focus on the Marj as Sulṭān site faded and internal instability in Syria increased, it is possible that the stocks were returned to the site since it was located adjacent to a military depot. The private residential compounds with swimming pools surrounding Marj as Sulṭān indicate a wealthy neighborhood which the government may have wanted at least initially to protect. For example, the head of the Syrian atomic energy agency Othman is reported to have a residence nearby this suspected nuclear site.

Once freed of the possibility of IAEA inspections, the regime may have believed that this location was a relatively safe one to store uranium and other sensitive assets. However, increased fighting in 2012 would have undermined that belief. The uranium could be anywhere within government controlled areas today, if it even remains in Syria. Determining its fate must be a priority.

Conclusion

The possibility that the Marj al Sulṭān site was the scene of fighting raises several issues. The first is the adequacy of physical protection over Syria's nuclear assets, whether part of a declared or undeclared nuclear program. The second is the whereabouts of the nuclear and nuclear-related assets associated with the Al Kibār reactor. A special concern is any undeclared natural uranium and equipment associated with a secret infrastructure to make and process reactor fuel. The concerns raised by the *Financial Times* are warranted.

Although Syria's stock of chemical weapons remains a much higher priority, its nuclear assets deserve significant attention. Currently, the IAEA is unlikely to want to take the risk of entering Syria to inspect its declared nuclear facilities and materials, let alone investigate its past, undeclared nuclear programs and facilities. In the interim, the United States and its allies should continue monitoring the status of all known or suspected Syrian nuclear sites and search for evidence of locations of any nuclear assets. A key goal should be to locate nuclear assets including any natural uranium associated with the Al Kibār reactor, ensure that nuclear assets are secure, and possibly remove materials and equipment that pose a proliferation risk in consultation with the IAEA.

If the United Nations Security Council places Syria's stocks of chemical weapons under international control, it should also address Syria's undeclared nuclear assets. The goal should be to verifiably determine that the undeclared program and its assets are fully understood, rendered harmless, and dismantled.

Figure 1a: November 29, 2012 Digital Globe image showing the area in front of the alleged processing facility cleared of vegetation. Trenches, debris from equipment and a partially collapsed building are visible in the adjacent military depot, which also shows signs of fighting. Inserted images from October 12, 2012 and November 12, 2012 show the orchard in place.

Figure 1b: October 12, 2012 image of alleged processing building showing orchard. Source: Financial Times

Figure 1c: November 12, 2012 image of alleged processing building showing orchard. Source: Financial Times

Figure 2: December 10, 2012 Digital Globe image of the Marj as Sulṭān processing facility showing unidentifiable objects visible due to the removal of vegetation in the courtyard of the facility.

Figure 3: February 4, 2013 image of the Marj as Sulṭān site showing cleared vegetation in the courtyard of the alleged processing facility and nearby compound.

Figure 4: Image from July 25, 2008 showing clearly visible vegetation in the courtyard of the processing facility and the original state of the adjacent military depot without any debris or potential signs of fighting.

Figure 5: Image matching the description of an alleged scrubber previously mentioned by the *Süddeutsche Zeitung* and in ISIS reports on the Marj as Sulṭān facility.

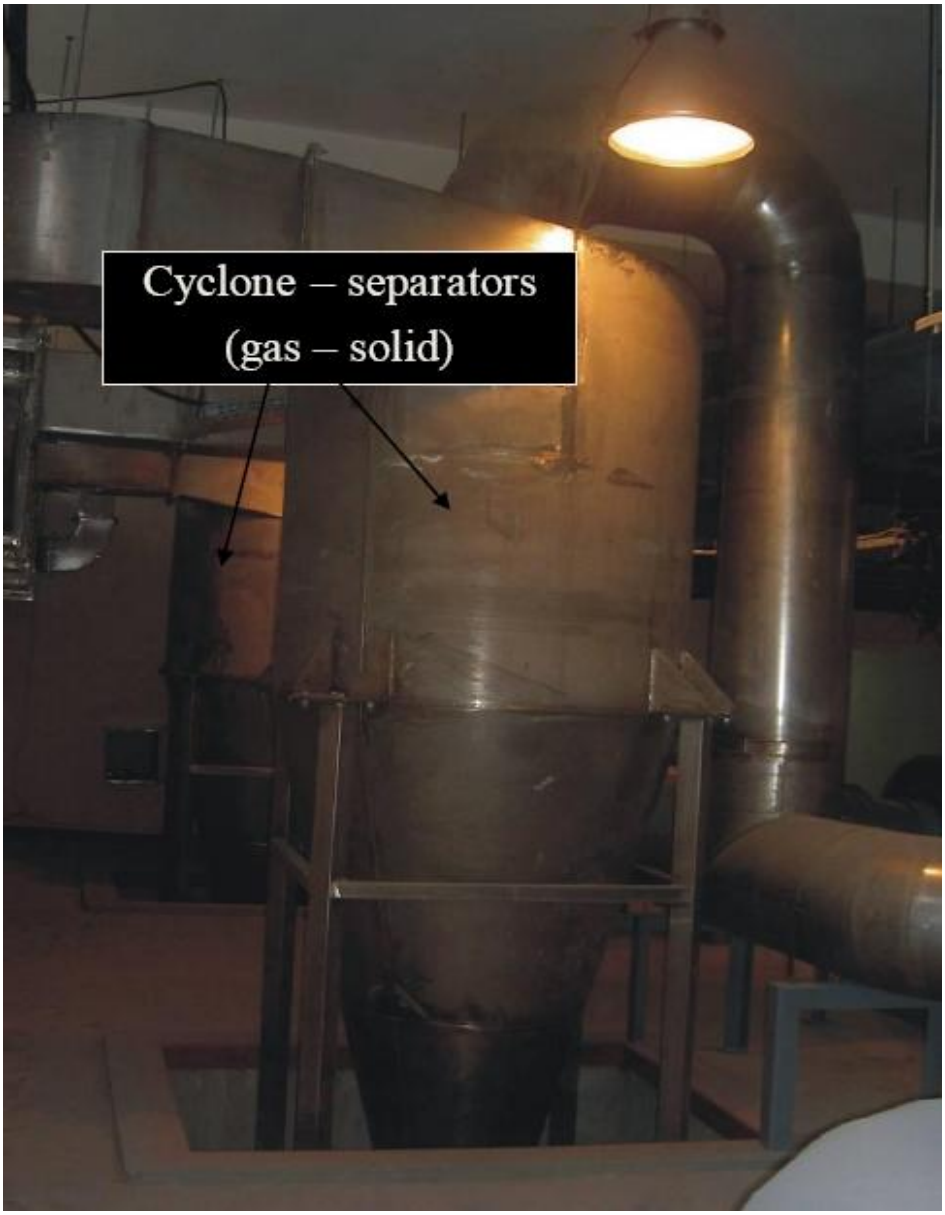

Figure 6: Image of alleged cyclone separators that were reportedly located in the basement of the main building at the Marj as Sulṭān facility.

Figure 7: Image of alleged manifolds in one of the buildings at the Marj as Sulṭān facility.

Figure 8: An image of the alleged purifying column suspected to have been housed in the secondary building at the Marj as Sulṭān compound.

Figure 9: Image made available to ISIS of alleged natural uranium rods related to fuel in the Al Kibār reactor. The rough surface indicates the lack of cladding. The golden tips could suggest recent sampling that would have exposed the unoxidized metal.

Figure 10: Image taken from the video of the 1992 IAEA tour of North Korean nuclear facilities. The image shows uncladded/uncanned natural uranium rods. The rods appear very similar to those suspected to have been related to Al Kibār reactor (see also figure 9).

Figure 11: Spent fuel rods from the 5 megawatt-electric reactor at the Yongbyon nuclear center, showing the cladding of the fuel.