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PHOSPHATE FERTILIZERS AS A PROLIFERATION-RELEVANT SOURCE OF URANIUM

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I. INTRODUCTION

Uranium, mined from the earth, is the most important material in any nuclear weapon programme and used in a variety of other applications. Uranium is the feedstock for nuclear power and nuclear weapons. In its natural isotopic form, it can be used as fuel in reactors to produce electricity or plutonium for nuclear weapons. When it is slightly enriched in the fissile isotope uranium-235, it is the fuel of choice for other kinds of power reactor.[1] Uranium-238, the non-fissile isotope of uranium, can be irradiated in a nuclear reactor to make plutonium, which is used in the manufacture of fuel for a civil power reactor, or in the explosive core in a large proportion of the world's nuclear weapons.

In addition, the radioactive isotopes used in medicine, industry and research are largely produced in nuclear reactors fuelled by uranium. They can also be used for harm in Radiological Dispersal Devices (RDDs), or so-called dirty bombs. This theoretical terrorist device has many disadvantages and, thus far, has not been used on any large scale. Enriched uranium is also used as fuel for naval propulsion: sometimes in icebreakers, but mostly in military submarines and aircraft carriers. Finally, natural uranium or uranium depleted in the uranium-235 isotope is used in industry for both peaceful (e.g. as counter-balance weights for aircraft and shielding containers) and military (in ammunition) purposes.

[1] Fissile materials are those that are capable of sustaining a nuclear fission chain reaction, which is used in both nuclear reactors and nuclear weapons. For an official definition see IAEA, *IAEA Safeguards Glossary: 2001 Edition*, International Nuclear Verification Series no. 3 (IAEA: Vienna, 2001), p. 73.

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SUMMARY

A historical and often overlooked source of uranium for weapons and nuclear power is the extraction of uranium from phosphate fertilizers. In this way, uranium can be acquired legally but in an undeclared fashion, invisible to international commerce and export controls. One example is the production of 109 tonnes of uranium in Iraq, which was dedicated to a clandestine weapons programme. The equipment and processes used were European, supplied legally and openly. The International Atomic Energy Agency was unaware of the uranium extraction at the fertilizer plant and it is an important example of the dangers of supplying this technology to a country in the absence of proper export controls. The fertilizer industry is not normally seen as an industry that enables nuclear weapon acquisition through the use of dual-use equipment, but past events and current international trade practices clearly demonstrate that better-informed export controls and end-user processes are required.

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Uranium is mildly radioactive. The soft radiation it gives off and its long half-life and low activity mean that it is not particularly hazardous to humans. Its chemical toxicity in refined form may be more dangerous than its radiation. Nonetheless, uranium has the potential to cause negative health effects if improperly handled, and especially if inhaled.

The potential for uranium to be used in weapons, military vessels or terrorist devices, as well as the fact that it is radioactive and chemically toxic, brings about the need for it to be tightly controlled in international commerce, and for its use to be carefully monitored from mining to disposal. The nuclear fuel cycle is a system of nuclear installations and activities involved in the production of nuclear power or nuclear materials that are interconnected by streams of nuclear material.[2] Nuclear material can be imagined as 'moving' through the fuel cycle from one facility to another, changing its chemical and physical properties, from ore to nuclear fuel to waste.[3] It is very important to ensure that control of and accounting for the nuclear material are reasonably robust at the point where the material enters the fuel cycle—at the stage of uranium mining and milling. It is hard to secure a material or control its proliferation if it is not known how much of it has been produced in the first place. For all of these reasons, companies that mine and refine uranium have a special responsibility to ensure that their activities are transparent to the public and regulators.

Uranium is not nearly as valuable as rare materials such as gold.[4] It is ubiquitous and about as abundant in the Earth's crust as tin. Uranium is normally obtained from what are officially known as 'conventional resources', that is resources that 'have an established history of production where uranium is a primary product, co-product or an important by-product'.[5] Conventional resources are mined using four 'conventional methods': open-pit mining, underground mining, 'in situ leaching (ISL)' and 'heap leaching'.[6] All four methods are economic at current uranium prices. The output of all mining operations is uranium ore concentrate (UOC), sometimes colloquially referred to as 'yellowcake'.[7]

In 2015 the European Union (EU) member states imported 15 835 tonnes of uranium (tU), or 90 per cent of their total annual nuclear fuel requirements, from outside the EU.[8] In 2015, 48 per cent of uranium production in the world was carried out using the ISL method and 46 per cent was obtained from uranium mines.[9] The remaining 6 per cent of the global uranium supply in 2015 was obtained as a by-product of mining the large poly-metallic Olympic Dam mine in South Australia.[10] These operations are quite visible and relatively easy to monitor.

II. UNCONVENTIONAL URANIUM RESOURCES

There are also a number of 'unconventional' uranium resources, defined as 'very low-grade resources or those from which uranium is only recoverable as a minor by-product'.[11] Examples of such sources are phosphate rocks, non-ferrous ores, carbonatite, black shale, lignite and seawater. Unconventional uranium

[2] International Atomic Energy Agency (note 1), p. 37.

[3] See e.g. Wilson, P. D. (ed.), *The Nuclear Fuel Cycle: From Ore to Waste* (Oxford University Press: Oxford, 1996).

[4] The average spot price for uranium in Europe in 2015 was €88.73 per kilogram. European Commission, Euratom Supply Agency, Nuclear Observatory, 'ESA average uranium prices', <http://ec.europa.eu/euratom/observatory_price.html>.

[5] Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency and International Atomic Energy Agency, *Uranium 2014: Resources, Production and Demand* (OECD: Paris, 2014), <http://www.oecd-nea.org/ndd/pubs/2014/7209-uranium-2014.pdf>, p. 477.

[6] In the first two cases, the ore is removed from the mine, crushed and ground, and then subjected to chemical treatment (milling) to extract uranium. In case of in situ leaching, the ore is left in the ground. The leaching solution is instead pumped through the ore body underground. The uranium-bearing minerals dissolve in the solution and are pumped out back to the surface, where the uranium is recovered in a milling process similar to the one used for mined uranium ore. In the case of heap leaching, the uranium ore is mined, placed on a pad in heaps 5–30 metres high and irrigated with acid or alkaline solution over many weeks, leaching uranium into the resulting 'pregnant liquor', which is then collected and treated to extract the UOC. World Nuclear Association, 'In situ leach (ISL) mining of uranium', Information library, July 2016, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium.aspx>; and World Nuclear Association, 'Uranium mining overview', Information library, Feb. 2016, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx>.

[7] UOC can consist of various chemical compounds but has to contain at least 65% uranium. ASTM International, 'C967-13: Standard specification for uranium ore concentrate', 2013, p. 1.

[8] Euratom Supply Agency, *Annual Report, 2015* (Publications Office of the European Union: Luxembourg, 2015), <http://ec.europa.eu/euratom/ar/last.pdf>.

[9] World Nuclear Association, 'World uranium mining production', Information library, July 2016, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx>.

[10] World Nuclear Association (note 9).

[11] OECD Nuclear Energy Agency and International Atomic Energy Agency (note 5), p. 477

resources are harder to verify and most of them currently produce uranium that is more expensive than that produced from traditional rock mining. European companies have pioneered many of the unconventional resource mining processes in the past. Some of this uranium produced from unconventional sources was diverted for clandestine purposes to produce nuclear weapons (see below).[12] Other processes have the potential to generate extremely negative publicity if steps are not taken to ensure that companies know where and how their technologies are being used.

The exploitation of unconventional sources of uranium is perfectly legal and ethical as long as international guidelines are followed. A kilogram of uranium produced in a hard rock mine or a kilogram extracted from seawater are equally legitimate. If industrial processes for uranium extraction from unconventional resources become more competitive, or the price of uranium significantly increases, the use of such resources could become much more common.[13]

This distinction between 'conventional' and 'unconventional' is made for the purposes of the peaceful use of nuclear power and is not connected to International Atomic Energy Agency (IAEA) nuclear safeguards. However, unconventional resources can be a cause for concern from a nuclear non-proliferation standpoint because they can be misused or their exploitation can go unreported.

The introduction states that uranium is the only starting material for a nuclear weapon programme. Thorium can be irradiated in a uranium fuelled nuclear reactor to proceed nuclear fuel but is not discussed below. In the 70-year development of atomic energy for civil and military purposes, this technology has only been pursued as a curiosity. It seems possible, even likely, that thorium might one day be part of a nuclear fuel cycle for advanced reactors, but that dream remains well in the future and has no impact on these discussions. In addition, the thorium cycle is not possible without building a uranium-fuelled reactor first.

Some radioactive isotopes can be produced in a particle accelerator where there is no need for a reactor. Quantitatively, however, this is a very small contribution to global stocks of fissile and radioactive material and again has no bearing on the trade in uranium for reactors and weapons, which is enormous by comparison.

III. SAFEGUARDS PERTINENT TO URANIUM RESOURCES AND MINING

The IAEA concludes Comprehensive Safeguards Agreements (CSAs) with member states to allow verification that none of the nuclear material in a state's fuel cycle is being diverted for use in nuclear weapons or other nuclear explosive devices. Natural uranium is a source material as defined by the IAEA Statute and therefore one type of nuclear material according to IAEA definitions.[14] A CSA requires a state to provide the IAEA with information on UOC imports and exports, unless the material is being transferred 'for specifically non-nuclear purposes'.[15]

However, applying IAEA safeguards to mines is neither cost-effective nor useful as the material quantities involved in mining are so huge, uranium concentrations are low and the associated uncertainties are too large. For this reason, CSAs explicitly state that the full extent of safeguards procedures, including IAEA accountancy and control provisions, should not apply 'to material in mining or ore processing activities'. Paragraph 34 (c) of a CSA states that full-scope safeguards begin when 'nuclear material of a composition and purity suitable for fuel fabrication or for being isotopically enriched' is either imported into the country or 'leaves the plant or the process stage in which it has been produced'.[16] Materials that have not yet reached such a composition or purity are known as 'pre-34 (c) materials'.

The description of materials in paragraph 34 (c) has historically been interpreted as referring to the final products of the process of converting

[12] United Nations, Security Council, Fourth consolidated report of the Director General of the International Atomic Energy Agency under para. 16 of Security Council resolution 1051 (1996), S/1997/779, 6 Oct. 1997, <https://www.iaea.org/OurWork/SV/Invo/reports/s_1997_779.pdf>, p. 27.

[13] These judgements are based on recent prices for uranium on the open market. Like many mining commodities, the price of uranium can fluctuate and during periods when the price is high, the incentive to find unconventional sources increases. Ux Consulting Company, 'Ux U3O8 price: full history', <https://www.uxc.com/p/prices/ UxCPriceChart.aspx?chart=spot-u3o8-full>.

[14] International Atomic Energy Agency (note 1), p. 30.

[15] See paras 34(a) and 34(b) in IAEA, The structure and content of agreements between the Agency and States required in connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected), June 1972, <http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/44/089/44089080.pdf>.

[16] See IAEA (note 15), paras 33, 112.

natural uranium. In 2003 the IAEA issued a new interpretation, according to which purified uranyl nitrate, a material produced near the beginning of the process, also satisfies the language in paragraph 34 (c) mentioned above. This means that at least in some cases the starting point for safeguards accountancy procedures had to be moved to the beginning of the conversion process, to the point where the UOC is added to the production line.[17] In 2013 the IAEA reinterpreted paragraph 34 (c) again, stating that the composition of some UOC is of such purity that it does not need to go through conversion, and therefore full-scope safeguards should be applied to it.[18] This decision moved the starting point of safeguards in some countries even further upstream to the uranium milling facilities that produce such UOC.

The discovery of an extensive clandestine nuclear weapon programme in Iraq in 1991 prompted the IAEA to supplement its CSAs with an Additional Protocol (AP). If ratified by a state, the Model AP grants the Agency additional legal authority to verify a state's safeguards obligations.[19] As is discussed below, Iraq was pursuing nuclear weapons on a broad front, which included extracting uranium from phosphates, at the Al Qaim Superphosphate Fertilizer Plant. During its six years of operation in the 1980s, without the IAEA's knowledge at that time, Iraq extracted from phosphates 109 tonnes of uranium in 168 tonnes of yellowcake.[20]

In order to prevent similar gaps in safeguards, an AP obliges the state that is implementing it to provide the IAEA with more information on pre-34 (c) materials. First, according to article 2.a.(v) of the Model AP, states must specify 'the location, operational status and the estimated annual production capacity of uranium mines and concentration plants'. Second, the AP tightens the CSA requirement to report the import and export of pre-34 (c) material, mandating such reporting even for material intended for non-nuclear purposes (article 2.a.(vi)(b and c)). Finally, article 2.a.(vi)(a) requires the provision of information on pre-34 (c) materials, such as quantities, the chemical composition and the use or intended use at each location at which the material is present. Such reporting is expected for material quantities exceeding 10 tonnes of uranium.[21] As of October 2016, 129 states and the EU had an AP in force.[22]

It is important to note that the nuclear weapon-possessing states that are outside of the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT)—India, Israel, the Democratic People's Republic of Korea (DPRK, or North Korea) and Pakistan—will not have signed an AP, and are therefore under no obligation to declare uranium production or extraction. Nonetheless, India, Israel and Pakistan are all members of the IAEA that from time-to-time are represented on the IAEA Governing Board.

European states and industry should be exceedingly careful not to provide uranium-bearing minerals to any state without ensuring that it is subject to IAEA safeguards. They should also be careful to ensure that nuclear material production technology is carefully monitored to verify that it is being used appropriately in the NPT states and especially in the nuclear weapon possessing states outside the NPT.

IV. URANIUM EXTRACTION FROM PHOSPHATE ROCK

One of the largest unconventional resources of uranium is phosphate rock or phosphorite. There is about 5.9 million tonnes of uranium in known recoverable conventional resources. Estimates of the amount of uranium available from phosphate rock range from 9 to 22 million tonnes.[23] Extracting uranium from phosphate rock is not economic at current prices but

[17] Owen, K. E., 'Implementation of IAEA policy paper 18 in Canada' (IAEA-CN-148/39), Further Strengthening Safeguards Practices and Approaches 1: Safeguards approaches (Session 6), *Addressing Verification Challenges: Proceedings of an International Safeguards Symposium on Addressing Verification Challenges*, International Atomic Energy Agency in cooperation with the Institute of Nuclear Materials Management and the European Safeguards Research and Development Association, Vienna, 16–20 Oct. 2006 (IAEA Verification Series: Vienna, 2007), <http://www-pub.iaea.org/MTCD/Publications/PDF/P1298/P1298_Contributed_Papers.pdf>, p. 155.

[18] Vestergaard, C., 'Safeguarding the front-end of the nuclear fuel cycle', *Trust&Verify*, no. 150 (July–Sep. 2015), pp. 2–3.

[19] IAEA, Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected), Sep. 1997.

[20] United Nations (note 12).

[21] IAEA, *Guidance for States Implementing Comprehensive Safeguards Agreements and Additional Protocols*, IAEA Services Series no. 21 (IAEA: Vienna, May 2016), <http://www-pub.iaea.org/MTCD/Publications/PDF/SVS-21_web.pdf>, pp. 32, 37.

[22] IAEA, Status of the Additional Protocol as of 7 Oct. 2016, <https://www.iaea.org/safeguards/safeguards-legal-framework/additional-protocol/status-of-additional-protocol>.

[23] World Nuclear Association, 'Uranium from phosphates', Information library, Aug. 2015, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/uranium-from-phosphates.aspx>.

the margin is not large. If the phosphorite is already being processed for other reasons, such as fertilizer production, many of the high initial processing costs will already be covered. In phosphate fertilizer manufacturing much of the phosphate is processed as phosphoric acid. It is straightforward from an industrial point of view to divert some of this acid to a specific uranium extraction unit and recover the uranium. The phosphoric acid, depleted in uranium, could then be returned to the fertilizer production stream. This technology is still more expensive at current uranium prices than mining uranium rock ore, but only marginally so.

Uranium extraction from phosphates may not be cost-effective at the moment, but it is dangerous from a non-proliferation perspective. It can be carried out quietly, even clandestinely. As uranium extraction technologies matured, the phosphate process lost its competiveness but it remains an attractive option in cases of undeclared nuclear programmes.

V. THE MILITARY USE OF URANIUM EXTRACTED FROM INDIGENOUS PHOSPHATE ROCK

United States

In the 1940s the United States obtained its first, conventionally mined, uranium from Canada and what was then the Belgian Congo. This uranium was used in the nuclear weapon programme that led to Hiroshima and Nagasaki. In later years conventional rock mining in the western USA was a major source of uranium, including for the military nuclear programme.[24] However, between 1954 and 1962 US companies recovered about 17 150 tU, which was mainly used for military purposes, from phosphate rocks in Florida.[25] Production was restarted in the 1970s and the mid-1990s. At that time, about 20 per cent of US uranium production was from phosphate fertilizer by-products.[26] US phosphate deposits are estimated to contain 140 000–330 000 tU.[27]

Israel

Israel seems likely to have relied on a number of different sources of uranium for its undeclared nuclear weapon programme, including various imports and indigenous production. A geological survey conducted in 1949–51 demonstrated that the only domestic source of uranium in Israel is low-level phosphate ore from the Negev desert.[28] These deposits are estimated to contain 25 000–50 000 tU.[29]

The Israeli nuclear establishment considered the uranium in these deposits, as well as the technologies for its extraction, to be a crucial part of the Israeli nuclear programme.[30] Israel has been making serious efforts to mine and extract significant amounts of uranium from indigenous phosphates at least since the 1960s.[31] Estimates made in the 1990s suggested that these efforts resulted in annual indigenous production of about 10 tonnes of UOC per year.[32] More recent estimates put the figure at 18 tonnes of uranium per year.[33] At present, phosphate rock is reportedly mined at three locations in the Negev desert: Arad, Zin and Oron, and uranium is extracted by Rotem Amfert Negev Ltd.[34]

[24] Squassoni, S. et al., *Governing Uranium in the United States*, Centre for Strategic and International Studies (CSIS) Reports (Rowan and Littlefield and CSIS: Washington, DC, March 2014), <https://www.csis.org/analysis/governing-uranium-united-states>, pp. 8–14.

[25] OECD Nuclear Energy Agency and International Atomic Energy Agency, *Uranium 2011: Resources, Production and Demand* (OECD: Paris, 2011), <http://www.oecd-nea.org/ndd/pubs/2014/7209-uranium-2014.pdf>, p. 32.

[26] World Nuclear Association (note 23).

[27] OECD Nuclear Energy Agency and International Atomic Energy Agency (note 5), p. 35.

[28] Cohen, A., *Israel and the Bomb* (Columbia University Press: New York, 1998), p. 26.

[29] IAEA, 'Uranium deposits in Israel', World Distribution of Uranium Deposits (UDEPO), 2012, <https://infcis.iaea.org/UDEPO/UDEPOMain.asp?Country=Israel&RightP=CountryReport>.

[30] Cohen (note 28), pp. 26, 33–34.

[31] Ketzinel, Z., Volkman, Y. and Yakir, D., 'Recovery of Uranium from the IMI Phosphoric Acid Process', Israel Atomic Energy Commission, Report IA1268, 1972, <https://www.ipen.br/biblioteca/rel/R32256.pdf>; and Derry, R., *The Recovery of Uranium from Phosphate Sources in Relation to the EEC: Warren Spring Laboratory*, EUR7324 EN (European Commission: Luxembourg, 1981), <goo.gl/Fg3nfs>.

[32] Albright, D., Berkhout, F. and Walker, W., SIPRI, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997), p. 259.

[33] Schnug, E., 'Where has all the uranium gone? Or what feeds Dimona, circumstantial evidence for an illicit fate of uranium from rock phosphate processing', eds B. Merkel and A. Arab, *Uranium: Past and Future Challenges, Proceedings of the 7th International Conference on Uranium Mining and Hydrogeology* (Springer: Berlin, 2015), <http://link.springer.com/chapter/10.1007%2F978-3-319-11059-2_84>.

[34] Nuclear Threat Initiative, 'Rotem Amfert Negev Ltd', 1 Jan. 2011, <http://www.nti.org/learn/facilities/336/>. The uranium content of phosphate deposits is estimated to be 'less than 225 ppm [parts per million]' at Arad, and 91–159 ppm at Zin and Oron. Dahlkamp, F. J.,

The use of phosphates as a source of uranium for Israel's undeclared military programme is raised repeatedly in intelligence assessments dating back to 1958. The initial conclusion of these assessments was that the supply was too small to support such a programme. In the early 1970s Israel Mining Industries (IMI) began to make serious efforts to mine and extract significant amounts of uranium from phosphates. In 1972 IMI published a paper in conjunction with the Israeli Atomic Energy Commission on the extraction of uranium using a hydrochloric acid process.[35] A report by the European Commission states that a plant was built to use this process, but it was unsuccessful and the plant was shut down in the 1970s.[36] The IMI mixer-settler process is one of the most commonly used worldwide for uranium extraction. It is used in industry in many countries but never acknowledged as having been used in Israel.

Technical support for the modern programme comes from a number of companies and various subcontractors. The employees of these companies highlight experience gained in solvent extraction of uranium from phosphates in their online CVs. These companies carry out solvent extraction separation of uranium from many ores including phosphates.

By far the most important uses for uranium in Israel are as the fuel for its heavy water plutonium production reactor at Dimona and in nuclear weapon components.[37] The reactor uses domestically manufactured natural uranium fuel elements to produce plutonium in uranium targets and in the fuel itself. Estimates of the annual uranium requirement for the Dimona reactor vary, but indigenously produced uranium seems to account for only 50–75 per cent of what needs to be loaded into the reactor every year.[38]

Uranium Deposits of the World: Asia (Berlin: Springer, 2009), <https://books.google.se/books?id=ShzwRGs5mDYC&lpg=PA30&pg=PA452#v=onepage&q&f=false>, p. 451.

[35] Ketzinel, Volkman and Yakir (note 31).

[36] Derry (note 31).

[37] In addition, Israel has a small 5 MW(th) nuclear reactor at the Soreq Research Centre in the Negev Desert, designated IRR-1 or the Israeli Research Reactor. It uses 93% enriched uranium fuel supplied by the USA and is regularly inspected by the IAEA as a declared activity. Nuclear Threat initiative, Soreq Nuclear Research Centre (SNRC), 1 Jan. 2011, <http://www.nti.org/learn/facilities/419/>.

[38] The most common estimate is that the Dimona reactor requires 22–24 tonnes of uranium annually. Glaser, A. and Miller, M., 'Estimating plutonium production at Israel's Dimona Reactor', n. d., <https://www.princeton.edu/~aglaser/PU056-Glaser-Miller-2011.pdf>; and Barnaby, F., *How Nuclear Weapons Spread: Nuclear-Weapon Proliferation in the 1990s* (Routledge: London, 1993), <https://books.google.se/books?id=ngokJKxyoT0C&pg=PT81&lpg=PT81#v=onepage&q&f=false>, p. 81.

Israel is likely to keep the Dimona reactor running for the foreseeable future. It is highly likely that tritium, a heavy isotope of hydrogen, is used in most Israeli weapons. Tritium is produced in a reactor, has a short, 12-year half-life and must be continually replaced in stockpiled weapons in order for them to function. Even if Israel decides that it no longer needs more plutonium for its nuclear weapon stockpile, the Dimona reactor will still need to be operated and, by extension, indigenous production of uranium from phosphate rocks will probably need to continue.

European exporters and export control authorities will have to make a judgement on the ethics and legality of assisting Israeli phosphate fertilizer production, due to the likelihood that uranium from that source is being used in military applications, and because Israel has not signed the NPT.

Iraq

Iraq has a number of significant phosphate ore deposits, the biggest of which (50 000–100 000 tonnes of uranium) is located at Akashat.[39] The Belgian company Sybetra was contracted by the Iraqi Government in 1975 to build the Akashat Phosphate Rock Mine and a phosphate fertilizer plant at Al Qaim.[40] The mine was opened in 1981 and the first ore was delivered to the Al Qaim plant in 1982.[41] The Iraqi Government contracted a second Belgian company, Mechim SA, to design, build and commission a production unit (Unit 340) at Al Qaim between 1982 and 1984. It used the Prayon process to extract uranium from phosphoric acid. The first batch of yellowcake was delivered to the Iraqi Atomic Energy Commission (IAEC) in December 1985.[42] With this Belgian-built unit in operation, Al Qaim became the Iraq nuclear weapon programme's main source of UOC until it was destroyed in 1991. During its six years of operation, it produced 109 tonnes of uranium in 168 tonnes of yellowcake.[43]

[39] IAEA, 'Uranium deposits in Iraq', World Distribution of Uranium Deposits (UDEPO), 2012, <https://infcis.iaea.org/UDEPO/UDEPOMain.asp?Country=Iraq&RightP=CountryReport>.

[40] Japan International Cooperation Agency (JICA) et al., *Preliminary Feasibility Study Report on Mining and Industrial Sector in Mid-Western Iraq* (JICA: Tokyo, Apr. 2010), <http://open_jicareport.jica.go.jp/pdf/11995206.pdf>.

[41] Europa Regional Surveys of the World, *The Middle East and North Africa, 2004*, 50th edn (Europa Publications: London, 2004), p. 502.

[42] US Central Intelligence Agency, *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD (Duelfer Report)*, vol. 2 (CIA: Washington, DC, 2005), p. 11.

[43] United Nations (note 12)

Iraq is the most important case of the undeclared production of uranium from phosphates. The fact that Iraq was producing uranium at a phosphate plant was known to the European suppliers of the technology but not widely known otherwise. Iraq did not advise the IAEA of its activity because, as noted above in relation to the starting point of safeguards, it was not technically required to do so. However, the uranium produced was transported to other facilities and converted to materials for use in a clandestine nuclear weapon programme. The fact that the IAEA was unaware of the uranium extraction at the fertilizer plant underlined the dangers of supplying this technology without proper export controls.

It is also clear that the existence of the uranium extraction facility at Al Qaim was known to intelligence agencies even if it was not shared with the IAEA. Unit 340 at the fertilizer plant was one of the first targets to be bombed in the Gulf War of 1991, indicating that it was known to be a proliferation risk. One of the goals of that bombing was to thwart the Iraqi nuclear programme. Unit 340 was demolished in the 1990s.[44]

VI. URANIUM FROM INDIGENOUS PHOSPHATES AND CASES OF PROLIFERATION CONCERN

Syria

Uranium extraction from phosphate fertilizers in Syria and Egypt (see below) shares many common roots. Both countries received IAEA Technical Cooperation Programme (TC) assistance to develop the technology for nuclear power—and possible future weapons—programmes, and much of the technology came from the same sources.

Syria's potentially recoverable uranium resources from phosphate rocks are estimated to be approximately 40 000 tU.[45] In 1986 Syria requested assistance from the IAEA with obtaining a micro-pilot plant for UOC recovery from phosphoric acid. This was known as IAEA TC Project SYR/3/003.[46] Syria also asked the United Nations Development Programme (UNDP) to construct a larger uranium recovery plant, but it was deemed uneconomic at that time.[47]

In 1996 the IAEA (Project SYR/3/005) and the UNDP (Project SYR/95/002) initiated a programme to build a small pilot-scale uranium extraction facility at the Homs Fertilizer Plant. The goal was to extract uranium from the phosphoric acid produced there. This project was successful and small-scale UOC production began in 1999.[48] The main product of the plant, however, was industrial-grade phosphoric acid free of heavy metal.

In 2004 the Swedish company Metallextraktion AB (MEAB) was investigated (but not prosecuted) by the Swedish authorities for exporting to the Syrian Atomic Energy Commission (SAEC) without obtaining the proper export licences.[49] MEAB has reportedly supplied equipment to the Homs Fertilizer Plant.[50] In 2010 MEAB described the process apparently in use at the plant at Homs (the SAEC process) as purification of green phosphoric acid to food grade quality.[51] The same purification process can also result in the production of UOC. The acronym SAEC appears to stand for Syrian Atomic Energy Commission and a photograph on the MEAB website illustrating the SAEC process is identical to one of the interior of the food grade processing plant at Homs taken directly from a Syrian presentation describing uranium extraction from phosphate.[52]

In 2008 and 2009 the IAEA found natural uranium particles at a small research reactor facility near Damascus, the Chinese supplied Miniature Neutron

[44] IAEA, Iraq Decommissioning Project, Al-Qaim Site, 9 Dec. 2014, <http://www-ns.iaea.org/projects/iraq/qaim.asp?s=8&l=66>.

[45] Dahlkamp (note 34), p. 452.

[46] Technical Cooperation Project SYR/3/003: Uranium Recovery from Phosphoric Acid, IAEA, 'IAEA-TC Projects by Country: Syria', <https://fas.org/nuke/guide/syria/iaea-syria.pdf>.

[47] Nuclear Threat Initiative, 'Phosphoric acid pilot plant', 1 Jan. 2011, <http://www.nti.org/learn/facilities/457/>.

[48] Stas, J. et al., 'Uranium extraction from Syrian phosphate: case study', *International Journal of Economic and Environmental Geology*, vol. 1, no. 2, pp. 30–34, <http://econ-environ-geol.org/pdf/feb/Article-6.pdf>; and IAEA, Technical Cooperation Report for 1998, GC(43)/INF/3, <http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/32/004/32004850.pdf>, p.35.

[49] Åklagarmyndigheten i Göteborg, Chefsåklagare Mats Sällström, 'Beslut i åtalsfråga' [Chief Prosecutor Mats Sällström, 'Decision regarding prosecution'], C09-1-19-04, 26 Nov. 2004.

[50] Wallkvist, J., 'Han säljer teknik för kärnvapen' [He sells technologies for nuclear weapons], *Expressen*, 19 Feb. 2004, <http://www.expressen.se/nyheter/han-saljer-teknik-for-karnvapen/>.

[51] Metallextraktion AB (MEAB), 'The SAEC process: purification of green phosphoric acid to food grade', Nov. 2010, <http://www.meab-mx.se/pdf/The_SAEC_process.pdf>.

[52] Stas, J. et al., 'Uranium extraction from Syrian phosphate: case study', Presentation slides, Syrian Atomic Energy Commission, n. d., Damascus; and Stas, J. et al., 'Uranium extraction from Syrian phosphate: case study', *International Journal of Economic and Environmental Geology*, vol. 1, no. 2, <http://econ-environ-geol.org/pdf/feb/Article-6.pdf>, pp. 30–34.

Research Reactor (MNSR).[53] After two years of investigation the IAEA concluded that about 10 grams of uranium had been diverted from the pilot plant at Homs to the MNSR for simple irradiation experiments.[54] This case would normally be treated as a minor violation of IAEA safeguards. However, an Israeli air strike on a suspected undeclared nuclear facility located at al Kibar, conducted in September 2007, and its political and diplomatic repercussions ensured that the uranium diversion from the Homs plant received an unusual degree of attention.[55]

With these plants in place, Syria acquired the know-how to build a much larger uranium extraction unit but there is no evidence that it did so or that it had any plans to do so. The most logical location for an undeclared uranium extraction plant would be the huge fertilizer plant at Palmyra, but no satellite imagery has ever identified such activity and the ongoing civil war in Syria makes an investigation impossible.

Egypt

Egypt followed a path similar to Syria in investigating uranium production through extraction from phosphates. Egypt has been mining phosphates since 1908 and still has significant production volumes and reserves.[56] Egypt's uranium resources in phosphates are estimated at 40 000 tU or more.[57] Phosphoric acid is produced in Egypt mainly by the Abu Zaabal Fertilizer Company and the El-Nassar Company. In 1996, the Egyptian Nuclear Materials Authority established a semi-pilot plant for experimental uranium extraction from phosphoric acid. The plant is located at Inshas, 60 km north-east of Cairo, about 1 km away from the Abu Zaabal Fertilizer Company. It is operated by the Egyptian Nuclear Materials Authority. Visitors to the Egyptian extraction facility found it to be dirty and dilapidated. The floor was covered in water and acid. Uranium sludge was being dumped unceremoniously on the ground outside the plant. The main activity seemed to be the production of industrial grade phosphoric acid with heavy metals removed. Egypt reports that the system is uneconomic for extracting uranium and that there are many operational problems. Nonetheless, as of 2015 Egypt was continuing its attempts to further develop its uranium extraction capabilities with technical assistance from the IAEA as part of its general policy to develop its nuclear energy infrastructure.[58]

Egypt has concluded a CSA with the IAEA but refuses to sign an AP, citing as its reason the absence of a CSA between the IAEA and Israel.[59] As discussed above, a CSA alone, even with the new interpretations concerning the starting point of safeguards, does not require Egypt to report its production of uranium from phosphates.

Egypt's nuclear programme came under particular scrutiny in 2004 when the IAEA noticed information in scientific publications that indicated activities that should have been reported to the IAEA. According to one account, these activities involved uranium extraction.[60] Further safeguards anomalies were uncovered in 2007 and 2008 when IAEA inspectors discovered highly enriched uranium particles in an environmental sample taken at Inshas. These anomalies turned out to be small-scale, did not appear to be part of an attempt to produce nuclear weapons

[53] IAEA, 'Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic', GOV/2009/75, 16 Nov. 2009, <https://www.iaea.org/sites/default/files/gov2009-75.pdf>.

[54] IAEA, 'Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic', GOV/2011/30, 24 May 2011, <https://www.iaea.org/sites/default/files/gov2011-30.pdf>.

[55] Kile, S. N., 'Nuclear arms control and non-proliferation', *SIPRI Yearbook 2010: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2010), pp. 393–94.

[56] Notholt, A. J. G. et al., *Phosphate Deposits of the World*, vol. 2, *Phosphate Rock Resources* (Cambridge University Press: Cambridge, 2005), <https://books.google.se/books?id=nw230cCn2EoC&pg=PA192>, p. 192; and US Geological Survey, Mineral Commodity Summaries, Jan. 2016, <http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/mcs-2016-phosp.pdf>, p. 125.

[57] IAEA, 'Uranium deposits in Egypt', World Distribution of Uranium Deposits (UDEPO), 2012, <https://infcis.iaea.org/UDEPO/UDEPOMain.asp?Country=Egypt&RightP=CountryReport>; World Nuclear Association (note 23).

[58] Taha, M. H., 'Uranium from phosphates: Current status of Egyptian UxP project', Presentation at the IAEA Regional Training Course, Luxor, 18–22 Oct. 2015, <https://www.unece.org/fileadmin/DAM/energy/se/pp/unfc/unfc_ws_U.Th_Luxor.Oct.2015/9_Helmy-Luxor.pdf>; and Egyptian Nuclear Materials Authority, 'Uranium Extraction Unit', n. d., <https://www.iaea.org/OurWork/ST/NE/NEFW/documents/RawMaterials/TM%20JOR/35%20New%20Microsoft%20PowerPoint%20uranium.pdf>.

[59] IAEA, Application of IAEA Safeguards in the Middle East, GOV/2015/45-GC(59)/15, 28 July 2015, <https://www.iaea.org/About/Policy/GC/GC59/GC59Documents/English/gc59-15_en.pdf>.

[60] Findlay, T., *Proliferation Alert! The IAEA and Non-Compliance Reporting* (Belfer Center for Science and International Affairs, Harvard Kennedy School: Cambridge, MA, Oct. 2015), <http://belfercenter.ksg.harvard.edu/files/Proliferation%20Alert.pdf>, p. 75.

and were probably ‘an inadvertent rather than deliberate case of non-compliance’.[61]

The reasons for Egypt’s interest in uranium extraction are unclear. Egypt has no domestic demand for uranium. Given that experienced uranium producers find extraction from phosphates uneconomic at current prices, extracting uranium from phosphates for the purposes of international trade is hardly an option. Russia has announced plans to collaborate with Egypt on building a nuclear power plant at Al Dabaa.[62] Russia normally supplies the nuclear fuel for the reactors it sells and takes back the spent fuel. However, unless Egypt signs and ratifies an AP, Russia would be making a startling exception to the modern policy of no nuclear industry sales to states without an AP in place.

Egypt is located in a volatile region. It has operated close to the edge of its existing obligations to report nuclear activities in the past. It refuses to sign and ratify an AP for political reasons, and its incentives for pursuing uranium extraction are legal but obscure. European suppliers and export control agencies will need to consider the legality and risks of supplying equipment to the Egyptian fertilizer and phosphate industries, while also considering verification of the end-use of any equipment supplied.

VII. LEGAL INTERNATIONAL TRADE IN PHOSPHATES AND PROLIFERATION ISSUES

The cases discussed above illustrate that uranium extraction from indigenous phosphate rock has played a significant role in the development of some nuclear weapon programmes. In most cases, such uranium production was undeclared but not illicit. Another layer of complexity, including from an export control perspective, is added if the phosphates are produced in one country and transferred to another country where uranium extraction is either possible or openly carried out. Such an arrangement, even if clearly legal, could lead to review and criticism, especially in cases where the phosphates—and the undeclared uranium in them—are supplied to countries with actively expanding nuclear weapon programmes.

[61] Findlay (note 60).
[62] Baker, L. et al., ‘Egypt, Russia sign deal to build a nuclear power plant’, Reuters, 19 Nov. 2015, <http://www.reuters.com/article/us-nuclear-russia-egypt-idUSKCN0T81YY20151119>.

Morocco and Pakistan

Morocco (with Western Sahara) has by far the largest reserves of phosphate rock ore in the world: 50 billion tonnes or about 72 per cent of the world total.[63] The Organisation for Economic Co-operation and Development estimates that these reserves contain about 6.5 million tU.[64] Morocco has both a CSA and an AP in place with the IAEA. The Office Chérifien des Phosphates (OCP) is the Moroccan Government entity entrusted since 1920 with mining, processing and marketing all the phosphate reserves of the Kingdom of Morocco.[65] The OCP produced 30 million tonnes of phosphate rock for fertilizers in 2015.[66]

The OCP has considered extracting uranium from its phosphate reserves. In 2007, the French multinational nuclear power company, Areva, signed a mining and research cooperation agreement with the OCP concerning the extraction of uranium from phosphoric acid produced from Moroccan phosphate ore.[67] Morocco announced that it would start extracting uranium from its phosphate by 2015 in a partnership with France, but it is not clear whether production has begun.[68]

The OCP operates in partnership with several entities in Pakistan under the umbrella of the Fauji Foundation, a charitable trust founded in 1954 ‘for the welfare of ex-servicemen and their dependants’ which has stakes in many strategic industries in Pakistan.[69] The servicemen in question are senior retired officers, normally generals. Leadership roles in large industrial enterprises are a significant patronage privilege. Part of the foundation’s business is devoted to phosphate fertilizer supply and distribution in Pakistan.

[63] US Geological Survey, Mineral Commodity Summaries, ‘Phosphate rock’, Jan. 2016, <https://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/mcs-2016-phosp.pdf>.
[64] OECD (note 5), p. 35.
[65] OCP Group, ‘A key international player since 1920’, OCP Group website, <http://www.ocpgroup.ma/group/group-overview>.
[66] US Geological Survey (note 63).
[67] Areva, ‘Morocco: Areva and OCP sign mining cooperation agreement’, Press release, 23 Oct. 2007, <http://www.areva.com/EN/news-6503/morocco-areva-and-ocp-sign-mining-cooperation-agreement.html>.
[68] El Hajji, Z., ‘Morocco to extract uranium from its phosphates by 2015’, Morocco World News, 4 Jan. 2015, <https://www.moroccoworldnews.com/2014/01/118597/morocco-to-extract-uranium-from-its-phosphates-by-2015/>.
[69] Fauji Foundation, Fauji Foundation Overview, n. d., <http://www.fauji.org.pk/fauji/about-us/aboutus-overview>.

Pakistan Maroc Phosphore (PMP) is a joint venture between the OCP and the Fauji Foundation. One of the PMP's purposes is to provide two other parts of the Fauji Foundation (Fauji Fertilizer Co. Ltd, FFCL, and Fauji Fertilizer Bin Qasim, FFBQ) with a long-term, reliable source of phosphoric acid, the raw material for its diammonium phosphate (DAP) fertilizer production. As part of this project a plant capable of producing 375 000 tonnes of phosphoric acid per year opened in 2008 at Jorf Lasfar, OCP's phosphate hub in Morocco. The plant capacity is being increased to 425 000 tonnes. It is the sole supplier for a major FFBQ fertilizer plant near the Qasim port in Karachi, and any surplus acid is sold on the international market.[70]

Pakistan operates four nuclear reactors to produce electricity, another is under construction and two more are planned. All are under IAEA safeguards. Almost all of the uranium fuel for current and future Pakistani reactors is supplied in finished form by China under IAEA safeguards. Pakistan's oldest power plant, the Karachi Nuclear Power Plant (KANUPP), was reportedly operating at reduced power as of January 2017.[71] The uranium for KANUPP came from safeguarded Canadian fuel, now in storage as spent fuel, and uranium acquired from Niger under an IAEA Safeguards Agreement.[72] Hence, Pakistan's entire civil nuclear electricity programme is fed by safeguarded fuel with a guaranteed supply. There is therefore no domestic demand from civil programmes.

Pakistan does, however, have a critical shortage of uranium for its military nuclear programme, both its gas centrifuge enrichment plants and its plutonium and tritium producing nuclear reactors at Khushab. There are various possible sources of uranium for these purposes: domestic mining, re-enrichment of depleted uranium 'tails' left from previous operations and the extraction of uranium from phosphates. Production from domestic uranium mining is considered insufficient for the needs of Pakistan's nuclear programme. Re-enrichment of tails might be possible, but inefficient. Extraction of uranium from phosphates is therefore a logical choice. Domestic production of phosphate fertilizers began in Pakistan in 1999.[73] According to some studies, the uranium content of the phosphate fertilizers imported from Morocco and Jordan is much higher than that from locally produced material.[74]

There is no evidence from open sources that Pakistan is extracting uranium from domestic or imported phosphoric acid, but the possibility of such extraction now or in the future cannot be excluded. Phosphoric acid is a common and legitimate commodity, and its import and export are not controlled. Under the circumstances, however, European exporters and export control authorities might decide to be vigilant and require, for example, end-use certificates or other export control measures to be in place in connection with the phosphate fertilizer industry in Morocco or Pakistan.

Jordan and India

Like Morocco, Jordan also has extensive phosphate reserves, estimated to amount to 1.3 billion tonnes. In 2015 the Jordan Phosphate Mines Company (JPMC), which operates four mines and a plant that converts phosphate rock ore into phosphoric acid and DAP, mined 7.5 million tonnes of ore.[75] Jordan's uranium resources in phosphate rocks are estimated to be 60 000 tU.[76] Jordan has had a CSA in force with the IAEA since 1978 and ratified its AP in 1998.[77]

India has an ambitious and largely indigenous nuclear power programme. India acknowledges that expansion of its current nuclear energy generating facilities to commercially viable levels will be impossible to achieve in the short term based solely on domestic supplies of ore. In 2013 it was estimated that India's nuclear power generation programme is

70 FFBL, 'Pakistan Maroc Phosphore, S.A.', n. d., <http://www.ffbl.com/?page_id=8775>.

71 World Nuclear Association, 'Nuclear power in Pakistan', Information library, Jan. 2017, <http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/pakistan.aspx>; and Patton, T., 'Uranium fuel constraints for Pakistan's nuclear weapon complex', Arms Control Wonk, Dec. 2012, <http://www.armscontrolwonk.com/archive/205928/patton-on-pakistans-u-supply/>.

72 IAEA and Pakistan, Agreement for the application of safeguards, Signed at Vienna on 2 Mar. 1977, no. 15864. This agreement was signed before the present system of numbering safeguards agreements was adopted.

73 Patton (note 71).

74 Tufail, M. et al., 'Radioactive rock phosphate: the feed stock of phosphate fertilizers used in Pakistan', *Health Physics*, vol. 90, no. 4 (Apr. 2006), pp. 361–70; and Khan, K. et al., 'Radiometric analysis of hazara phosphate rock and fertilizers in Pakistan', *Journal of Environmental Radioactivity*, vol. 38, no. 1 (1998), pp. 77–84.

75 US Geological Survey (note 63); and Jordan Phosphate Mines Company, Company profile, n. d., <http://jpmc.com.jo/Pages/viewpage.aspx?pageID=2>.

76 OECD Nuclear Energy Agency and International Atomic Energy Agency (note 5), p. 35.

77 IAEA, Status of the Additional Protocol (note 22).

dependent on 60 per cent domestic and 40 per cent imported uranium.[78] India also has a nuclear weapon programme and has never been a signatory to the NPT. Its failure to join the NPT has created multiple obstacles to nuclear trade for India. Following the conclusion of a special safeguards agreement with the IAEA and a special resolution by the Nuclear Suppliers Group, India was able to begin importing uranium from a number of international suppliers. All of these imports are still rather sensitive politically and the uranium ore concentrate supplied is invariably placed under IAEA safeguards. Domestic debate in Australia illustrates this problem. The Government of Australia is keen to supply uranium for India's civil reactor programme, in spite of the fact that although India will guarantee that Australian uranium is for civil purposes, it frees India to use uranium from undeclared sources for its weapon programmes.[79] The large unsafeguarded part of the Indian nuclear fuel cycle has to be supplied from unsafeguarded sources. One such source is indigenous mining of uranium. The question of whether India considers uranium from unconventional sources, such as phosphates, to be another source of unsafeguarded uranium deserves close scrutiny.

India has 'near total dependence' on 'imported raw materials for production of phosphatic fertilizers'. The Indian Government has encouraged multiple joint ventures with many countries where the phosphoric acid is produced abroad and shipped to India in very large quantities. These include two large joint ventures with Jordan's JPMC and one with Morocco's OCP.[80]

Phosphoric acid from Jordan and other suppliers arrives in India at Kandla in the west and Paradeep in Odisha in the far north-east.[81] The Indian Government has announced that two plants will be built at Paradeep to extract uranium from the phosphates: a project to extract uranium and other rare earth elements from wet phosphoric acid (WPA) produced at Paradeep Phosphates Limited (PPL); and a similar project at the Indian Farmers Fertiliser Co. Ltd phosphatic fertilizers complex. The Heavy Water Board (HWB), an entity in India's Department of Atomic Energy, has been working to set up both plants. The PPL plant has been declared strategic by the government on the recommendation of the Department of Atomic Energy and with the approval of India's National Security Adviser.[82] Records show that thousands of tonnes of phosphate rock arrive from Jordan at the Port of Tutincorin in the south-east. Tutincorin is the location of another Heavy Water Plant operated by the HWB.[83]

The activities of Jordan and Morocco in the phosphate fertilizer trade are completely legal and legitimate. These countries are not extracting uranium, even though the uranium content of their phosphates is the highest in the world. Morocco and Jordan are not required to report uranium content because they are not mining uranium, simply selling the raw materials for fertilizers. Nor is Pakistan or India required to report the importation of uranium. In this way, the uranium mined in Africa and the Middle East essentially disappears from international commerce. Once the uranium is extracted in India or Pakistan it can be used to fuel nuclear power reactors or nuclear reactors that produce plutonium for nuclear weapons, or it can be enriched to make uranium-based nuclear weapons.

In the case of India, the suppliers of conventional uranium ore, export control authorities and other entities involved essentially make a policy decision on the extent to which these suppliers, even if acting legally under existing regulations, are contributing to India's military nuclear programme. Safeguarded uranium supplies that enter the civilian nuclear fuel cycle allow the uranium available from unsafeguarded sources, such as phosphates, to be used in military programmes.

[78] IHS Markit, 'India: Nuclear production capability', *Jane's CBRN Assessments Intelligence Centre*, <https://janes.ihs.com/CBRN/Display/1321423>, accessed 5 Oct. 2016.

[79] Green, J., 'Australia's uranium agreement with India under attack', On Line opinion, 8 Oct. 2014, <www.onlineopinion.com.au/view.asp?article=16752&page=0>.

[80] Government of India, Ministry of Chemicals and Fertilizers, Department of Fertilizers, 'Joint ventures', 3 Mar. 2017, <http://fert.nic.in/page/joint-ventures>; and 'Jordan, India open $860m phosphoric acid plant', Chemicals Technology, 12 Oct. 2015, <http://www.chemicals-technology.com/news/newsjordan-india-open-860m-phosphoric-acid-plant-4690952>.

[81] Acid plant database, Sulphuric Acid on the Web, n. d., <http://www.sulphuric-acid.com/sulphuric-acid-on-the-web/acid%20plants/Paradeep%20Phosphates%20-%20Paradeep.htm>.

[82] World Nuclear Association (note 23); and NM Leo News, 'India's 2nd strategic uranium extraction plant on the anvil', 7 Dec. 2014, <https://nareshminocha.com/index.php/miscellaneous/1688-india-s-2nd-strategic-uranium-extraction-plant-on-the-anvil>.

[83] Global Export Import Market Intelligence, 'Rock-phosphate import in India at Tuticorin Sea in MTS: InfodriveIndia.com', <http://www.infodriveindia.com/india-import-data/rock-phosphate-import/lp-tuticorin_sea/unit-mts-report.aspx>.

VIII. CONCLUSIONS

The fertilizer industry is not normally seen as an industry that enables the acquisition of nuclear weapons through the use of dual-use equipment, but past events and current patterns of international trade clearly demonstrate that better-informed export controls and end-user processes are required.

This paper demonstrates that phosphates have historically been an important source of uranium for weapon programmes. Many countries have explored uranium extraction from indigenous or imported phosphates quite openly, while some have preferred not to publicize it. Several countries are possibly exploiting phosphates today as an undeclared but legal source of uranium.

European states and industry should be exceedingly careful not to provide uranium-bearing minerals to any state without ensuring that it is subject to IAEA safeguards. They should also ensure that nuclear material production technology is carefully monitored to verify that it is being used appropriately in the NPT states and especially in the nuclear weapon-possessing states outside the NPT.

ABBREVIATIONS

AP	Additonal Protocol
CSA	Comprehensive Safeguards Agreement
DAP	Diammonium phosphate
EU	European Union
IAEA	International Atomic Energy Agency
ISL	In situ leaching
NPT	Non-Proliferation Treaty
OCP	Office Chérifien des Phosphates
RDD	Radiological Dispersal Device
tU	Tonnes of uranium
UOC	Uranium ore concentrate

EU Non-Proliferation Consortium

The European network of independent non-proliferation think tanks

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In July 2010 the Council of the European Union decided to create a network bringing together foreign policy institutions and research centres from across the EU to encourage political and security-related dialogue and the long-term discussion of measures to combat the proliferation of weapons of mass destruction (WMD) and their delivery systems.

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The main aim of the network of independent non-proliferation think tanks is to encourage discussion of measures to combat the proliferation of weapons of mass destruction and their delivery systems within civil society, particularly among experts, researchers and academics. The scope of activities shall also cover issues related to conventional weapons. The fruits of the network discussions can be submitted in the form of reports and recommendations to the responsible officials within the European Union.

It is expected that this network will support EU action to counter proliferation. To that end, the network can also establish cooperation with specialized institutions and research centres in third countries, in particular in those with which the EU is conducting specific non-proliferation dialogues.

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