



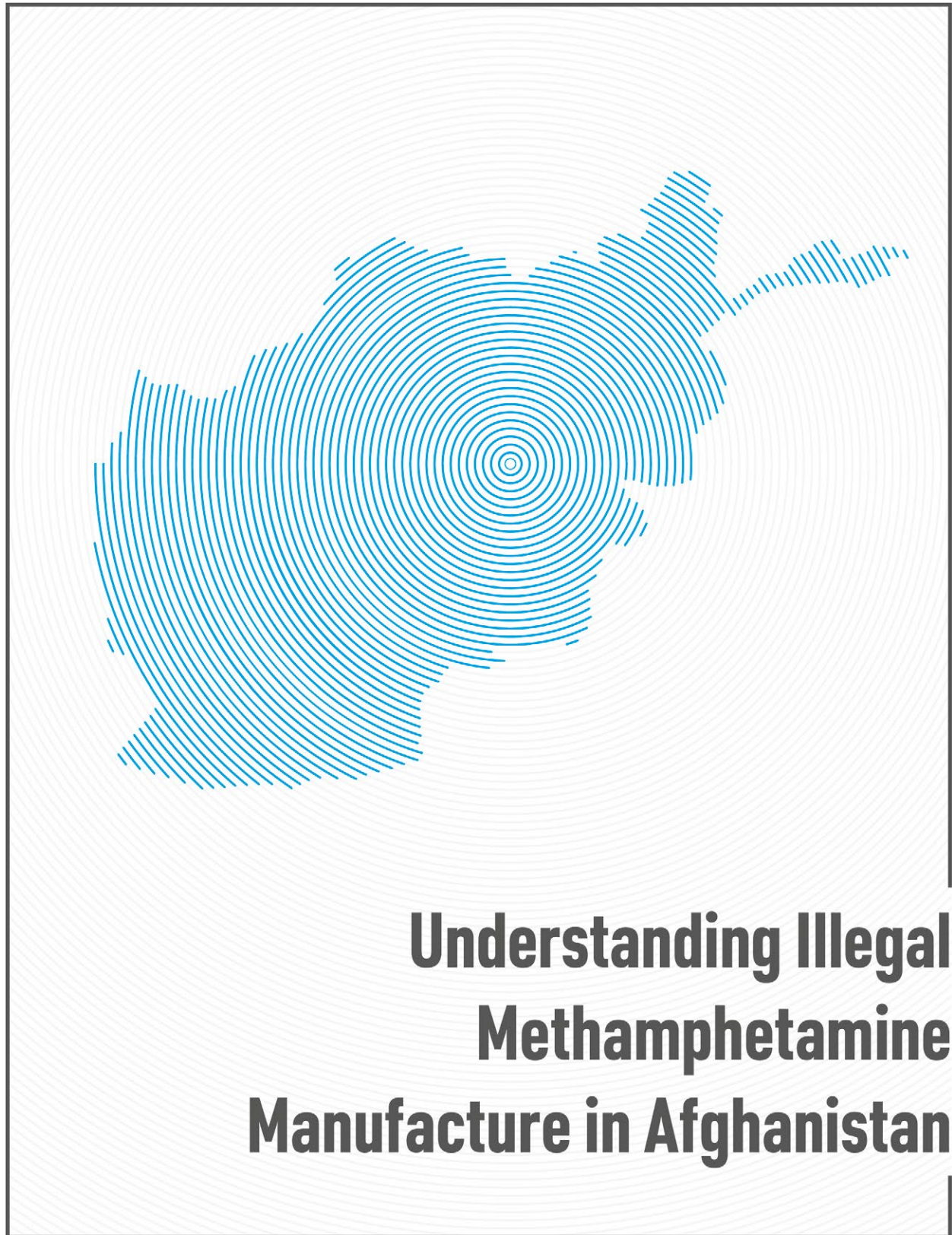
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Understanding Illegal Methamphetamine Manufacture in Afghanistan

UNODC Research Brief

August 2023

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Understanding Illegal Methamphetamine Manufacture in Afghanistan

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Introduction and key takeaways

This analysis examines the modalities of illegal methamphetamine manufacture in Afghanistan, highlighting risks to the region.

Coverage of suspected methamphetamine manufacture in Afghanistan, particularly in the news media in recent years, has generally focused on the use of the ephedra plant as a major contributing driver. Ephedra grows abundantly in the region and contains ephedrine that can be extracted to make methamphetamine. Although ephedra harvesting for the explicit purpose of methamphetamine manufacture has been documented, precursor chemicals, including cold medication preparations that contain ephedrine, generally offer more straightforward means to make methamphetamine, and analysis of seizures in Afghanistan suggest they are used in illegal methamphetamine manufacture. Moreover, little scientific research has been published on the feasibility of using ephedra in large-scale illegal methamphetamine manufacture in Afghanistan.

The findings presented here contextualize illegal manufacture of methamphetamine with respect to quantify total methamphetamine production, different input materials. The analysis contained in this report does not seek to evaluate or assess the effectiveness of counternarcotics measures in the country, nor does it consider the effects of the April 2022 announcement of enforcement against the production, trafficking, and consumption of all illicit drugs in Afghanistan.

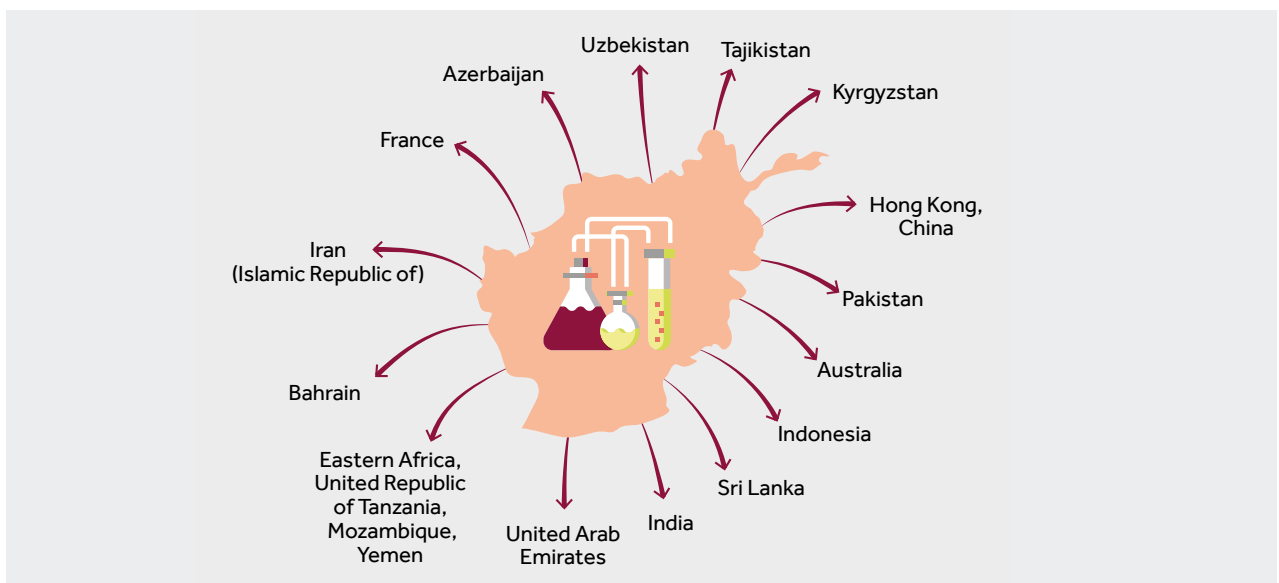
The research shows that common cold medications and industrial-grade bulk precursors offer more efficient, reliable and virtually limitless means to support illegal manufacture compared with naturally occurring sources of ephedrine.

Continued focus on the ephedra plant bears the risk of overlooking emerging or existing trends such as the diversion of chemicals from licit markets or their trafficking for the illegal manufacture of methamphetamine. Law enforcement efforts that are regionally coordinated and that target the diversion and smuggling of bulk chemical precursors may be more effective in preventing and curbing the long-term expansion of illicit methamphetamine manufacture in Afghanistan and the wider region.

Takeaway 1: Methamphetamine may be reshaping illicit drug markets long dominated by Afghan opiates

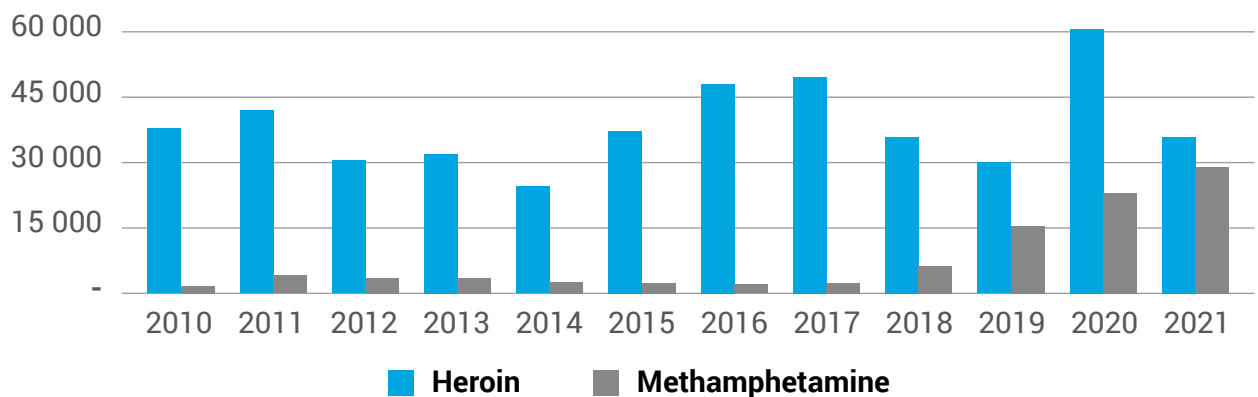
- Illegal manufacture of methamphetamine in Afghanistan is a growing threat.
- Suspected Afghan-origin seizures of methamphetamine have been reported from places as far away as the European Union, the Near and Middle East, South-east Asia and Eastern Africa.
- The drastic increase in methamphetamine seizures in Afghanistan and neighbouring countries indicates that methamphetamine trafficking is expanding rapidly, changing illicit drug markets traditionally focused on the trafficking of opiates from Afghanistan.

Reported destination of methamphetamine originating in Afghanistan, 2019 and 2022



Source: UNODC, Drugs Monitoring Platform

Heroin and methamphetamine seizures in Afghanistan and neighbouring countries, 2010 - 2021 (kgs)

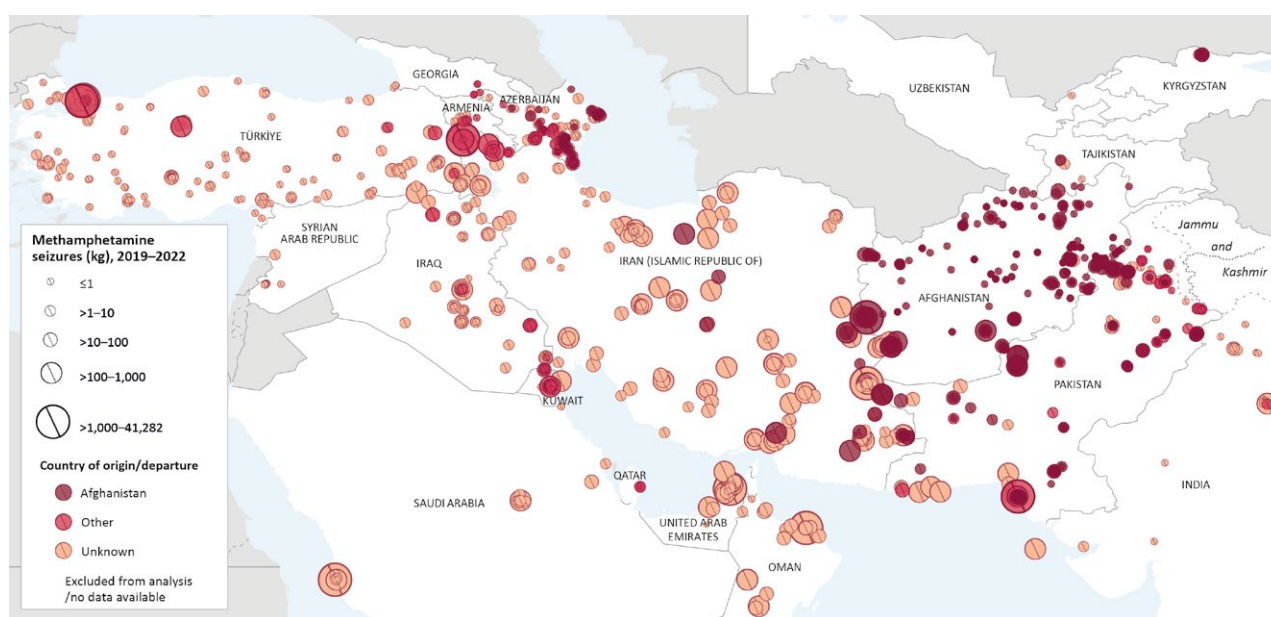


Source: UNODC, responses to the Annual Report Questionnaires.

Takeaway 2: Seizure data suggests Afghanistan has emerged as a major regional producer of methamphetamine

- Seizures of methamphetamine have increased from some 2.5 tons in 2017 to 29.7 tons in 2021 in Afghanistan and neighbouring countries, with an increasing share originating from Afghanistan.
- Within Afghanistan, annual seizure totals rapidly rose from less than 100 kg in 2019 to nearly 2,700 kg in 2021, suggesting increased production.
- The Government of Afghanistan prior to August 2021 had reported methamphetamine production in many provinces in the country, using chemical inputs from neighbouring countries.

Significant Seizures of Methamphetamine in Selected Countries of the Near and Middle East/ South-West Asia, South Asia, Central Asia, Caucasus and Türkiye, by Origin, 2019-2022



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: UNODC, Drugs Monitoring Platform

Data shows significant seizures recorded in the UNODC Drugs Monitoring Platform.

Box 1: Methamphetamine can be produced in several ways and the main precursors in Afghanistan, based on available data, are ephedrine obtained from chemicals diverted from legal markets or extracted from the ephedra plant

- The available evidence in Afghanistan points towards ephedrine as the dominant precursor used in methamphetamine manufacture. The transformation of ephedrine into methamphetamine is a relatively simple process which can be performed with limited knowledge, compared with other precursor chemicals, such as P2P.
- Ephedrine and pseudoephedrine can potentially come from three sources:
 - from the ephedra plant that is commonly found in parts of Afghanistan
 - pharmaceutical products, such as cold medications, that are diverted from legal markets
 - bulk industrial-grade ephedrine/pseudoephedrine that is diverted from licit markets or illegally imported

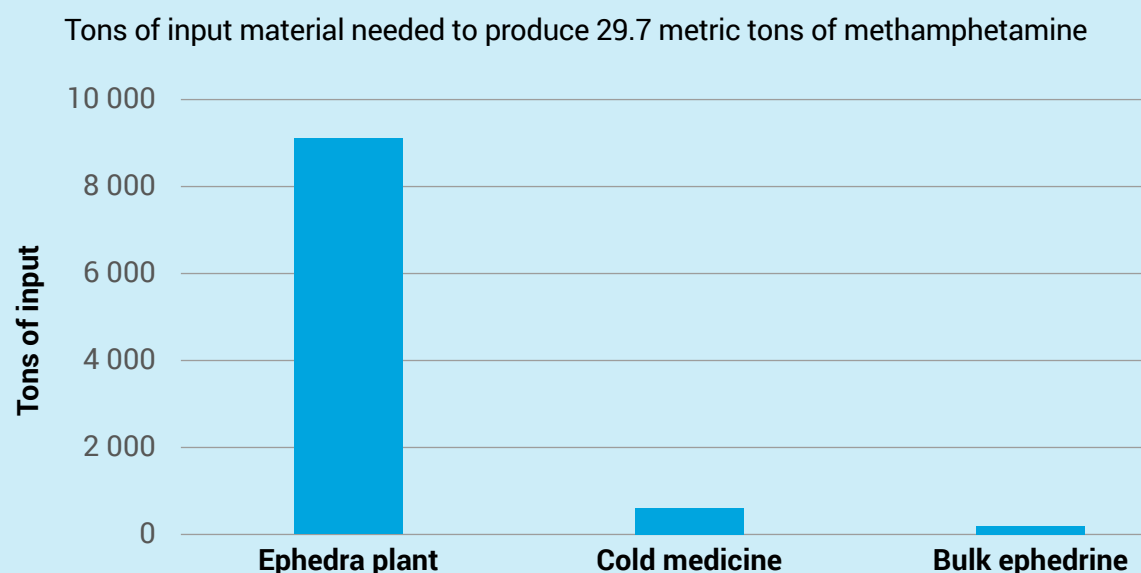
Comparing necessary primary inputs for methamphetamine manufacture in Afghanistan at a glance

	Ephedra	Cold medication	Bulk ephedrine
Weight needed to yield one pure kilogram of methamphetamine	196.8 kg of dried and processed plant matter	27.8 kg of medications in tablet preparation	1.75 kg of industrial-grade material
Sourcing	Wild ephedra plants are collected (not cultivated) in mountainous and remote areas in the country during a seasonal harvest.	Imported year-round for medical use and diverted or purchased from legal sources	Smuggled into the country year-round
Ephedrine content	Trace (0-5%)	Modest (9-15%)	Nearly pure (>95%)
Efficiency in methamphetamine production (i.e., number of steps, reaction times, yields, etc.)	Low	Medium	High

	Ephedra	Cold medication	Bulk ephedrines
Input costs for a pure kilogram of methamphetamine	US\$590	US\$1,069	US\$500
Financial return for 1 kilogram of methamphetamine (50% purity) ^a	US\$405	US\$162	US\$450
Weight needed to reflect regional seizures of 29.7 tons (50-90% purity)	6,500-11,700 tons of fresh plant matter	414-745 tons of cold medication in tablet preparations	26-47 tons of industrial-grade material

^a Only accounts for cost of primary inputs, excludes other fixed costs and other necessary chemicals or material which may vary considerably by input.

Source: Responses to the UNODC Annual Report Questionnaires.



Takeaway 3: Ephedra plant offers a cheaper precursor for methamphetamine manufacture but with many drawbacks

- Assuming a purity range of 50-70% for methamphetamine, total primary input costs to manufacture methamphetamine may drop to US\$295-413 for ephedra and to US\$538-748 for cold medications, making ephedra slightly more profitable given a recent wholesale price of US\$700 per kilogram of methamphetamine¹.
- However, to produce one kilogram of pure methamphetamine, an estimated 200kg of dried harvested ephedra is needed. Considering that about half of the plant's weight consists of water, the equivalent amount of freshly collected ephedra may come to 437kg.
- The amount of freshly collected ephedra needed to manufacture all of the 29.7 metric tons of methamphetamine seized in and around Afghanistan in 2021 could amount to **between 6,500 and 11,700 metric tons** (using a purity range of 50 to 90%).
- Given that these estimates reflect only seizures, the actual amount of ephedra plant material needed for illegally manufacturing all methamphetamine seized in Afghanistan and neighbouring countries is likely to be far larger than the upper range of 11,700 tons.
- To put that into context, total opium production for Afghanistan in 2022 was estimated at 6,200 tons².

Takeaway 4: Rapidly expanding methamphetamine manufacture is unlikely to rely on ephedra plant alone

- The precarious nature of ephedra growing wildly on steep and unstable slopes make the harvest time-consuming. The currently available evidence suggests that a harvester can collect between 25-45 kg of ephedra a day.
- It may take somewhere between 9.7 and 17.5 labour-days to collect enough ephedra to produce a single kilogram of pure methamphetamine. That would come to 202,000 to 363,000 labour-days needed to meet the 29.7 tons of methamphetamine seized in Afghanistan and neighbouring countries (assuming 50-90% purity).
- Satellite imagery, field observations, and harvested plant weights of test sites suggest that it may take an area of 34 hectares to source enough raw ephedra to produce one pure kilogram of methamphetamine under non-ideal conditions during a short three to four-month harvest period.
- Assuming adjusted purity ranges of 50 and 90%, some 507,000 to 913,000 hectares would have been needed to source enough ephedra to manufacture the 29.7 tons of methamphetamine seized in Afghanistan and neighbouring countries. To place this into context, this hectareage is about 2-3 times the area that was under illicit cultivation of opium poppy in its 2017 record year.
- Ephedra, while appearing cost-effective in the short term, is an unlikely sole source for all illegally manufactured methamphetamine because of its remoteness, limited harvest period, and low plant density.

Takeaway 5: Industrial-grade chemicals are more efficient and cost effective for the manufacture of methamphetamine and the focus on ephedra risks undermining responses

- The use of bulk quantities of ephedrine, often diverted from the legal market, seems to be a more cost effective and convenient approach to illegally manufacture methamphetamine in Afghanistan. These chemicals can be directly synthesized into methamphetamine with fewer steps and their higher purity requires much less input material.
- To understand the magnitude of chemicals needed to manufacture methamphetamine in Afghanistan, it is estimated that between 414-745 metric tons of cold medications would have been needed to produce the 29.7 metric tons of methamphetamine seized in Afghanistan and neighbouring countries (at purity ranges between 50- 90%). Assuming a 12% share of active ingredient, this would have been equivalent to 50-89 metric tons of ephedrine/pseudoephedrine, which is far above the 13 metric tons of annual legitimate requirements in preparations reported by the INCB for Afghanistan and other neighbouring countries in 2022³. This is only a probable scenario if considerably large amounts of cold medication are diverted in the region.
- In contrast to cold medication, bulk ephedrine are produced and traded in large quantities in the region and therefore could be accessible. In 2022, more than 100 metric tons of bulk industrial grade ephedrine were reported in annual legitimate requirements for Afghanistan and countries in the neighbouring region⁴. Among these countries are also major global exporters of ephedrine and other precursor chemicals needed in the manufacture of methamphetamine or other drugs. Seizures of these chemicals have been periodically reported by authorities in recent years. Sudden increases in seizures or in the legitimate imports of these chemicals in South and South-West Asia in the future could be signs of large diversion into illegal manufacture of methamphetamine.

Takeaway 6: Policy responses need to be regionally coordinated and focus on tracking and analyzing precursors and inputs used in illegal manufacture of methamphetamine in and around Afghanistan

- Traffickers in the region are likely to use a variety of sources of precursors for methamphetamine manufacture.
- To better respond to emerging threats and trends, it is critical to strengthen the understanding of the scope and use of different primary inputs for illegal manufacture of methamphetamine in Afghanistan through more regular mapping and chemical signature analysis of seizures and licit flows of cold medicines and ephedrine, as well as monitoring ephedra plant harvesting and trading. Sudden changes in these indicators could give early warning signals on manufacturing approaches and trend.
- To counter the use of diverted cold medications and industrial-grade precursors in methamphetamine manufacture, greater regional coordination and cooperation will be needed. Regional policies and efforts targeting the diversion and smuggling of chemical precursors could help reduce the illegal supply of methamphetamine.
- Reviewing regulations over formulations of cold medications, including exploring possible reformulations of products containing ephedrine could identify steps that could be taken to reduce the availability of these inputs for methamphetamine manufacture, while safeguarding the appropriate access to such medications for medical use.
- Compared with opium poppy cultivation – which appears to have decreased sharply following the the April 2022 announcement on the ban on drug manufacture in Afghanistan, according to UNODC findings⁵ - synthetic drug manufacture does not require land or extensive labour and is easier to relocate and conceal.
- The effects of the ban on illegal drug manufacture remain to be seen. Rapidly growing markets could reinforce demand and incentivize continued or expanded production capacity inside Afghanistan. Enforcement of the ban could also displace methamphetamine manufacture to other countries in the region, especially where precursor chemicals are more readily available.

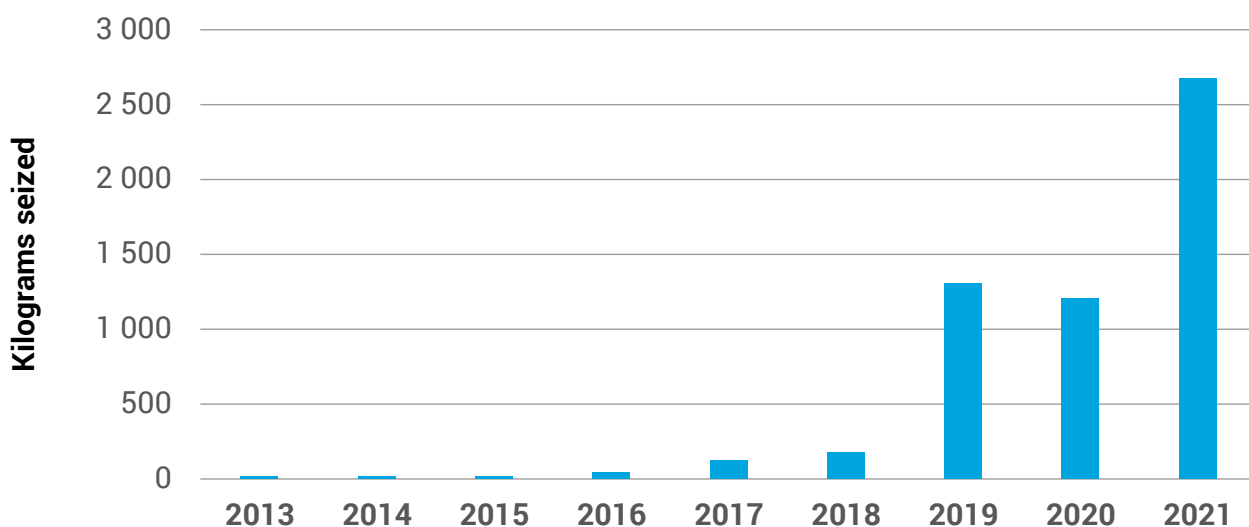


Methamphetamine supply in Afghanistan and neighbouring countries is rising

Seizures inside and outside Afghanistan point to a sharp increase in methamphetamine manufacture in Afghanistan in the last few years. An analysis of significant individual drug seizures shows that an increasing amount of methamphetamine seized in neighbouring countries reportedly originated in Afghanistan. This suggests that Afghan traffickers may be capturing an increasing share of the methamphetamine market in the country and region⁶.

Officially reported methamphetamine seizures within Afghanistan reflect a rapid and sustained expansion. Prior to 2017, methamphetamine seizure totals never surpassed more than 100 kg a year. There was modest increase between 2017 and 2018, but 2019 witnessed sharp and sustained seizure totals above a single metric ton. Seizure totals doubled between 2020 and 2021 to nearly 2.7 metric tons.

Figure 1: Kilograms of methamphetamine seizures in Afghanistan, 2013-2021



Source: UNODC, responses to the annual report questionnaires

Methamphetamine seizures around Afghanistan have also been increasing in recent years. Authorities in some countries have noted an increasing amount of product reportedly coming from Afghanistan. In 2019, the Islamic Republic of Iran reported that methamphetamine seizures originating in Afghanistan amounted to nearly 90% of methamphetamine seizures⁷. Seizures in neighbouring Pakistan showed a similar trend as authorities reported that most product originated from Afghanistan⁸.

Overall, there was an increase in regional methamphetamine seizures in countries neighbouring Afghanistan during the period between 2019 and 2022 as shown in Figure 2. The source country is not determined in most events, but for those that were, Afghanistan was noted with increasing frequency. Some seizure events as far away as Southeast Asia and Australia have been reported to originate from Afghanistan⁹. This may indicate possibly new supply routes for methamphetamine with suspected Afghan origins.

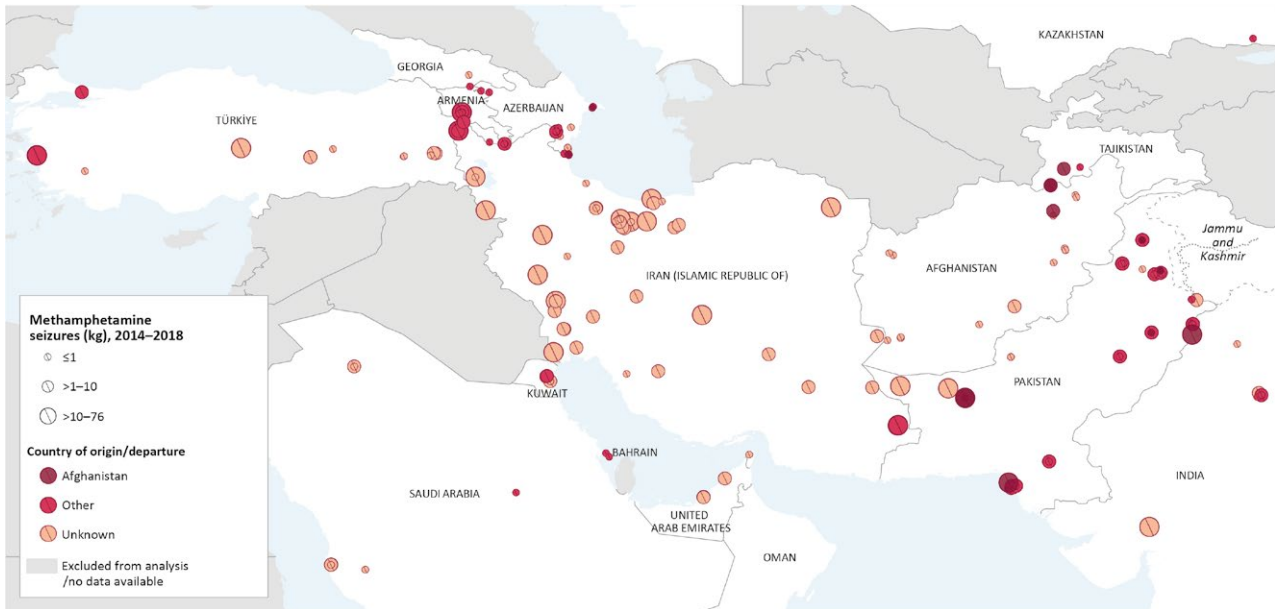
Box 2: Research motivation

Understanding the primary inputs used in illicit methamphetamine production in Afghanistan has important implications for policy. There has been increasing interest in the role of ephedra harvesting and ephedrine extraction in illegal manufacture of methamphetamine in Afghanistan. However, general attention on one input source may overlook more plausible and efficient means of manufacture using chemicals. At present, there are no robust or systematic estimates of the shares of methamphetamine that are produced using either chemical or naturally derived ephedrine/pseudoephedrine. There are, however, recent media reports documenting the use of ephedra in the illegal manufacture of methamphetamine¹⁰, though many of those estimates derive from a single market case study and may not necessarily be representative of the entire national market.

This study aims to assess the different starting materials to help better inform policy responses targeted at curbing rising illegal methamphetamine production in Afghanistan. It uses a modelling approach to quantify the total amount of different source material used to produce one pure kilogram of methamphetamine in Afghanistan, using parameter estimates (or offering plausible estimates and ranges). Not all estimates are known with perfect certainty or can be modelled directly (e.g., the range of efficiency when it comes to synthesis). UNODC summarises the current understanding of conditions on the ground in Afghanistan as they relate to methamphetamine production and ephedra growth, the extent of the review of the literature relevant to ephedra and offers some initial side-by-side comparisons of when starting from either plant or pharmaceutical inputs.

Figure 2: Increase in methamphetamine seizures near Afghanistan, from 2014-2018 and 2019-2022

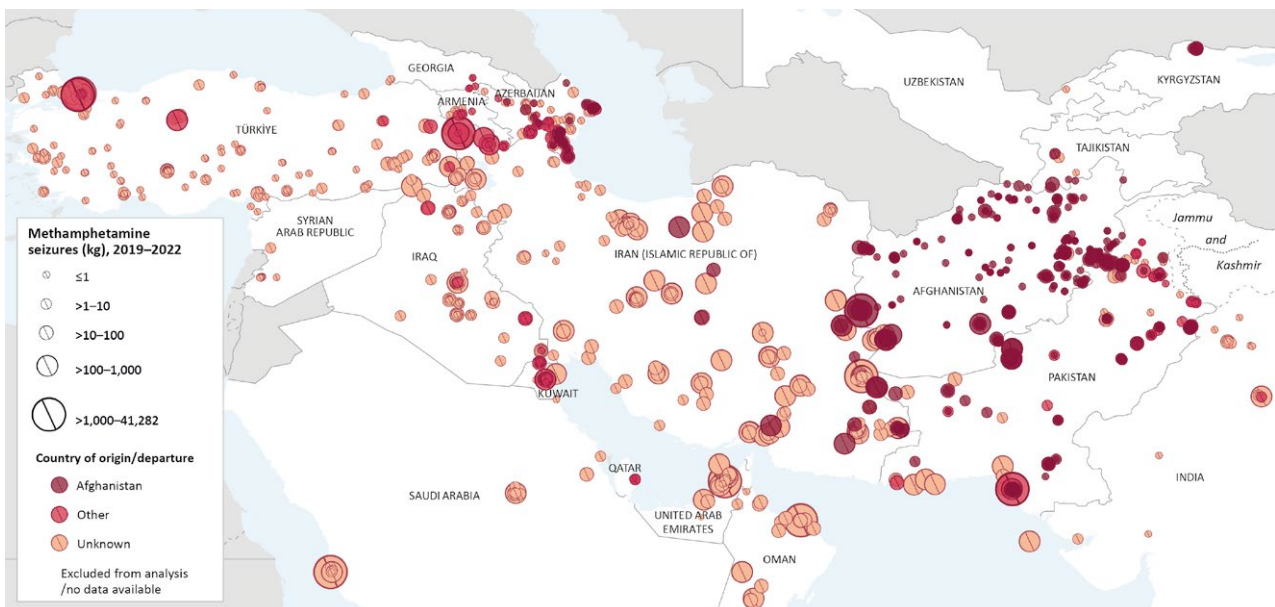
Significant seizures of methamphetamine in selected countries of the Near and Middle East/South-West Asia, South Asia, Central Asia, Caucasus and Türkiye, by origin, 2014-2018



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Source: UNODC, Drugs Monitoring Platform

Significant seizures of methamphetamine in selected countries of the Near and Middle East/South-West Asia, South Asia, Central Asia, Caucasus and Türkiye, by origin, 2019-2022



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Source: UNODC, Drugs Monitoring Platform

Ephedra has been implicated in the production of methamphetamine in Afghanistan, but the phenomenon is still not well understood

Overall, indicators point to the increasing production and trafficking of methamphetamine out of or around Afghanistan. Signs of domestic manufacture may have started as early as 2013 when seizures originating in Afghanistan started to be reported in Iran¹¹. Over the past five years, the evidence of emerging methamphetamine manufacture in Afghanistan has become more definitive with clandestine laboratories in the country's western and southern provinces and reports of rising seizures amounts in and around Afghanistan¹². Additionally, methamphetamine use in Afghanistan has also been increasing. According to one recent drug use survey of adolescents carried out in 2020, the past-year prevalence of methamphetamine was comparable to heroin, 1.8 versus 1.3 percent of those aged 13-18, respectively¹³.

According to some sources, methamphetamine production prior to 2018 utilized ephedrine and pseudoephedrine obtained from diverted or illegally imported cold medications¹⁴. Since 2018, several accounts have suggested that an increasing share of methamphetamine production in Afghanistan is derived from domestically harvested ephedra plants¹⁵. Seizures of methamphetamine precursors for Afghanistan are sparse, with the country last reporting that 440 kg of cold medication preparations containing pseudoephedrine were seized in 2019¹⁶. According to the INCB precursor report, no pharmaceutical-grade ephedrine was seized in 2020, which "may indicate an increase in the use of the Ephedra plant"¹⁷. However, Afghanistan seldom reports seizures of ephedra plant to the INCB and most evidence remains anecdotal¹⁸.

Though both the ephedra plant and ephedrine and pseudoephedrine from cold medications can be used in the manufacture of methamphetamine, determining the precise starting material requires confirmatory forensic analysis (e.g., impurity profiling or isotope ratio mass spectrometry). Such analysis can detect by-products of different manufacturing inputs. Methamphetamine produced by plant-based ephedrine or pseudoephedrine leaves behind trace amounts of dimethylamphetamine¹⁹. The latest UNODC assessment of methamphetamine seizures in Afghanistan was published in 2022, using a sample of 536 tablets seized from September 2020 to March 2021. Though some trace amounts of by-product may have been lower than detection thresholds used in the cited study, only 8 samples (2%) of tablets containing methamphetamine also contained dimethylamphetamine, suggesting use of plant-based ephedrine²⁰. Additionally, other ingredients found in common cold medications were also detected with high frequency in other samples tested. As indicated in this analysis, "ephedrines extracted from pharmaceutical preparations and/or bulk pharmaceutical ephedrine seem to play a [...] prominent role" in methamphetamine manufacture in Afghanistan²¹.

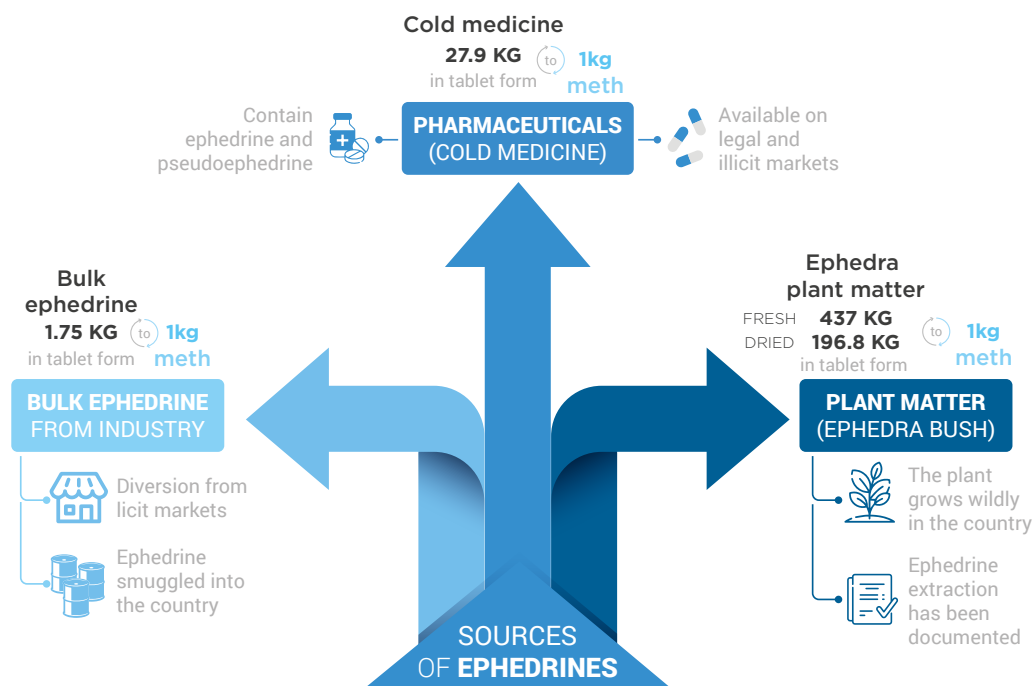
Illegal methamphetamine manufacture in general and specifically in Afghanistan

Primary chemicals used in illegal manufacture of methamphetamine are typically illegally imported or diverted from licit use (Figure 3)²². Methamphetamine is considered a synthetic drug, though when the starting ephedrine comes from plants, in this case ephedra, it could be considered a semi-synthetic drug. However, unlike heroin which requires opium poppy, methamphetamine can be manufactured entirely from chemical inputs.

There are two main approaches to manufacturing methamphetamine: 1) the P-2-P-based method, which start with phenylacetone (phenyl-2-propanone, or P2P, also known as benzyl methyl ketone, or BMK, or one of its pre-precursors) or 2) the ephedrines-based method, which starts from ephedrine or pseudoephedrine (or one of their pre-precursors)²³. There are advantages and disadvantages to either approach, with some regional trafficking groups preferring one method over the other depending on access to starting materials and learned techniques²⁴. Furthermore, the use of ephedrine/pseudoephedrine is less technical, requires fewer steps, and is faster than starting from P2P²⁵.

It is generally possible to determine either method based on the presence of the l-methamphetamine isomer, which is produced through the P2P method²⁶. From analysis of seizures in and around Afghanistan, the ephedrine/pseudoephedrine approach appears to be more commonly used for methamphetamine production²⁷.

Figure 3: Sources of ephedrines for methamphetamine production in Afghanistan



There are three main potential sources (Figure 3) for producing methamphetamine in Afghanistan using ephedrine/pseudoephedrine²⁸:

- Bulk pharmaceutical-grade ephedrine/pseudoephedrine that is illegally manufactured or diverted from legitimate sources and illegally imported.
- Ephedrine/pseudoephedrine extracted from pharmaceutical products, such as cold medications, that contain other combinations of medications for reducing cold symptoms (e.g., antitussives, antipyretics, antihistamines) that are detectable in forensic analysis of seizures.
- Ephedrine/pseudoephedrine extracted from plant material found naturally in the ephedra plant that is common in mountainous regions of Central Asia.

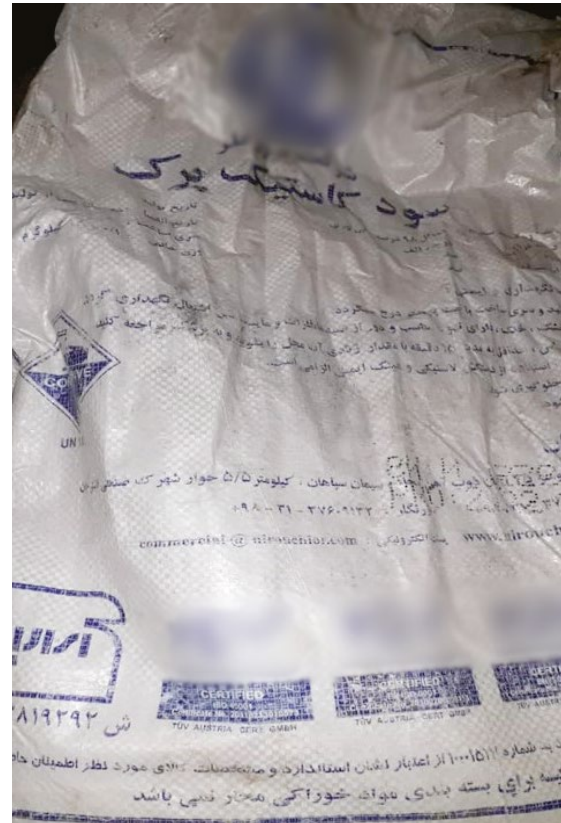
Some have asserted that, compared to using ephedra, cold medications require additional technical knowledge to extract ephedrine²⁹. However, the processing of ephedrine/pseudoephedrine from cold medications in other times and places has been reported to be fairly easy using a “shake-and-bake” method that is operationalizable in small settings, especially when using tamper-resistant formulations³⁰. There is little direct evidence apart from general assertions of the supposed difficulty of extractions of ephedrines from cold medication. However, the concentration of ephedrine/pseudoephedrine in the preparation is known, unlike the content of the alkaloid in the plant, which can vary significantly given the species, growing conditions, time of harvest, and even within different parts of the same plant.

When it comes to manufacturing methamphetamine from ephedrines, there are several synthesis routes that can be used. It is not clear if traffickers in Afghanistan employ various routes, but research and news reports to date note the use of caustic soda, iodine, and red phosphorous, suggesting the use of the “Nagai” method³¹. The literature reports that this particular route has a yield rate of around 50%, which is lower than some other synthesis methods³². However, manufacture using chemical inputs can be modified to yield large amounts of methamphetamine under certain conditions³³. At present, there is no reliable information on the quality of synthesis approaches of illegal methamphetamine manufacture in Afghanistan, let alone the means to quantify synthesis results.

The information to date allows for conclusions to be drawn regarding the starting chemicals, i.e., ephedrines, but not their specific sources, i.e., plant or chemical origin. There is little evidence pointing to more complex production of methamphetamine in Afghanistan using P2P. Evidence so far notes the use of both plant-based ephedrines as well as pharmaceutical ephedrines derived from cold medications. There may also be synthesis using bulk quantities of industrial and illegally imported ephedrines (as evidenced by large-format chemical imports, Figure 4), though much less is known about that approach.

A wide range of purities of methamphetamines originating in Afghanistan has been reported. For instance, tablet methamphetamine was reportedly of low purity, while crystalline methamphetamine is generally considered to be nearly pure (90% or more)³⁴. One media source from 2014, citing authorities from the Afghan counternarcotics lab, mentions a figure of 90% purity for seizures of crystal methamphetamine³⁵. EMCDDA suggested that product coming from Afghanistan to Iran is highly impure, but confirmatory quantification of purity in samples is not available³⁶. Uncertainty in purity can complicate a firm understanding of methamphetamine production and the value of the trade.

Figure 4. Caustic soda is one chemical that may be used in the illegal manufacture methamphetamine



While the product has many legal uses, this photograph was taken at a facility in Afghanistan where illegal production of methamphetamine was taking place. Company logos and other branding has been blurred.

Source: UNODC.

The ephedra plant and its alkaloid content

Box 3: Licit uses of the ephedra plant

The ephedra plant is not internationally controlled, unlike coca bush or opium poppy. In parts of Central Asia, ephedra (also known as *ma huang*) has been used for centuries as a traditional medicine, including in Traditional Chinese Medicine, to treat respiratory ailments, allergy symptoms, and colds. In some places, dried ephedra is sold as a dietary supplement to increase energy or for weight loss³⁷. In parts of Central Asia, including Afghanistan, it is also used as animal feed, such as for camels and sheep, and as biomass fuel for cooking and heating³⁸. Ephedra is also cultivated commercially in some regions; the active alkaloids, pseudoephedrine and ephedrine, are chemically extracted from the plant material and processed for industrial purposes in food supplements.

The ephedra plant (Figure 5) grows natively in many arid high elevation places around the world. Different ephedra strains contain different amounts of the key alkaloids (ephedrine/pseudoephedrine) necessary to manufacture methamphetamine. Studies of the plant have noted that variants that are native to the Americas contain little amounts of ephedrines. In contrast, some variants native to Central Asia are known to contain among the highest concentrations³⁹. Alkaloid concentrations across many species are highest in stems and nodes⁴⁰. Variants common to Central Asia are found to have combined ephedrine and pseudoephedrine concentrations somewhere around 1-5% of dry weight (*E. equisetina* and *E. distachya*). This is confirmed in studies of Uzbek ephedra which note that, "Almost all *E. distachya* contained only pseudoephedrine (1.25–1.59% of dry weight, %DW), while *E. equisetina* contained from 1.31 to 2.05%DW ephedrine and from 1.29 to 2.80%DW pseudoephedrine⁴¹." Ephedrine and pseudoephedrine content for varieties found in Tibet, such as *E. gerardiana*, were closer to 1.8-2.4% of dry weight⁴². For context, the cocaine alkaloid content for dried coca leaf, an illicit crop that is harvested year-round varies less, around 0.4 to 0.6% of dry weight⁴³.

Figure 5. Ephedra plant growing wildly on an Afghan mountain slope in 2019.



Ephedras are hardy plants that tend to favour poor soils in dry environments.

Source: UNODC.

Box 4: Factors that are likely to contribute to greater ephedrine/pseudoephedrine content in ephedra

- **Variety or sub-species:** not all species contain ephedrines and some are known to produce more ephedrines than others.
- **Individual variability:** even within the same species, there can be specimens that have ephedrines while other may not. This also goes for parts of the same plant, with alkaloid content highest in the nodes and older stems.
- **Altitude:** most ephedra that grows higher than 2500m above sea level seems to have higher concentrations of alkaloids. Plants at lower altitudes tend to have less, if any, content.
- **Topography and soil composition:** plants harvested on dry alpine slopes are associated with higher alkaloid content as are those that grow in more alkali soils.
- **Season:** Ephedrine content peaks during certain seasons, usually the fall, before seasonal rains.
- **Hardship:** Overall, those plants that grow under harsh environmental conditions are more likely to present higher ephedrine/pseudoephedrine content.

Ephedrine extraction from dried plant matter has been documented in the scientific literature as well as by those observing developments in Afghanistan⁴⁴. By several accounts, it is not difficult to extract ephedrine/pseudoephedrine from the ephedra plant using available chemicals and solvents⁴⁵. Ephedrine is water soluble, and UNODC field research in 2022 indicate that extraction is done by boiling milled ephedra in large barrels with water and filtering the ephedrines out. Variations in extraction methods result in greater or lesser amounts of loss.

Alkaloid content also varies by species, growing circumstances, environmental conditions or by locally present genetic mutations⁴⁶. However, there is limited and often contradicting information about what factors—external or internal—affect the concentration of ephedrine/pseudoephedrine in individual plants. Research on species that are known to contain ephedrine/pseudoephedrine such as *E. strobilacea* and *E. lomatolepis*⁴⁷, and which are reported to be harvested in Afghanistan to produce methamphetamine, found no alkaloids in the specimens analysed across the border in Uzbekistan. This research suggests that alkaloid content can vary and be less consistent than in poppy.

Presently it is not fully understood what species are commonly found in Afghanistan or harvested for methamphetamine manufacture. Recent reports indicate that *E. strobilacea*, *E. major (procera)*, and *E. sarcocarpa* are harvested for drug production in southern provinces⁴⁸, while other species may also be used in different degrees depending on the region.

The altitudinal range for ephedra growth is extremely wide, with plants being present at sea level altitudes⁴⁹ to up to 5000 m⁵⁰. Altitude seems to play a role in the ephedrine/pseudoephedrine content of the plant. While some reports indicate that harvesting prioritizes plants located at altitudes of 2500-3000 m⁵¹, other research indicates that specimens found at even higher altitudes contain higher concentrations of ephedrine alkaloids⁵². However, ephedrine/pseudoephedrine content appears to diminish over a certain altitude, suggesting a non-linear relationship with altitude⁵³.

Ephedra prefers arid to semi-arid environments with high levels of solar radiation⁵⁴, so it is commonly found on rocky mountainous slopes (Figure 6). When it comes to soils, it is somewhat versatile, but soil type seems to have an influence on alkaloid content, with higher pH usually meaning higher alkaloid presence⁵⁵ so not all soils seem to be suitable for alkaloid production.

The conditions for ephedra species to thrive can be found in most parts of Afghanistan. Presently, it is unclear to what extent local harvesters are aware or knowledgeable about ideal growing conditions, or about which species produce the highest concentrations of ephedrines. Unlike coca or poppy, which have a long history of cultivation and human involvement, ephedra harvesting for methamphetamine in Afghanistan is a newly investigated phenomenon and the plant remains largely undomesticated and wild.

Ephedra harvesting

Ephedra harvesting can be a difficult and time-consuming process. While there is an indication that only those plants that grow between 2500 and 3000 m are harvested and used for production of methamphetamine⁵⁶, UNODC field research indicate that plants at much lower altitudes are also being collected in different parts of the country.

Research conducted in the country points towards seasonality of harvesting and indicated that the harvest in Afghanistan typically occurs between July and October⁵⁷. Research suggests that the end of the harvest season may coincide with higher alkaloid content in the plant due to lower moisture levels⁵⁸. However, the evidence is not fully conclusive as some plants in certain environments have reported decreased alkaloid content from late July with a minimum in October, but peak in November⁵⁹. For historic comparison, the harvesting of the ephedra plant for extracting ephedrine for legal purposes in Pakistan peaks in October and November, to maximize ephedrine content, but harvesting can continue until the start of winter in mid-December⁶⁰. Therefore, seasonality could affect methamphetamine manufacture, as there is only one period of annual harvest, and alkaloid content could vary depending on the region in question and time of year, although the degree to which these facts are known by illegal producers are yet to be determined.

Figure 6. Ephedra plant growing at an altitude of around 1300 m on the rocky slopes of Western Afghanistan

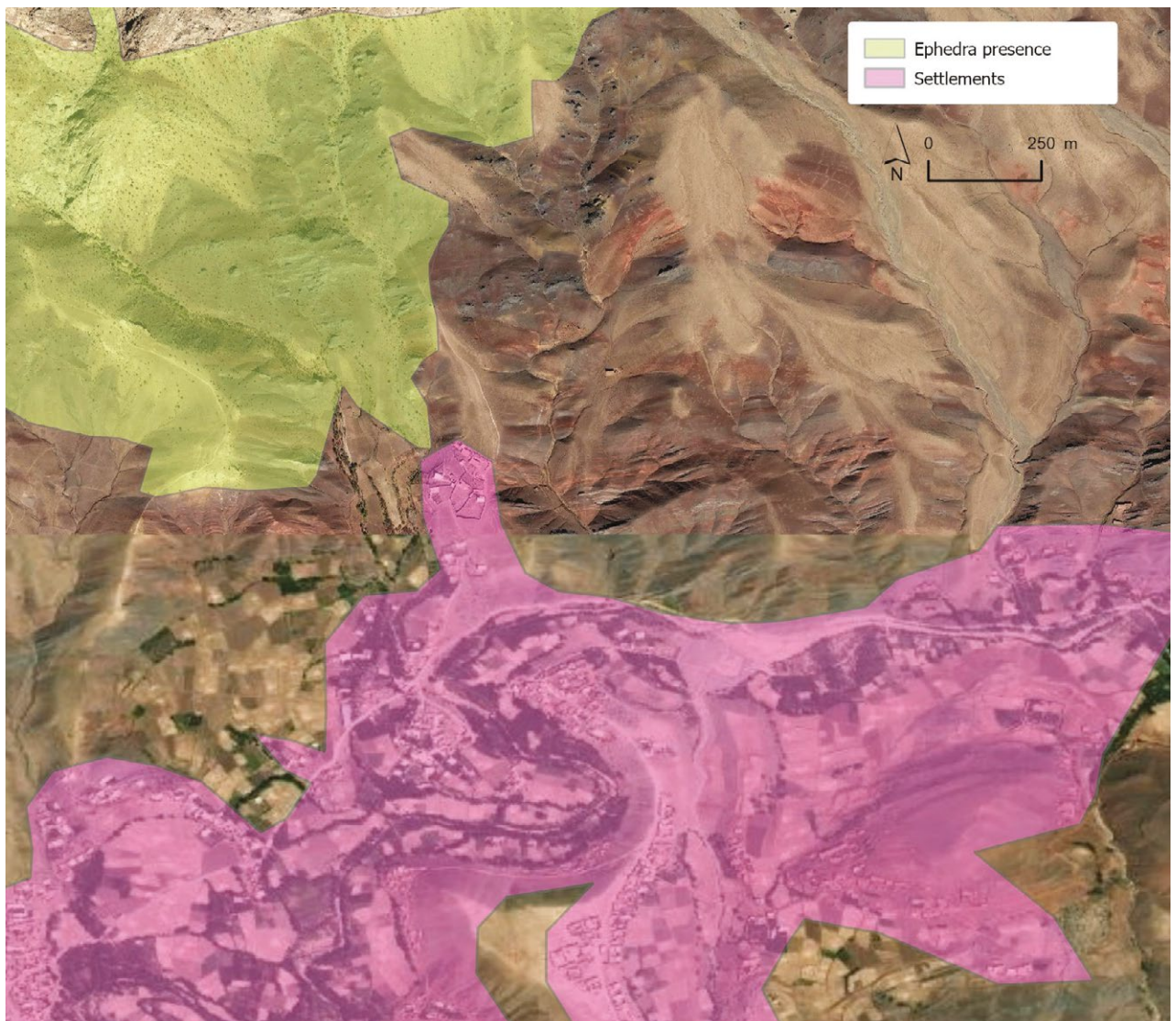


Source: UNODC.

The characteristics of the plant and the different levels of alkaloids present might make harvesting an arduous job. The collection of the plants likely takes place in more remote areas of the country under strenuous conditions⁶¹. Due to the harsh environmental conditions necessary to produce higher alkaloid concentrations, desirable specimens for collection are more likely to be found in areas where plant density is lower, increasing the required effort to harvest them. This contrasts with coca leaf or opium poppy, which are usually cultivated to maximize ease of harvest and alkaloid concentrations.

All these conditions, added to the fact that some plants may contain lower concentrations of ephedrine/pseudoephedrine, mean that harvesting enough raw materials to produce methamphetamine can require considerable effort and substantial labour even if located near settlements (Figure 7).

Figure 7. Slopes with ephedra presence in Ghor province in central Afghanistan located very close to settlements.



Source: UNODC.

Ephedra processing and 'cooking'

UNODC field research indicated that, to facilitate transport, harvested ephedra is dried and often processed so that only the parts of the plant with the highest alkaloid content are transported to market. Ephedra contains substantial amount of water weight, with perhaps as much as 50-60% of the plant's weight is made up of water and other moisture, making drying a useful necessary step⁶². Drying may take several weeks, with some reports from the literature and elsewhere referencing 15 to 25 days after harvest⁶³.

The large volume of plant material collected (some reports suggested that harvesters can collect up to 45 kg of raw ephedra a day⁶⁴) encourages the drying and threshing, sometimes milling, relatively close to harvest sites (Figure 8) before transport for ephedrine extraction. Traditional methods used elsewhere dry ephedra in open air conditions under shade and later under the sun⁶⁵.

UNODC field research indicates that after drying, ephedra is processed by threshing or threshing and milling the plant matter to further reduce transport costs associated with material that does not contain ephedrine alkaloids. Sometimes this processing is done near where harvesting took place. In other areas, where the threshing and milling facilities may be further out, the plant is transported directly to the area where it will be processed, and most steps of the process other than the harvesting occur in a more integrated manner.

Figure 8. Threshed -left- and milled -right- ephedra. These procedures help reduce transportation costs between point of harvest and point of ephedrine extraction.



Source: UNODC

UNODC field observations suggest that there are different procedures used to extract the methamphetamine precursors from the ephedra plant. One method consists of mixing the processed ephedra plant matter with other chemicals and solvents that allow the extraction (acid-base extraction) of the ephedrine needed for producing methamphetamine. Another extraction method involves boiling large quantities of milled ephedra in water (Figure 9). Different extraction methods may take different amounts of time or yield different quantities of ephedrine/pseudoephedrine. Facilities where extraction takes place have traditionally not been located near to where the plants are harvested, but closer to marketplaces where processed ephedra is traded⁶⁶. Extracted ephedrine is sold to traffickers who then synthesize methamphetamine using methods described below.

Figure 9. Ephedrine/pseudoephedrine from plant origin being extracted and processed by boiling in liquid at an industrial scale in Western Afghanistan.



Source: UNODC.

Ephedrines from cold medications

Afghanistan reported to INCB annual licit requirements of 150 kg of ephedrine and 2,800 kg of pseudoephedrine in 2021 (in both bulk and pharmaceutical preparations)⁶⁷. This is up substantially from 2014, when legitimate requirement totals were reported at 50 and 300 kg, respectively⁶⁸. Legitimate requirements fell to about 1.4 metric tons in 2022⁶⁹. The 2018 INCB report on estimates of legitimate precursor needs suggested that the estimates submitted by Afghanistan, especially for pseudoephedrine, may be beyond the capacity of the country's "limited pharmaceutical industry," which suggests possible diversion⁷⁰. Further, the amount of unreported and illegally trafficked imports are not known but could be an important source for illegal methamphetamine manufacture⁷¹.

Afghanistan reports seizures of methamphetamine precursors sporadically. In 2019, a total of 440 kg of pseudoephedrine preparations were seized. Ephedrines and other related precursor chemicals that can be used in the illegal manufacture of drugs are also legally produced in India and Pakistan and periodically have been seized by authorities in the region in recent years⁷².

Latest UNODC analysis of seized tablets points largely to the use of cold medications as a source of ephedrine in manufacturing methamphetamine. Of the samples of methamphetamine seizures in Afghanistan made between 2020 and 2021, about 46% contained other trace amounts of other medications (e.g., antihistamines, antitussives) found in cold remedy medications licensed by Pakistani or Afghan health authorities⁷³. Cold medications containing ephedrines (mostly pseudoephedrine) are sold in Afghanistan as tablet and syrup formulations. There may be a preference for using tablets for methamphetamine manufacture due to their weight, but given the limitations of access, any medication with the necessary formulation could eventually be used. Photographic evidence in some reports point to large dump sites of discarded bottles of liquid formulations, suggesting that the liquid form is used as well⁷⁴.

The following cold medication formulas commonly reported in Afghanistan (Table 1) are documented by Pakistani licensing authorities and other industry trade groups in that country; information on active and inactive ingredient content were used to calculate the share of ephedrines (mostly pseudoephedrine)⁷⁵. Some of these products have been documented in UNODC field observations to be diverted to illicit markets, which may be a source for inputs being used in the manufacture of methamphetamine in Afghanistan. Figure 10 highlights three common cold medications in Afghanistan and their dosages of pseudoephedrine.

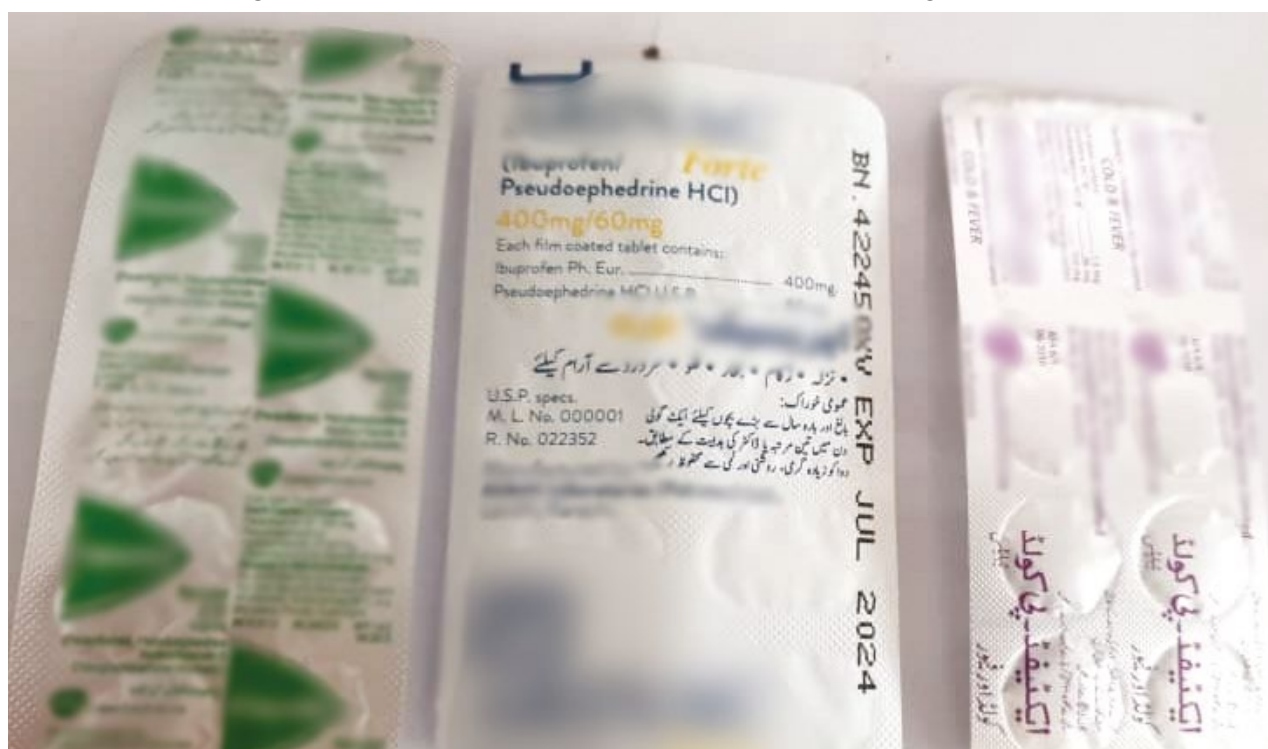
Table 1: Details about common formulations of cold medications tablets and syrups containing ephedrines in Afghanistan

Medication	Pseudoephedrine (mg)	Share of active ingredient (estimated) ^a
A	60	10%
B	36	9%
C	60	12%
D	30	15%
E	120	60%
F	15	5%
G	36	9%
H	36	9%
I	36	9%
J	30	15%
K	36	9%

Sources: ⁷⁶; brand and formula names have been omitted.

^aEstimated share of active ingredients is calculated by dividing the dosage in milligrams of pseudoephedrine by the total estimated weight of all ingredients, including other medications and allowing for a small amount of excipients.

Figure 10. Examples of popular cold medication in Afghanistan.



Source: UNODC

The left two have 60 mg of pseudoephedrine per tablet, while the right one has 36mg. Medicines like these, while being legal and sold in pharmacies to treat illnesses, could be diverted to the illicit market for methamphetamine production due to their availability and composition. Company names and logos have been blurred.

Contextualizing methamphetamine production

Estimating the production of methamphetamine requires knowledge of various parameters for either plant or pharmaceutically derived methamphetamine. The focus here is on these two starting points, setting aside industrially sourced and illegally imported precursors⁷⁷. Using available information from the literature, reports, media sources, and other data, a preliminary model was constructed to approximate production for either plant or pharmaceutically derived methamphetamine. Future efforts can build on these models by improving precision of parameter estimates through on-the-ground validation.

Box 5: Improving measures and information needed to estimate input quantities for methamphetamine manufacturing

There remain many gaps in the data and information on how methamphetamine is manufactured in Afghanistan. Data gleaned from surveys of key informants and market participants can help improve precision of the process and its parameters through a better understanding of inputs, techniques, such as extraction, and outputs (e.g., purity of final or intermediary product). It is unknown, for example, which ephedra variety is most used, if harvesters can distinguish plants with more alkaloid content from the various existing varieties, and how efficient are methods of ephedrine extraction and how quickly the plant regrows after harvest. Reports on ephedrine extraction vary and are sometimes contradictory, which may represent misinformation or different practices across different regions. Reported extraction and synthesis yields under controlled conditions from the scientific literature may not reflect realities on the ground where synthesis reportedly occurs in rudimentary settings.

Geographic Information System (GIS) can help determine the extent of ephedra growth, regrowth, and availability. Determining the possible areas of cultivation and those in closest proximity to transit routes can improve the understanding of the scope of harvesting. Further, when GIS is combined with remote sensing data it can help to determine the extent of harvesting if ground disturbances (e.g., vehicle tracks or trails left behind by pack animals) and changes in vegetation density.

Systematic collection of other relevant price-related data along each step of production, e.g., price per kilogram of dried plant matter, price per kilogram of ephedrine, etc., can also provide additional information about the overall illicit methamphetamine economy and can help monitor any trends.

Table 2 describes several key parameters needed to quantify total methamphetamine production starting with either plant or cold medication inputs. Without knowing other specifics (i.e., changes in synthesis routes or other practices), modelled estimates are best used to quantify orders of magnitude of production inputs along the manufacturing process.

Table 2: Key parameters needed for quantifying methamphetamine production either via plants or cold medication inputs

Parameter	Ephedra plant	Ephedrine from cold medication
Amount of raw input	Total amount harvested in a season that is dried and threshed	Total amount of cold medication smuggled into the country or diverted from legitimate channels
Concentration of input material	Dry weight of ephedrine/pseudoephedrine content in processed (e.g., threshed or milled) plant matter	Amount of ephedrine/pseudoephedrine in the cold medication (mg or ml) by formulation (tablet or liquid)
Extraction of primary inputs	Efficiency of extraction techniques of ephedrine bases from plant material	Efficiency of extraction techniques of ephedrine bases from other tablet ingredients and medications
Conversion to finished product	Efficiency of yields to convert ephedrine into methamphetamine	

Existing estimates of methamphetamine production

Presently, there are a few estimates cited in the grey literature and news media for quantities needed of inputs at the different stages of producing methamphetamine in Afghanistan and they often do not contain measures or ranges of all parameters needed. Table 3 reproduces estimates reported in open sources of parameters needed to produce one kilogram of methamphetamine of unknown purity, which, when not explicitly stated by the reference, were calculated by dividing output weight by input weight (e.g., kilograms of methamphetamine produced from kilograms of ephedrine inputted). Sometimes the original source of information published ranges of raw material, in which cases midpoints were used for calculations. All consulted references did not specifically account for different levels of purity (though some references mention “good” or “export” quality). So, purity considerations may challenge the validity of the raw weights of inputs reported in the table and may help explain differences in estimated parameters across studies.

As Table 3 shows, the parameter estimates across reported studies, with one exception, fall within similar ranges. Ephedrine alkaloid content estimated in the context of illicit manufacture in Afghanistan appears within reasonable ranges when compared to what is reported in the scientific literature. Similarly, synthesis yield rates are within the ranges of those reported by the scientific literature but skew toward the upper bounds. No open sources discuss residual moisture or the efficiency of extraction of ephedrines from the ephedra plant in Afghanistan, though Billing (2021)⁷⁸ may have factored in these parameters in their calculations. There are also no explicit mentions of reaction loss in each step of the process. It is likely that previous studies overestimated the inputs needed or did not account for additional parameters needed to produce pure methamphetamine.

Table 3: Parameters discussed in studies reported by media and grey literature to produce one kilogram of methamphetamine in Afghanistan at unknown purity

Starting material	Estimated amount of starting material	Estimated ephedrine content	Ephedrine extracted	Estimated yield rate	Reference
Plant (processed) ^a	45 kg	3.3%	Not discussed	67-75%	79
Plant (presumed processed)	56 kg	2.67%	Not discussed	67%	80
Plant (unclear if processed) ^b	287 kg	0.5%	Not discussed	67%	81
Plant (processed) ^c	41 kg	3.6%	Not discussed	Not stated. Assumed 67%	82
Chemical ^d	1.25 liters	>95%	Not discussed	Cannot be calculated	83

^a The report features a graphic with an input-to-output ratio of 15 kg of ephedrine to 10 kg of methamphetamine, but a table later in the document describes the production of 15 kg of methamphetamine from 20 kg of ephedrine.

^b Given such large starting quantities and low ephedrine content, is likely that the author is assuming raw ephedra plant that has not been dried/processed. If 55% of the plant material consists of moisture, then a dried amount of pre-processed plant is closer to 129 kg with an alkaloid content closer to 1.3%, which is low but in line with other studies. It is possible that the author accounted for alkaloid loss in extraction or drying, but that is not explicit in the article.

^c The report only gives starting volume of processed ephedra and final estimate of equivalent tonnage of methamphetamine (purity unknown). Volume was converted to weight using a conversion density of 750 kg per cubic meter, which is roughly the same density for shelled corn, alfalfa seed or wheat. A yield rate of 67% of methamphetamine from ephedrine was assumed to arrive at an estimated ephedrine content.

^d The study refers to methamphetamine "cooks" in Iran using inputs from Afghanistan, converting ephedrine presumably in near pure form, to kilograms of methamphetamine. No additional information was reported that would allow for determining yield rates.

Modelling production for one kilogram of methamphetamine

Bringing together various parameters, a generalized approach for estimating production of one pure kilogram of methamphetamine using either cold medication or ephedra plant takes the following simplified equation:

$$\text{methamphetamine} = \text{input material} \times \text{concentration of ephedrines} \times \% \text{ extracted} \times \text{yield ratio of synthesis}$$

Where *input material* is in weight and can be either plant-based inputs that are harvested and processed (i.e., dried and thrashed with no remaining moisture content) or pharmaceutical or chemical products containing ephedrines obtained through diverted legal channels or illegal imports. The *concentration* is the amount of alkaloid in the input material, either plant matter or the concentration of active ingredient reported in medications. When ephedrines are extracted from either the plant or cold medications, some amount of key ingredients are lost in the process, hence it is important to consider the *percent extracted* or extraction rate to calculate how much ephedrines are needed to manufacture methamphetamine. Lastly, *yield ratios* are estimates of the efficiency of synthesis reactions when reducing ephedrines to methamphetamine in typical settings in Afghanistan (ignoring other reagents or solvents). These parameter estimates vary for plant versus pharmaceutical ephedrines.

Defining the parameters for estimating methamphetamine production

MOISTURE

Dried and processed ephedra may still contain a small but non-negligible amount of moisture weight. Laboratory examined samples of ephedra in dietary supplements were found to contain up to 5% moisture content⁸⁴. Likewise, traditional harvesting methods in China indicate that typically 80% of the moisture content is removed in open-air shade drying before final sun drying⁸⁵. So it is possible that dried and processed material still contain anywhere between 5-20% residual moisture content (in addition, moisture may be reabsorbed; harvested and milled medicinal plant material has been found to reabsorb ambient moisture over time depending on the means of storage⁸⁶). In contrast, cold medications do not contain residual moisture content and therefore have a value of 0% residual moisture.

EPHEDRINE CONTENT

The ephedrine content in the plant is unknown in Afghanistan, but scientific literature generally reports ranges between 0.5 and 5% in Central Asia for more productive variants of the ephedra plant. In terms of pharmaceutical products, the content of ephedrines (mostly pseudoephedrine) can range depending on the formulation and manufacturer. A search of most common brands (mostly in tablet form) suggests ranges from 15 to 120 mg per dose of products sold in Pakistan. Depending on the presence of other cold medications and excipients, the content of pseudoephedrine per dose ranged from 9 to 60%, with most formulations not surpassing 15% (see Table 1). A conservative range of 9 to 15% was chosen for modelling estimates.

EFFICIENCY IN EPHEDRINE EXTRACTION

Presently, it is unknown how efficient ephedrine/pseudoephedrine extraction processes are in Afghanistan. The research literature on ephedrines extraction from the ephedra plant, made in laboratory setting report extraction rates around 78-90%⁸⁷. But the context of illicit manufacture in Afghanistan is quite different, more rudimentary and cannot reach the laboratory level of efficiency. Traditional extraction methods that appear to be used in Afghanistan involve boiling the ephedra plant in water for long periods of time. The literature on these methods reports much smaller extraction rates. Assuming a 1.5% alkaloid content (which is the midpoint of the alkaloid content reported for ephedra plant species in reported studies, 0.5-2.5% range⁸⁸), water-boiling extraction may yield 10-72% of the ephedrine content existing in the plant⁸⁹. It is likely that ephedrine extraction from ephedra in Afghanistan suffers greater loss. Therefore, a range of 10 to 70% extraction rate was used, reflecting extraction techniques reported in country.

Similarly, it is unclear how sophisticated ephedrine/pseudoephedrine extraction is from cold medication in Afghanistan or if such methods can defeat tamper resistant formulations. Some studies mention that extraction from cold medications in the country is complicated and produces lower yields⁹⁰; however, that may depend on what medication is used and in what formulation. Medication in syrup formulation may result in higher extraction rates⁹¹ because perhaps it is harder to tamper proof the medication and the extraction is easier from a liquid. Trace amounts of other cold medications found in tableted methamphetamine seizures in Afghanistan suggest that extraction from tablets occurs but is insufficient in eliminating all starting material⁹². The literature on pseudoephedrine hydrochloride (HCl) extraction from cold medication reports wide ranges depending on the starting medication, formulation, and method used. Yields can be between 3% and 75%, with most close to 50%⁹³. However, tamper resistant formulations appear to account for lower extraction yields⁹⁴. Other analyses of pseudoephedrine HCl extraction from standard cold medication (i.e., formulations that do not contain means to deter tampering) using common methods and solvents employed in clandestine settings have reported much higher yields, upwards of 89 to 97%⁹⁵. It is unclear at this time to what extent cold medication production in the region are manufactured to deter illegal methamphetamine production.

Therefore, a wide range of 35 to 95% pseudoephedrine HCl extraction was chosen for cold medication. This range was adjusted to convert the weight in hydrochloride salt, which is heavier, to its basic form (82%)⁹⁶. This resulted in a final adjusted range of rate of extraction of ephedrine and pseudoephedrine base from cold medication at 29 to 80%.

EFFICIENCY IN SYNTHETIZING METHAMPHETAMINE FROM EPHEDRINES

Given that methamphetamine production appears to be using the Nagai method, synthesis yield rates may be somewhere at or just under 50%; however, a 67% yield rate is theoretically possible⁹⁷. A range of 50-67% was chosen to more closely reflect the realities on the ground in Afghanistan and falls in line with other ranges of theoretical yields using methods employed by traffickers elsewhere, e.g., the “one-pot” reaction method⁹⁸. It is assumed that these synthesis rates do not vary between plant versus cold medication inputs.

Table 4 outlines estimates for each parameter. To solve the above equation for *input material*, assuming an output of one pure kilogram of methamphetamine hydrochloride, results from a model simulation produce a range of values to account for uncertainty regarding parameter estimates. In essence, a series of mathematical products are rendered from the simulation of the below equation, and the distribution is plotted and examined (Figure 11).

$$\text{kg of input material} = \frac{1 \text{ kg of pure methamphetamine}}{(1-\% \text{ humidity}) \times \% \text{ of ephedrines} \times \% \text{ extracted} \times \text{yield ratio of synthesis}}$$

Table 4: Modelling production inputs for one pure kilogram of methamphetamine

Parameter	Ephedra plant	Cold medications	Notes	References
Residual moisture content	5-20%	0%	Unclear as to the degree of residual moisture of ephedra from Afghanistan, but dried plant matter in dietary supplements retains some non-negligible amount of moisture. Dried plant matter may also reabsorb ambient humidity.	99
Total ephedrine & pseudoephedrine content	1-5%	9-15%	E = Ranges are typical for species found in Central Asia. CM = Ranges were obtained by a review of ingredients of commonly found medications in Afghanistan and Pakistan.	E = ¹⁰⁰ CM = See Table 1
Extraction rate of ephedrine & pseudoephedrine	10-70%	29-80% ^a	E = Ranges are informed by literature but assumed to be less than rates of extraction in laboratory settings. CM = Ranges informed by empirical examination and the literature involving formulations without tamper resistant ingredients.	E = ¹⁰¹ CM = ¹⁰²
Yield rate from ephedrine & pseudoephedrine to methamphetamine	50-67%	50-67%	Information to date suggest that producers in Afghanistan use the Nagai method for synthesis.	¹⁰³

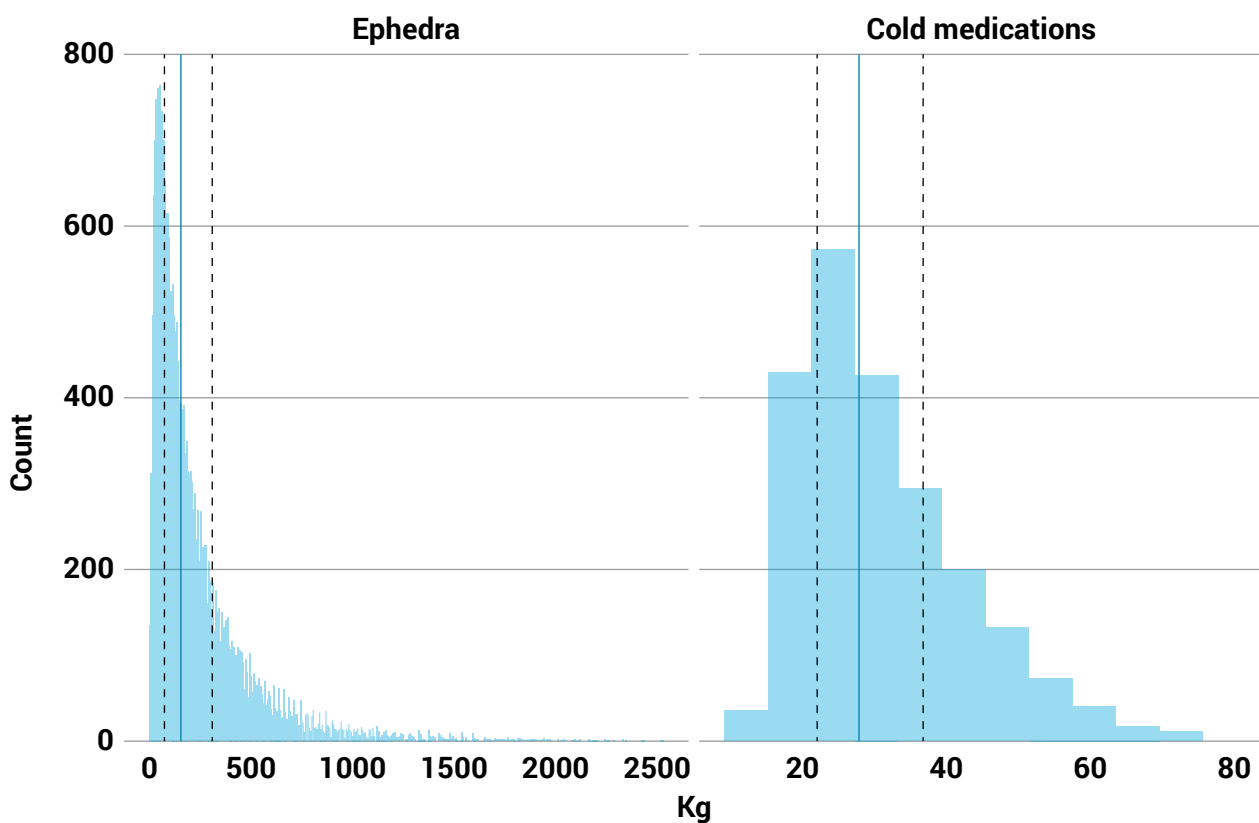
E = ephedra; CM = cold medications.

^a Ranges have been adjusted to convert from hydrochloride to base using a conversion rate of 82%.

Figure 11 shows the distribution in modelled estimates of total input material used for either ephedra or cold medications. For dried ephedra, the median estimate is of 196.8 kg (25th-75th percentiles 119.3-346.6 kg) needed to produce one kilogram of methamphetamine compared with 27.9 kg (25th-75th percentiles 21.9-36.8 kg) for cold medications. Table 5 reproduces the statistics for each

set of estimates. It is clear that cold medications require almost a seventh of input weight compared with dried and processed ephedra. Assuming a 50 to 60% moisture content would mean that about 394-492 kg of harvested ephedra is needed to produce one pure kilogram of methamphetamine. The dried weight estimates here are, with one exception, about 3.5 to 5 times more than those reported by media and other studies shown in Table 3. These estimates would justify the results of studies presented in Table 3 as producing one kilogram of methamphetamine at 20 to 30% purity. The estimate of 287 kg of plant presented in one study in Table 3 is closer in line with the model estimates, but it is unclear if the author was referring to dried or freshly harvested ephedra. Estimates here are more in line with what Chinese authorities suggested may be possible when using ephedra, e.g., 200 kg of ephedra for one kilogram of methamphetamine¹⁰⁴.

Figure 11: Distribution of simulated model estimates of kilograms of ephedra or cold medications needed to yield 1kg of pure methamphetamine in Afghanistan



Median kilograms are shown in solid vertical line.
25th and 75th percentiles indicated by vertical dashed lines.

Table 5: Statistics of the distribution of simulated model estimates of kilograms of ephedra or cold medications needed to yield 1kg of pure methamphetamine in Afghanistan

Input	Mean	Minimum	Median	Maximum
Dry ephedra	284.8 kg	46.5 kg	196.8 kg	2,500 kg
Cold medications	30.4 kg	13.0 kg	27.9 kg	77.4 kg

By adjusting for purity, holding all other parameters constant, one can arrive at weights for impure methamphetamine production. Table 6 shows the raw weights of inputs needed to result in purity-adjusted amounts of a kilogram of methamphetamine. Estimated harvested raw weight of ephedra is also calculated assuming 55% moisture content.

Table 6: Median raw weight of inputs needed for a one kilogram of methamphetamine of different purity

Input	100% pure	90% pure	75% pure	50% pure
Dry ephedra (harvest weight)	196.8 kg (437 kg)	177.12 kg (394 kg)	147.6 kg (328 kg)	98.4 kg (219 kg)
Cold medications	27.9 kg	25.11 kg	20.925 kg	13.95 kg

Harvested weight has been rounded to the nearest whole number and assumes 55% moisture content of raw harvested ephedra.

Estimates here only examine methamphetamine production using ephedra or cold medications that contain ephedrine or pseudoephedrine.

A more efficient and direct method of production involves industrial format of bulk ephedrine or pseudoephedrine. Higher purity inputs (often above 95%¹⁰⁵) that do not require further extraction face no loss through additional processing steps. It is likely that use of bulk chemicals would make the process more efficient because it would require low-end single digit kilogram amounts to yield a kilogram of pure methamphetamine.

Extrapolating scope of production from seizures

To offer some sense of magnitude, estimates in Table 6 can be extrapolated to the total amount of methamphetamine seized in Afghanistan for 2021. Nearly 2.7 metric tons of methamphetamine were seized that year, all presumably manufactured inside the country. The true production totals are much higher but are impossible to calculate without knowing how much is seized relative to how much is produced. Thus, extrapolated estimates are low-end estimates.

Another complicating factor is the uncertainty around the purity of seizures, which likely vary considerably between retail level seizures in tablet form (relatively low purity) versus export level methamphetamine in crystalline form, or “ice” (relatively high purity). For context, Türkiye, an important transit country for drug trafficking from Afghanistan to Europe, reported in 2018 (latest available data) an average purity of methamphetamines of 73% (with a minimum purity of 25% and a maximum purity of 86%) and India reported an average purity of 54%¹⁰⁶.

Therefore, Table 7 reproduces low and high estimates as ranges in terms of total metric tons needed of inputs to generate 2.7 metric tons of methamphetamine at 50 or 90% purity. For ephedra plant estimates, harvested weight is included in parenthesis below each estimate to account for loss of water weight. From the above extrapolations, assuming 90% purity of the methamphetamine obtained at the end of the manufacturing process, some 478 metric tons of dried and processed ephedra (1062 metric tons harvested) would be needed to result in 2.7 metric tons of methamphetamine. Assuming purity was 50%, those figures drop to 266 and 591 metric tons for dried and fresh ephedra, respectively.

Ranges for the equivalent amount of cold medication come to 38 to 68 metric tons, assuming 50 to 90% purity of the 2.7 metric tons seized. This is the total weight of cold medication formulations containing ephedrine and pseudoephedrine. Taking a 12% midpoint for the concentration of ephedrines, this comes to 4.6 to 8.2 metric tons of ephedrine and pseudoephedrine. To put this last figure into context, Afghanistan’s annual legitimate requirements for preparations containing ephedrine and pseudoephedrine in 2022 came to 0.7 metric tons¹⁰⁷, although there may be considerable under-reporting as imports or exports of preparations containing ephedrines are not required to be reported to the INCB. This suggests that considerable smuggling is needed to meet the demand of cold medication for illegal manufacture of methamphetamine, if methamphetamine is only produced with cold medication.

Table 7: Amount of ephedra plant and cold medication needed to produce 2.7 metric tons of methamphetamine of different purity seized in Afghanistan in 2021

Input	100% pure	90% pure	75% pure	50% pure
Dry ephedra (harvest weight)	531 tons (1180 tons)	478 tons (1062 tons)	399 tons (887 tons)	266 tons (591 tons)
Cold medications	75 tons	68 tons	57 tons	38 tons

Figures rounded to the nearest metric ton. Harvested weight assumes 55% moisture content of raw harvested ephedra.

In 2021, the last year for which data was available, a total of 29.7 tons of methamphetamine of unknown purity were seized in Afghanistan and neighbouring countries, presumably all manufactured in Afghanistan. Assuming a purity range of 50 and 90%, between 2,900 and 5,300 metric tons of dried and harvested plant matter would have been needed. This translates to a range of 6,500 and 11,700 tons of freshly collected ephedra, assuming a moisture content of 55%. And this is seizure data alone, actual production and trafficking exceeds these amounts by far more. To put that into context, total opium production for Afghanistan in 2022 was estimated at just under 6,200 metric tons¹⁰⁸.

For cold medications, the equivalent amount needed to produce 29.7 metric tons of methamphetamine at purity ranges between 50 and 90% comes to 414 and 746 metric tons. Using a 12% midpoint, this would translate to 50 and 90 metric tons of ephedrine and pseudoephedrine in preparation form. According to the INCB legitimate requirements for ephedrines in preparations reported by Afghanistan and neighbouring countries in the region came to 13 metric tons in 2022¹⁰⁹. The regional legitimate requirement totals are far below the estimated amount of ephedrines in cold medication preparations that would be needed if all methamphetamine was produced with cold medication. Meeting the need of cold medication to illicitly produce methamphetamine (between 451 and 812 metric tons only counting the seizures, far more for total production) is likely to draw considerable attention by authorities. Recent news of shortages of other medications used in these preparations¹¹⁰ may also put further constraints on smuggling of medications containing ephedrines.

Considering the large quantity needed if cold medication is the main input for methamphetamine manufacture in Afghanistan and ongoing shortages of cold medications, illegal production may resort to industrial-grade ephedrines. The amount of these chemicals traded each year is far more than the amount reported by INCB in cold medication preparation form. In 2022, more than 100 metric tons of bulk industrial grade ephedrines were reported for legitimate requirements to Afghanistan and neighbouring countries in the region¹¹¹. India reports virtually no annual legitimate requirements to INCB but is known as a major exporter of ephedrines. In 2021, the country reported total global exports of nearly 335 metric tons of ephedrines and their salts¹¹². The higher purity of these chemicals, their history of diversion and trafficking in the region¹¹³, and Afghanistan's experience with smuggling of large quantities of chemicals needed in the manufacture of drugs, suggest that industrially sourced ephedrines could play an important role in the illegal manufacture of methamphetamine in the country.

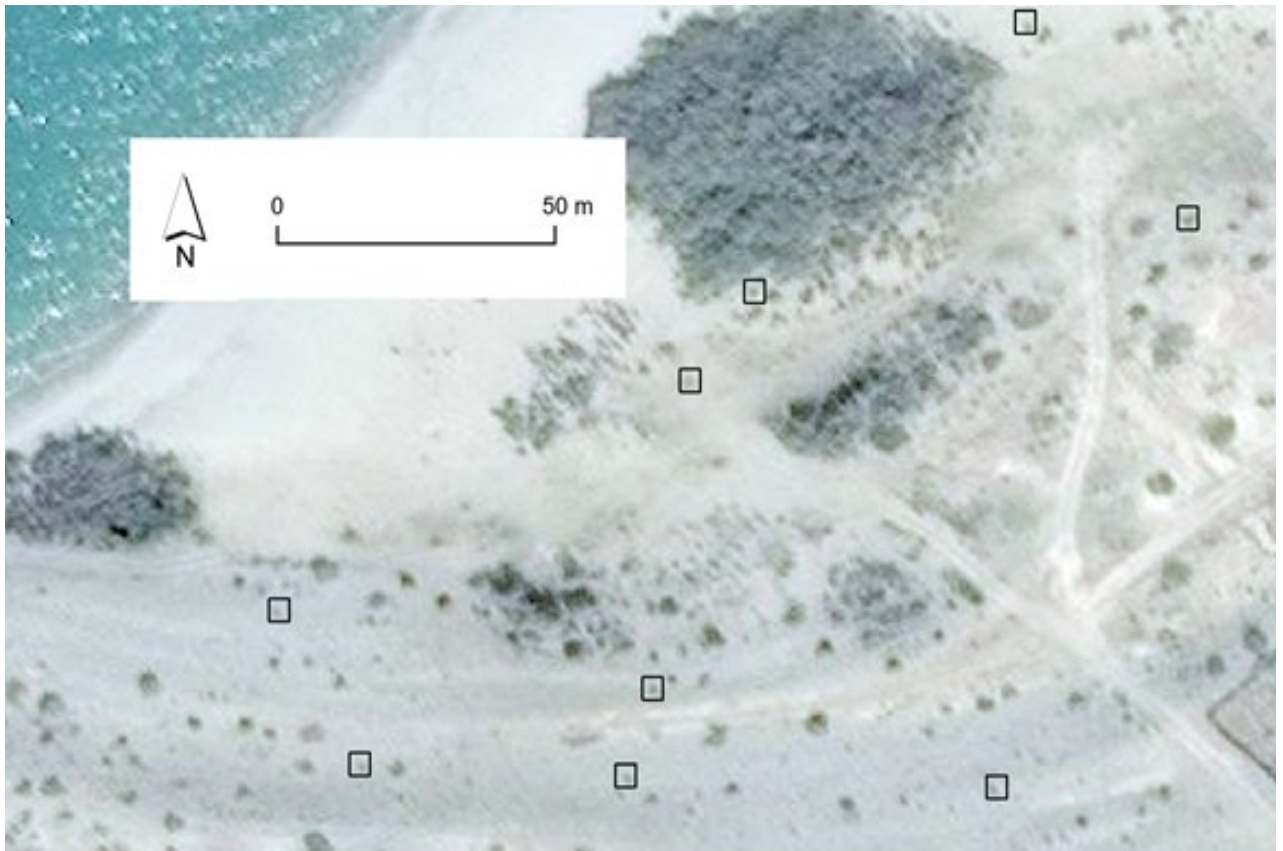
Additional measures to contextualize production

From total quantities of ephedra needed to produce one kilogram of methamphetamine, it is possible to contextualize total surface area and labour needed to facilitate ephedra extraction (Figure 12).

Using the estimates above, it takes approximately 437 kg of fresh ephedra to result in one pure kilogram of methamphetamine, assuming a 55% moisture content. Based on field information from 20 test samples collected in different areas of Afghanistan, Uzbekistan and Kazakhstan, the harvest weight from one ephedra plant can range considerably with common plant weights being between 0.1 to 1 kg, depending on the plant's age and the environmental conditions, with an average of 400 g per plant. In terms of surface area, 437 kg of fresh ephedra would translate to about 1,093 plants. Based on field and satellite image observations by UNODC, the average ephedra plant density can be about 32 plants per hectare. Under these conditions, about 34 hectares would need to be harvested to collect enough ephedra to produce one pure kilogram of methamphetamine.

According to some reports¹¹⁴ corroborated by UNODC field observations, a single labourer may be able to harvest somewhere between 25 and 45 kg per day depending on ephedra abundance, which translates to between 63 to 113 plants per day. Assuming a 10-hour workday during peak harvest season, this comes to 6.3 to 11.3 plants per hour. Given low plant density, the precarious nature of ephedra growing wildly on steep, unstable slopes, and the wide range in amount harvested, it can be assumed that ephedra harvesting requires extensive search and travel time. So, it may take somewhere between 9.7 and 17.5 persons per day to produce one kilogram of pure methamphetamine.

Figure 12. Very high resolution (40cm/pixel) satellite imagery from a test site on the shores of lake Issyk-Kul in Kyrgyzstan.



Source: UNODC
Squares indicate confirmed individual ephedra plants.

Using these estimates, it can be assumed that the harvest of a total surface area of 46,000 to 83,000 hectares of ephedra plant would be needed to manufacture the total reported seizures of 2.7 metric tons seized in Afghanistan in 2021, assuming a purity range of 50 to 90%. The same amount of labour required comes to between 18,400 and 33,000 person-days (using a midpoint of 13.6 labourers for figures reported above). Assuming a 70-day harvest, that translates to roughly 263-472 full-time harvesters.

Extrapolating these production inputs to regional seizure totals of 29.7 metric tons, using a purity range of 50 and 90%, between 6,500 and 11,700 tons of collected plant matter were needed. That would come to around 202,000 to 363,000 labour-days needed to meet the 29.7 tons of methamphetamine seized. Assuming adjusted methamphetamine purity ranges of 50 and 90%, some 507,000 to 913,000 hectares were harvested to source enough ephedra to reflect 29.7 tons of methamphetamine seizures. For context, this is about 3 to 4 times the number of hectares under opium poppy cultivation in its record year 2017.

Additional measures on price

It has been suggested that ephedrine extracted from ephedra plant is currently cheaper than that extracted from pharmaceutical product¹¹⁵. UNODC field observations suggest that traffickers have purchased bulk quantities of cold medications at a price that is 1.5 times higher than abroad, with higher prices if purchased from a pharmacy. For example, 100 tablets of cold medication containing ephedrines, would typically be priced at 650 PKR (or US\$3)¹¹⁶ when purchased in bulk on the illicit market and 800 PKR (US\$3.60) at pharmacy retail prices, but would cost only 432 PKR (US\$2) in neighbouring Pakistan¹¹⁷. In contrast, indications from the UNODC price monitoring system in Afghanistan suggest that 1,000 tablets of common cold medications (approximately 600g raw weight) known to be used in illegal methamphetamine manufacture can cost US\$23 (100 tablets reportedly goes for 650 Pakistani rupees on the illicit market; no quantity discount is assumed and mark-ups for import to Afghanistan are not considered).

On the ground measures of prices of bulk quantities of ephedra plant vary depending on the region and degree of processing (dried, threshed, and milled versus simply dried). Limited and opportunistic sampling may bias estimates, but so far observations of prices per kilogram ranged from US\$2.50 to US\$3.50¹¹⁸ depending on the region, averaging at some US\$3 for a kilogram of dried and processed ephedra. Table 8 examines the relative costs of ephedrine/pseudoephedrine between ephedra plant and cold medication needed to produce one pure kilogram of methamphetamine based on above estimates, assuming the use of a common cold medication brand.

Table 8: Comparing cost of inputs needed from either ephedra plant or common cold medication to produce one kilogram of pure methamphetamine

	Ephedra (dried and processed)	Cold medication (1000 tablets)
Weight	1kg	600g
Price per kg	US\$3.00	US\$38.33
Median amount of raw weight in kg needed to produce 1 kg of pure methamphetamine ^a	196.8	27.9
Total cost for raw material	US\$590.40	US\$1069.41

^a Using estimates of 100% pure kilogram reported in Table 6

Estimates in Table 8 suggest that the cost of using cold medication as input to produce one pure kilogram of methamphetamine is about double than using the ephedra plant (US\$1069 versus US\$590). These estimates do not include other costs in the manufacture processing, such as solvents, reagents, labour-related costs or other fixed costs needed to extract and process ephedrines into methamphetamine, regardless of the input used. Presently, there is less reliable information regarding different processing and synthesis methods. If ephedrine extraction from

cold medications is indeed more complicated or costly, as asserted by some¹¹⁹, then input costs shown above may further favour the use of the ephedra plant over cold medications. If the opposite is true, however, the cost differential of the two types of inputs would be smaller.

The price of the methamphetamine end product, in theory, should capture these input costs. Currently, the UNODC price monitoring system in Afghanistan indicates that one kilogram of methamphetamine near point of production in Afghanistan reportedly went for approximately US\$700 in April 2023. Assuming 50 or 70% purity of the methamphetamine, the total primary input costs would drop to US\$295 to US\$413 for ephedra and US\$538 to US\$748 for cold medications. This would make methamphetamine production from the ephedra plant relatively profitable and production from cold medications marginally profitable. However, this price per kilogram is a general market average and there is little way a typical buyer could distinguish between methamphetamine produced using cold medications or ephedra.

The price of bulk ephedrines sold outside of Afghanistan suggest this could be a cheaper way to manufacture methamphetamine. Listed prices for a kilogram of nearly pure ephedrine HCl from chemical vendors in South Asia range from US\$200-800 with several suggesting the ability to send multi-kilogram shipments abroad¹²⁰. As these listings cannot be verified, it is hard to determine the veracity of vendors' ability to ship the product. It is also unlikely that industrial-grade chemicals are shipped by mail or courier service to Afghanistan and instead may face additional price markups if they are smuggled overland into the country. However, industrial-grade ephedrines are inexpensive. Using global trade data, a kilogram of ephedrines and their salts exported from several countries in Asia was valued at US\$60-94, depending on the country of origin¹²¹. Nonetheless, the price of industrial-grade ephedrine/pseudoephedrine suggest that diverted precursor chemicals are highly profitable and most efficient.

Conclusions, other considerations, and next steps

Methodically simulated estimates here suggest that the median amount of 196.8 kg (25th-75th percentiles 119.3-346.6 kg) of dried and processed ephedra plant are needed to produce a pure kilogram of methamphetamine. Considering that about half of the plant's weight comes from moisture, the equivalent amount of freshly harvested ephedra may weigh 437 kg. In contrast, the median amount of 27.9 kg (25th-75th percentiles 21.9-36.8 kg) of cold medications are needed to produce a kilogram of pure methamphetamine. Use of cold medication drastically reduces the total amount needed by one seventh. Use of industrial-grade ephedrine or pseudoephedrine was not modelled but because those inputs are highly pure, and synthesis of methamphetamine can be done directly, drastic reductions in input-to-output ratios, perhaps in the low single kilogram amounts¹²², are to be expected. Those starting inputs are much more efficient and seizures of ephedrine and pseudoephedrine precursors emanating from South Asia, a region with large chemical sectors, have been reported¹²³.

However, given available information in country on ephedra prices, estimates here suggest that the plant may be competitively priced such that it is a desirable input material in Afghanistan. Ephedra grows well in high altitudes and arid environments. Considering the availability of cheap manual labour, Afghanistan may be well positioned as a source for plant-based methamphetamine.

It is therefore clear that the environmental and social conditions allow for the growth and harvesting of ephedra for methamphetamine production in many areas. Media and other reports suggest that harvesting and transport occurs on a large scale.

The 2022 drug ban may affect levels of production and may push some of the processing activity across the borders or toward use of other input material. Recent news of ongoing shortages of cold medication, in particular paracetamol, is related to a discontinuing of the production of common cold medications in Pakistan¹²⁴. A reduction in the availability of cold medications may further encourage sourcing ephedrines from alternative sources, including the ephedra plant and diversion from legal sources.

Overcoming limitations and improving modelled estimates

There are several limitations when attempting to measure the scale of clandestine methamphetamine production anywhere, let alone Afghanistan. Parameter estimates above that are informed from the literature may not be directly applicable to the situation on the ground. There is no direct assessment of ephedra varieties in Afghanistan, or the alkaloid content of the plants harvested. Little is known about extraction or synthesis methods. Most critical, however, is the absence of forensic analysis of seizures to ascertain purity. Nonetheless, a series of ranges produced above capture some of that uncertainty. To date, figures cited in the media involving clandestine production in Afghanistan do not account for purity differences, which will bias estimates and overstate the productivity of inputs.

Box 6: Remote sensing to improve understanding of production

Remote sensing techniques may present a significant challenge when it comes to measuring the extent and locations of ephedra harvesting. The plant grows wild, and sometimes away from human-made markings and delineated fields and agricultural zones, making it difficult to identify and measure. Moreover, current remote sensing techniques relevant to this plant are not as developed as those used for poppy or coca, which further complicates its monitoring.

Identifying individual ephedra plants remotely poses a major obstacle, given their morphological similarities with other plant species and the limited resolution of current satellite imagery. Surveying the plant using photogrammetric planes, helicopters or even drones might be potential options, as well as alternative methods such as monitoring soil disturbance or, in areas with high ephedra density, changes in land cover.

Environmental impacts of the collection of ephedra plant and the extent of growth

The systematic collection of ephedra plants poses risks to the environment. Due to their ecological requirements which allow them to grow in poor, unstable and steep soils, ephedra plants help prevent soil erosion and in reduce environmental risks such as mud slides, flash floods, or soil depletion¹²⁵. Removal of these plants from semi-arid environments can have consequences both at short and long term, as the ecosystem can take a long time to recover¹²⁶. For example, Figure 13 shows an area of Ghor where ephedra is found. The plants help to stabilize, contain, and even accumulate the soil, which is a key role in the local and regional ecosystem.

When ephedra is more intensively harvested, there is an increased risk for natural disasters to affect surrounding communities and to impact their livelihoods. In neighbouring countries where ephedra has traditionally been used as a traditional method to treat respiratory ailments and consequently it has been collected¹²⁷, increased erosion challenges have arisen¹²⁸. Additionally, ephedra has been traditionally used for animal feed, such as for camels and sheep, and as biomass fuel for cooking and heating, so if resources are diverted to the production of methamphetamine the consequences will not be limited to public health, but also environmental, economic and social impacts¹²⁹.

Figure 13. Ephedra growing on the slopes of a mountain in Ghor province.



Source: UNODC

The plants help reduce soil erosion, which in such environments is a key ecological task. They also help reduce the incidence of flash floods and mud slides. Lowest point of the view is ~2200m, highest peak is ~2900m. This is a computer-generated image using satellite imagery from autumn 2019.

Policy implications

Responding to growing methamphetamine manufacture must address the input material and not only the finished product in order to design effective counternarcotics strategies. This research suggests that efforts to disrupt methamphetamine supply by focusing on plant-based ephedrine may overlook the use of pharmaceutical or chemical inputs. To that end, continued analysis and monitoring are needed. So far there is little systematic analysis, especially forensic analysis, of seizures reported to have originated from Afghanistan. Detailed information on purity and prices as well as carrying out interviews with those on the ground and involved with illegal methamphetamine production, ephedrine extraction, or ephedra harvesting can better determine inputs and methods used and thus appropriate responses.

Determining the primary source of illegal methamphetamine production has important implications for policy. If ephedra continues to play a dominant part of the illegal drug economy, then ongoing efforts might need to be taken to discourage its sourcing either through suitable alternative livelihoods or restrictions on the trade of the plant. Given that large quantities are needed to produce finished product, efforts might be successful in curtailing the transport and trade in ephedra and identifying and dismantling ephedrine processing plants.

On the other hand, if bulk industrial chemicals or cold medications are the dominant inputs, then greater international efforts will be needed to reduce diversion of legitimate trade in chemicals and cold medications. This may take the form of requiring that cold medications are manufactured in ways that deter or prevent ephedrine or pseudoephedrine extraction, or replacing ephedrine and pseudoephedrine formulations with suitable alternatives that cannot be diverted for methamphetamine manufacture (e.g., phenylephrine).

Depending on the policies, shifts in the market can occur. A successfully disruptive policy on sourcing ephedrines from the ephedra plant, e.g., through the Taliban ban on narcotics, might further push producers toward more efficient means of production if they can source industrially manufactured ephedrine and pseudoephedrine from other countries.

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