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Abstract

Medicinal tar is a reddish-brown liquid with a smoky odour, which is traditionally produced through pyrolysis of trunks or roots of different coniferous trees, e.g. *Juniperus oxycedrus, Juniperus phoenicea, Juniperus thurifera, Tetraclinis articulata* and *Cedrus atlantica.*

Trade and use of medicinal tars in Europe and North America is restricted due to potential carcinogenicity. The only presently allowed uses are as a fragrance substance in cosmetics.

This study carried out semi-structured interviews with producers, herbalists and traditional midwives/healers (*ferraga*) in the High Atlas mountains of Morocco, to assess saliency of use, what species are used and how medicinal tar is used in the Marrakesh region. We found that *Juniperus phoenicea* and *Juniperus oxycedrus* are used most frequently for tar production. Frequent trade was reported by retailers, and the traditional herbal intermediaries (both herbalists and ferraga) report that tar is used most commonly for hair care, skin diseases and fumigation.

Samples were collected and analysed with Gas Chromatography-Mass Spectrometry (GC-MS) and scanned for Poly Aromatic Hydrocarbons (PAHs) known to be present in mineral coal tar. Two of the samples were hydro-distilled to see if the composition would change. No PAHs were found in any of the samples but composition was clearly changed by hydro-distillation. GC-MS spectra showed that different species were used, but no identification using spectra of reference samples was possible.

Producers mentioned that admixtures to the tar by wholesalers and herbalists could be possible, and mentioned the use of engine oil and table oil. The GC-MS analyses showed no such admixtures in the samples gathered, but this does not rule out the possibility of admixture, as the utilization of additives could be a seasonal phenomenon, e.g. when resources are more scarce admixture could be more common.

The absence of PAHs in the analysed samples makes the question of their direct toxicity an open one. Further studies need to be done, both on toxicity of medicinal tars but also on the actual medicinal properties from the different biological sources, a field where information is scarce.

The more indirect threats to human health are the actual production sites. Unfiltered smoke from tar production is a definite source of PAHs and soot exposure, two well-known potentially harmful components of unfiltered smoke. The proximity of the production in the villages to houses causes continuous exposure of harmful fumes to children and the people in general.

The largest threat of medicinal tar production is not the one to health, but to biodiversity that dwindles with the increasing deforestation due to unsustainable harvesting of junipers in the High Atlas. Review of current legislation and implementation of improvements that benefit sustainable use are quintessential to save the last remaining juniper forests of the High Atlas.

Keywords: Juniperus oxycedrus, Poly-aromatic hydrocarbons, Medicinal Tars, Morocco, High Atlas, Juniperus thurifera, Biodiversity, Ethnobotany, Threatened Species, GC-MS, Cade Oil, Cedrus atlantica, Juniperus phoenicea, Tetraclinis articulata

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1. Introduction

This thesis is a part of an ongoing project concerning wildlife trade in southern Morocco, which is a collaboration between The Department of Systematic Botany, Uppsala University; the Natural History Museum of Marrakesh, Cadi Ayyad University and the Global Diversity Foundation. The field study was financed by the Swedish International Developmental Cooperation Agency (Sida) through a Minor field study (MFS) grant awarded through Uppsala University's Working group on Tropical ecology, and is a preliminary step in discerning the extent to which Medicinal tar is used and manufactured in Marrakesh and the surrounding High Atlas region.

1.1 Morocco

Morocco is situated in the north-western corner of the African continent, making it unique in the sense of being the only African country with both an Atlantic and a Mediterranean coast line.
The climates in the coastal areas are typically Mediterranean but the further from the coast the more extreme the landscape gets with deserts as the most extreme environment. (CIA 2007)

The country's population has increased with about 500 000 people since 2006 and is now 33,7 million. The main groups are Arabs and Berbers (Imazighen) which add up to around 99 % of the population (CIA 2007). The Imazighen numbered about 9,5 million in 2000 (EB 2007a). The main language is the Moroccan dialect of Arabic, and French is the language of trade, governmental functions and diplomacy (CIA 2007). Three Major Imazighen languages are also recognised as official languages (EB 2007a).

Tourism is a major source of income for Morocco and for Moroccans in general. But a large part of the Imazighen in the High Atlas region are farmers and live in primitive villages, some lack electricity and the roads, if present, are in poor condition.

1.2 Marrakesh

Marrakesh is situated in the middle of Morocco and lies at the feet of the High Atlas mountains. This gives the area a very variable climate with very dry summers with temperatures over 40 degrees Celsius and colder winters when the temperature is around 5 degrees. The plains around the city are irrigated with water from large dams in the north (EB 2007b).

The city is roughly divided between the New city (Guelize) and the old City (Medina). The Medina is since 1985 a UNESCO world heritage site with marvellous sites such as the Kotoubia mosque dating back to the 12^{th}-century, and the vibrant square Jamaa el-Fna with its many storytellers, acrobats, herbalists, food stalls and orange juice sellers (EB 2007b). Guelize on the other hand was founded under the French protectorate as means of governing the city and to provide modern housing for the French officials. (EB 2007b)

Today the city is inhabited by about 900 000 people and is the commercial centre for the High Atlas mountains and Saharan trade, giving it an important position in the general wildlife trade in Morocco (EB 2007b).

1.3 Medicinal tars

Cade oil, or juniper tar, is a reddish-brown liquid with a smoky odour. The traditional way of producing it is destructive distillation, or pyrolysis, of the wood or roots of *Juniperus oxycedrus* (Bellakhdar 1998). Bellakhdar (1998) mentions that in Morocco different coniferous species are used instead and/or alongside with *J. oxycedrus* but Cade oil is the one in highest esteem. In

Morocco the name for the different tars are Gatran, independent of what species are used in the production. Due to these circumstances I have chosen to call all the oils by the name Medicinal Tars in order to differentiate between original Cade oil made only from *J.oxycedrus* and tars from other sources.

Medicinal tars have a long history of manufacture and use around the Mediterranean basin from ancient Greece where the production and uses were described by Theophrastos (3rd Century BC), to Pharaonic Egypt where modern scientific investigations have shown 3500 year old embalming techniques to include tars from *Juniperus* sp. (Koller et al. 2003).

Today the uses in European and international medicine are highly restricted due to potentially high Poly Aromatic Hydrocarbon (PAH) content making it a potential carcinogen. But Juniper tar has recently been used as a treatment with documented effect against psoriasis (Shocket et al. 1990). Other modern uses with documented effect are against eczema (Budvari 1989) and against other chronic skin problems such as seborrhoea (Gennaro 1990). Currently the only allowed use in Europe and the US is as a fragrance substance in cosmetics and perfumery and then only in small amounts, the total amount of PAH in a product with Cade oil in it may then not be higher than 1 ppb. This is only true for rectified cade oil, the crude juniper tar is banned. (IFRA 2003)

DNA-adduct tests on the skin of mice and on psoriasis patients have shown that Cade oil causes similar levels of DNA adducts as those treated with coal tar. The adduct levels are significantly higher in lung tissue from mice exposed to Cade oil than tissue exposed to coal tar. (Shocket et al. 1990)

Studies show low acute toxicity in rats (Anon 2001). But there have been incidents when only a spoonful of crude Cade oil has led to death (Koruk et al. 2005) or severe health problems. A 4-month infant was reportedly nearly killed after it was given an enema that rendered a severe lung oedema that needed intensive medical treatment (Rahmani et al. 2004). Overall the studies and reported adverse reactions show inconclusive evidence of its toxicity and caution is therefore recommended in using the tar.

1.4 Species of special interest

The following species are to be expected to be the most commonly used for medicinal tar production in Morocco. (Bellakhdar 1998)

1.4.1 Juniperus oxycedrus

Greyish evergreen dioecious tree up to 15m or more shrub-like. The leaves are needle like with two distinct light bands and a green central nerve on upper surface. Cones round, reddish and berry like 6-10mm in diameter, ripening in second year. Grows in mountainous dry areas, garrigue and maquis. The wood degrades slowly and is traditionally used for wood carving. The species can also be used for charcoal. (Polunin & Huxley 1976, Polunin 1976, Blamey & Grey-Wilson 1993, Tutin 1993)

Fig 1. Berries and needles of Juniperus oxycedrus. (picture by M.Julin

There are several subspecies of *J. oxycedrus*, some that are larger and some that are smaller, some that grow closer to the ocean and some that grow in higher places (Tutin 1993). This study has for the sake of practicality, as the Imazighen do not differentiate between them, chosen to treat them all as *J. oxycedrus*. The local berber name for the species is *Tiqqi* (Bellakhdar 1998). The Imazighen claim that if you cut branches from *Tiqqi*, it will not regenerate.

1.4.2 Juniperus phoenicea

Fig 2. Berries and leaves of Juniperus phoenicea (photo by M. Julin)

Evergreen small monoecious tree or shrub up to 8m. Gray-brown bark, flattened scaly triangular leaves in ranks of four or six. The cones are 8-14 mm, globule to egg-shaped, black in the first year but when they ripen in the second year the colour turns dark red. Grows mainly in dry hills (Polunin & Huxley 1976, Polunin 1969, Blamey & Grey-Wilson 1993, Tutin 1993). *J. phoenicea* is an important forest tree in Morocco (Blamey & Grey-Wilson 1993). The local name for the species is *Ar'ar* (Bellakhdar 1998).

1.4.3 Juniperus thurifera

Fig 3. Juniperus thurifera in the High Atlas Mountains. (photo by M.Julin)

A pyramidal tree 6-20 m, the cones are 7-8 mm and dark purple in the second year when ripe. Lance-like leaves 1-2 mm with a toothed border. Grows in limestone mountains. The tree is used for firewood and feral gracing (Tutin 1993, Polunin 1969). In Morocco it grows in the open woodlands of the Atlas Mountains from 1700 up to 3000 m elevation (Gauquelin et al. 1999).
Local names for the species are: *Adroman, Ar'ar* (Bellakhdar 1998).

1.4.4 Tetraclinis articulata

Fig 4. Cup made from the root of Tetraclinis articulata.(photo by M. Julin)

Resembles *J. phoenicea* but the cones are woody and have only four scales. In contrast to *J. phoenicea* the branchelets are flattened but the leaves are scaly and in ranks of four. Local names for the species are *Azoka* or *Ar'ar (*Bellakhdar 1998). Traditionally used for wood carvings in the Essaouira region on the west coast of Morocco. The species is considered near threatened by the IUCN redlist (IUCN 2007).

1.4.5 Cedrus atlantica

Fig 5. Cones and needles of Cedrus atlantica. (photo by C. Gurk; Wikipedia)

A large tree up to 40 m high with dark grey bark and evergreen 1-3cm blue-green needles. The cones are barrel shaped and brown-purple and 5-8 cm in length. Grows mainly on mountain slopes but is planted on lower altitude for its aromatic timber. The local name for *Cedrus atlantica* is *Lerz* (Bellakhdar 1998). From 1940 to 1982 Morocco lost 75 % of the Cedar forests (Terrab et al. 2006), and today Cedar forests represent only 2.3 % of the total Moroccan forest (Renau-Morata, 2005).

1.5 Objectives

The study will try to answer the following issues related to the production and uses of medicinal tar in the Marrakesh region:

- What are the actual uses of Moroccan medicinal tar?
- What species are used to produce medicinal tar?
- Do the different Moroccan medicinal tars contain any PAHs and therefore pose a threat to human health in Morocco?
- Can steam distillation of the crude tars change their composition?
- If the crude tars contain PAHs can the concentration be reduced or completely removed by steam distillation?
- One of the main focuses of the thesis is to propose further studies on Moroccan medicinal tar production.

2 Methods

2.1 Interviews

Semi-structured interviews were conducted in two periods. The technique involves interviews where the main body of questions are prepared in advance but alteration to these questions can be made during the interview to fit the situation (Martin 2004).

In the first period May 23 – 28 2006, 11 Herbalists in the Medina (old city) of Marrakesh were interviewed about their general knowledge of Cade oil. The second period was carried out between October and December 2006. Six additional herbalists were contacted and interviewed about the same questions as the ones from the first period. In addition to the herbalists, six producers willing to be interviewed were found in the High Atlas region around Marrakesh.

My colleague Madeleine Julin located 16 *ferraga*, traditional midwives/healers. The ferraga were interviewed about their usage of medicinal tars and also about their general knowledge of the products. Madeleine Julin conducted Ferraga interviews with a female interpreter. A man would probably not have been let into their houses, due to cultural taboos.

An identification survey was also held on May 30 2006 where 15 herbalists were asked to identify fresh plant material from *J. phoenicea* and *J. oxycedrus.*

Samples of the different types of tar were collected from producers and herbalists; and stored in glass bottles.

2.2 Hydro-distillation

For hydro-distillation a Clevenger type apparatus (fig 6) was used as described by the European Pharmacopoeia (1997). 15ml from two samples were hydro-distilled, i.e. boiled together with water and the resulting vapour was water cooled to yield a distillate. The samples were distilled for three hours and 5 ml of distillate was collected for further study with GC-MS.

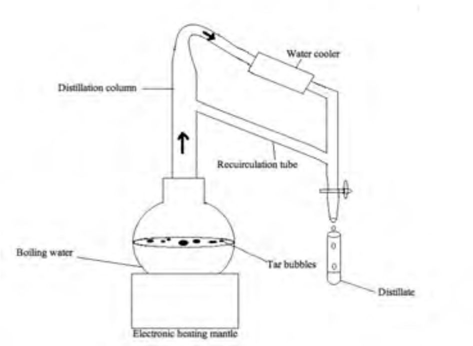

Fig 6. Clevenger type apparatus for hydro-distillation

2.3 Gas Chromatography/Mass Spectrometry

The medicinal tars and the two distillates were analysed using Gas Chromatography and Mass Spectrometry (GC-MS).

The GC was performed using an AgilentTechnologies 6890N (Wilmington, DE, USA) with 30m HP-5, 0.32mm id, 0.25µm solid thickness column.
Carrier gas (He) 1ml/min.
Injector temperature 275 °C, split 1/200
Temperature program: 60°C for 2min, +4°C/min to 280 °C, 280°C for 10 min.
The MS was performed on a Micromass GCT. Ionization EI+, 70eV. 33-800 amu, 2 scan/s
The tars and their derivatives were scanned for the following PAHs, (For PAH MS-spectra see Appendix II), all of which are components of mineral coal tar (Hughes et al. 1993):

- Benzo(a)pyrene
- Benzo ghi flouranthene
- Benzothiophene
- Benzo ghi perylene

- Dibenzo a,h anthracene
- Dibenzo def, mno chrysene
- Flouranthene
- Indeno 1,2,3-cd pyrene
- 1,2-dihydro-3-methyl-Benz [j] aceanthrylene
- 1-(2-naphtalenenylmethyl)-Naphtalene

3 Results

3.1 Species used

The main species named by producers as being used for medicinal tar production were *Juniperus phoenicea*, *J. oxycedrus* and *Acacia gummifera* (Table 1). *A. gummifera* is mentioned to be used when other species are unavailable. As opposed to Bellakhdar (1998) who only mentions conifers in the production of medicinal tar, addition of *Nerium oleander, Pistacia spp. Olea europaea* and *Eucalyptus globulus* was said to be used as sources when material is scarce. Surprisingly, *Cedrus atlantica* is mentioned by only one producer.

Table 1. Species used to produce medicinal tar as mentioned by six producers in the High Atlas region of Marrakesh.

Species (Moroccan name)	Species (Latin name)	Frequency	Respondent %
Ar'ar	*Juniperus phoenicea*	4	67
Tiqqi	*Juniperus oxycedrus*	4	67
Azuka	*Tetraclinis articulata*	2	33
Taddût	*Acacia gummifera*	2	33
Adruman	*Juniperus thurifera*	2	33
?	*Pistacia spp.*	1	17
Lerz	*Cedrus atlantica*	1	17
Zitun	*Olea europaea*	1	17
?	*Nerium oleander*	1	17
?	*Eucalyptus globulus*	1	17

3.2 Uses

Table 2 summarizes the use information gathered during the interviews. The most common answers amongst the respondents about the uses of medicinal tar were as a hair care product, as treatment for different skin ailments and for fumigation.

When used as a hair product, medicinal tar is often used together with other things to make up a hair product for a specific purpose. Most mixes contain olive oil and up to 30 different herbs.

In the category of skin treatment with medicinal tar, rashes, eczema and wound healing were mentioned and the treating method is topical application on the skin where the problem is located, either as pure tar or tar diluted with table oil.
Fumigation is when the medicinal tar is mixed with other ingredients to produce a thick smoke. The smoke is used to drive out evil spirits, to give good fortune and to heal from intrusions from evil spirits. It is either directly inhaled or spread out in the house or the area where it is needed.

Eight of the respondents mention that ferraga use medicinal tars for babies.
The use in pottery is by a traditional method where a line of medicinal tar is painted around the inside rim of a cup. The line is both a decoration and thought to be a disinfectant and insect repellent for the water kept in these containers.

In the countryside the use of medicinal tar is common in traditional veterinary medicine. This use is mainly for sheep and tar is utilised against intestinal parasites. It can be given to them in the fodder, for instance, by dipping the end of a corn cob in medicinal tar and feeding it to sheep or as a mixture with salt that is forced into the animals' mouth

Table 2. Actual uses of Moroccan medicinal tar as described by herbalists and producers (20 respondents) in Marrakesh and the surrounding High Atlas.

Uses	Frequency	Percentage
Hair	14	70
Skin	11	55
Pottery	9	45
Fumigation	9	45
Ferragas	8	40
Snake repellent	7	35
Animals	6	30
Black magic	6	30
Insect repellant	4	30
Water treatment	4	20

Out of 15 interviewed ferraga (one refused to be interviewed) only one claimed not to use medicinal tar. She reported that this was because: "Only people in hell use Gatran". The uses mentioned by the other informants were often limited to one or a few times in the treated persons life and only as a child. The purpose of the rituals was healing the babies from various problems believed to be caused by evil spirits, black magic or similar effects.

Ferraga claimed that only a small amount of medicinal tar was used each time. When asked where medicinal tars were placed on children the most common answers from Ferraga was around the nose and on the wrists. Two of the Ferraga mentioned using medicinal tar on the inside of the mouth, more specifically on the tonsils (Table 3).

Table 3. Uses of medicinal tar described by Ferraga (traditional female Midwives/healers) in Marrakesh and the High Atlas region.

Uses Ferragas	Frequency	Percentage
Nose	11	69
Wrists	10	63
Hands	8	51
Temples	8	51
Head	7	45
Ancles	5	33
Fontanelle	3	21
Feet	2	15
Tonsils	2	15
Ears	2	15

3.3 Production methods

Two main methods for the production of medicinal tar that work around the same principle were observed. The general principle for both processes is a pyrolysis, that is a partial anaerobic combustion. The main differences are the scale on which the medicinal tars are produced. One of the methods is used for small scale production that generates up to about 5 kg crude tar and the other is a large-scale version that will yield up to about

Fig 7. Large scale tar production unit.

30 kg. There were slight differences amongst the small scale producers, one could therefore argue that there are several distinct small scale versions but the principle is still the same and hence only one small scale model is considered in this thesis. Illustrations of the large and small scale models can be seen in figures 7, 8, 9 and 10.

One compartment is filled with plant material and covered with insulation material; the producer then starts a fire around the compartment. The result will be vapour, which leaves the compartment through a hole preferably in the bottom part. The resulting vapour then cools down and condenses in a new compartment. The resulting tar can when it is cooled be gathered and stored.

In the small scale model of the pyrolysis the upper compartment consists of a clay pot that is filled with the material. Between the upper and lower compartment a large clay plate is placed, the plate has a small hole in the middle where the vapour can escape to the lower compartment. This compartment is placed underground and the vapour condenses in to a clay, metal or glass container

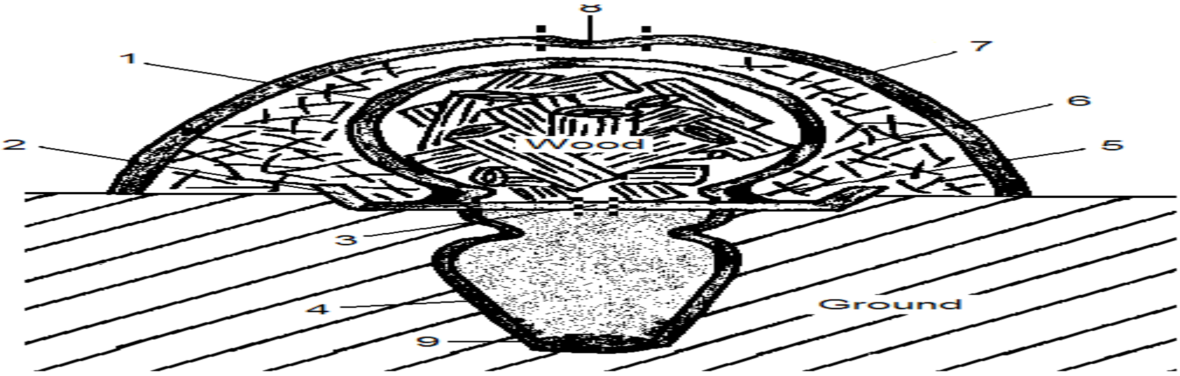

Fig 8. In the small scale model of the pyrolysis the upper compartment consists of a clay pot/metal container (1) that is filled with the material. Between the upper and lower compartment (4) a large clay plate (2) is placed, the plate has a small hole in the middle (3) where the vapour can escape to the lower compartment (4). The gap between the Clay pot/Metal container and the plate is filled with clay (5) to ensure that the vapour doesn't escape. The lower compartment is placed under ground and the vapour condenses in to a clay pot underneath the plate. The upper compartment is covered with firewood/straw(6). That is then covered in insulating clay (7) with a hole in it (8)for oxygen to reach the firewood. When the fire dies the tar (9) is ready to be collected. (Illustration by M. Julin)

underneath the plate. The upper compartment is covered with firewood and insulation with a small hole in the top to allow oxygen to reach the firewood. When the fire dies the tar is ready to be collected.

The large-scale model works, as mentioned earlier, around the same principles. Here, however, the upper compartment is a concrete tube placed partly underground. The tube is filled with the material and the topmost part is insulated with dirt and clay. The fire is lit in a semicircle-shaped hole around the concrete tube. A hole in the lower side of the tube leads the vapour down to an underground pit. The pit is about 2 m deep and in the bottom 30l of water is placed to aid in the cooling process. As an indicator to when the tar is ready, twigs from *J. phoenicea* are placed over a small opening in the roof of the pit. When the vapour that escapes from the pit has made the twigs black, the tar is ready. The tar is then collected from the walls and floor of the hole.

Fig 9: High Atlas village tar production site. Every mound is one production unit capable of producing 30l tar batches.

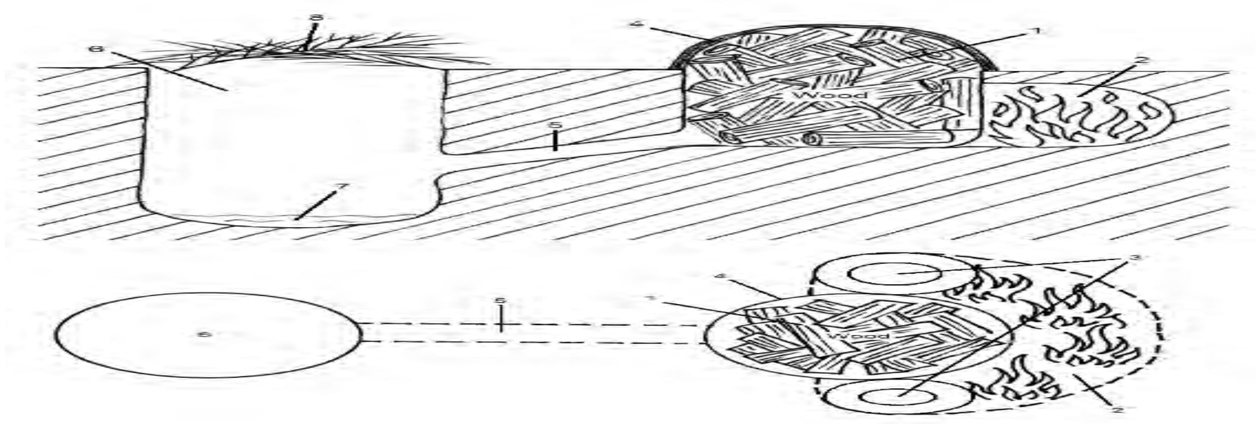

Fig 10. The large scale version of the pyrolysis. The upper compartment consist of a concrete tube where the material for the pyrolysis is placed (1). A fire is lit in a semicircular underground structure (2) around the compartment. The oxygen for the fire is let in though two holes(3) that connect to the semicircle The upper compartment is covered with a tarpaulin or old paper cement bags and insulated with clay (4). The resulting vapour passes through a pipe or just a plain tunnel in the ground (5). The vapour reaches the lower compartment (6) a large hole in the ground and is cooled down by the water that has been placed in the bottom of the pit (7). Twigs over the opening of the lower compartment (8) are used as indicators of when the process is done. When the twigs turn black the tar is ready to be collected. (Illustration by M. Julin)

3.4 General information

Both producers and herbalists mention possible admixtures, candidates mentioned are used engine oil, marjan (olive mill waste water) and vegetable oil.

The identification survey showed that none of the herbalists were able to identify fresh plant material of *J. oxycedrus* and 13 out of 16 identified *J. phoenicea* as *Ar'ar*, which is the common name for *J. phoenicea, Tetraclinis articulata* and *J.thurifera.*

The most common way to store medicinal tar is in plastic cooking oil bottles, and in a larger scale in used oil barrels. Small quantities for medicinal purposes are usually sold in glass bottles of 100 ml.

In one small village in the Demnat region in the High Atlas, approximately 100 km from Marrakesh, large amounts of tar was produced and distributed on domestic and foreign markets. One producer in this region, who also acted as a wholesaler, mentioned three separate buyers that bought 1000-2000 l each time and they came 5-15 times/ year. One of the buyers, a man from Spain, came 5 times/year and bought 2000 l each time and according to the producer, he exported the tar to Spain. The other two bought for local distribution within Morocco.

3.5 GC/MS

The GC-MS analysis shows none of the PAHs scanned for in any of the samples. This does not rule out that there are PAHs in the tars, only that the amounts could have been to small to measure with the chosen method. The analyses show that the distillates are different in composition from the original crude tars.

The Gas chromatograms from the various samples exhibited clear differentiation amongst some of the samples, which can be seen if you compare the gas chromatograms from fig. 11 with the one in fig. 12, an indication that they come from different species (see Appendix I for additional chromatograms). What species they are could not be established, however, due to lack of reference samples.

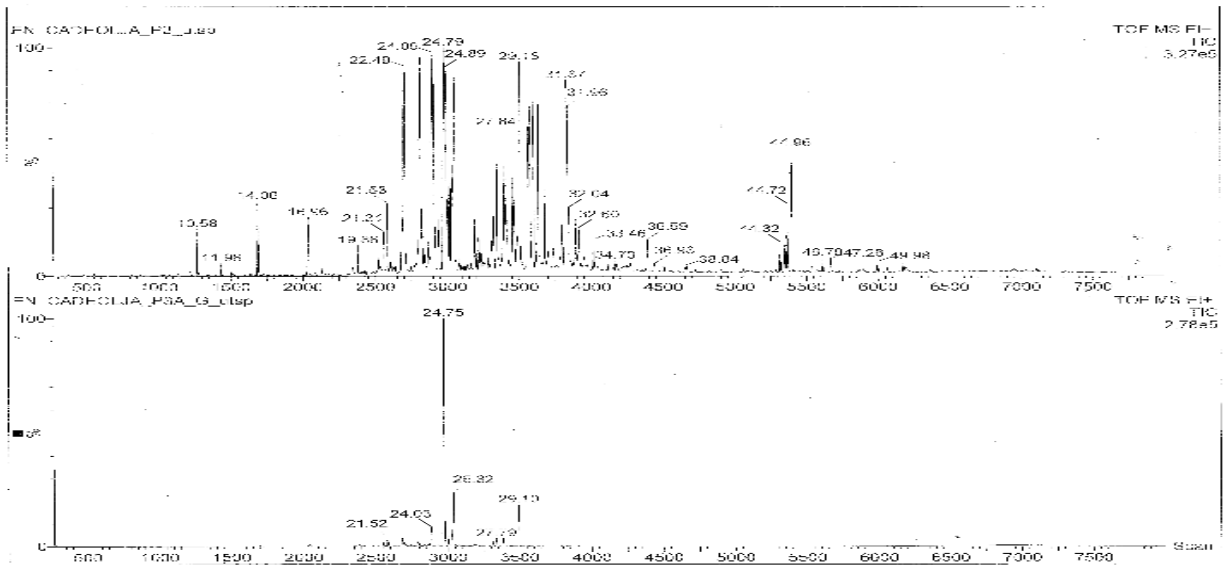

Fig 11. Gas chromatograms from a sample taken in the high atlas region. The GC was performed using an AgilentTechnologies 6890N with 30m HP-5, 0.32mm id, 0.25 µm solid thickness column. Carrier gas (He) 1ml/min. Injector temperature 275 °C, split 1/200Temperature program: 60°C for 2 min, +4°C/min to 280 °C, 280°C for 10 min. The top one represents the crude tar and the bottom one represents the hydro-distilled derivative. The composition is altered as can be seen over the whole scanning range.

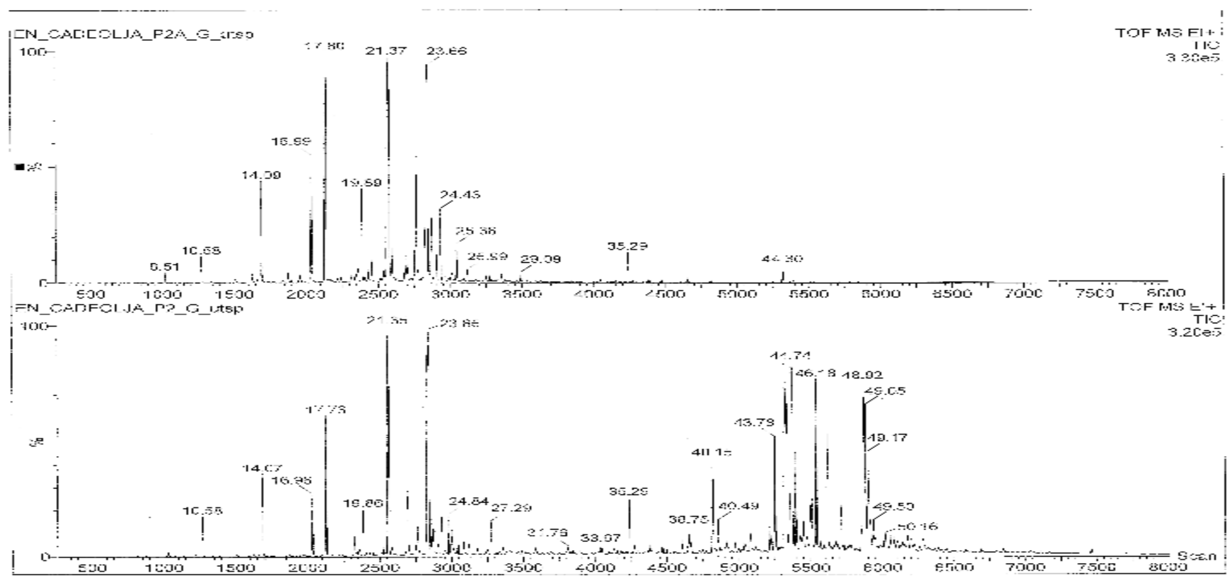

Fig 12. Gas Chromatograms from one sample collected from a producer in the High Atlas region. The GC was performed using an 6890N with 30m HP-5, 0.32mm id, 0.25µm solid thickness column. Carrier gas (He) 1ml/min. Injector temperature 275 °C, split 1/200Temperature program: 60°C for 2min, +4°C/min to 280 °C, 280°C for 10 min. The bottom chromatogram represents the crude tar and the top one is the hydro-distilled derivative. The composition is altered by the hydro-distillation as seen in the scanning interval 4000-6500s.

4 Discussion

This study clearly shows that medicinal tars are widely produced and used in the Marrakesh region The vast amounts of up to 50 000 l produced and sold in the small village in the Demnat area is a clear indication of this. What remains to be answered is the question whether the uses of medicinal tars are a threat to human health in Morocco.

Uses that involve application to skin and inhaling are two possible ways of getting DNA adducts mentioned by Shocket (1990). Table 3 shows that some of the most common uses are as a hair care product, on the skin and for fumigation. Both external uses cause direct exposure of mutagenic compounds and form a possible health hazard, although the extent to which such exposure and contact are a risk needs to be further investigated.

Adduct formation in lung tissue is an important factor when it comes to threats to human health. Fumigation, as described by the informants, is an important risk factor. In this process the medicinal tar is mixed with numerous other substances and ignited, to produce a thick smoke, it is used mainly for black magic but also as medicine. Large amounts of smoke are inhaled this way. The burning of the mixture may form PAHs from the incomplete combustion of any of the ingredients in the mixture, and practising this ritual is potentially a health hazard.

The traditional midwives or ferraga use medicinal tar on babies, a widespread use, with possible risks to the treated babies. One can argue that the babies are given such a small amount and only one or a few times in their life. But when dealing with mutagenic elements there usually are no determined threshold doses and even small amounts can lead to tumour formation (SCCNFP 1993). The direct use of medicinal tars on babies and infants should be considered as potentially harmful, and traditional use should be moderated until the risks and benefits are thoroughly assessed. Informing the Ferraga of this potential risk could be an important step in limiting possibleharmful effects.

However, the question if Moroccan medicinal tars are toxic is still an open one. The GC-MS analyses show no PAHs in any of the tars that were analysed. This does not rule out that there are any PAHs, as they could still be present in extremely small amounts. What can be the cause of this? One factor can be the large evaporation of smoke during the manufacturing process. The PAHs will in this scenario be in the fraction that escapes the final product. Moroccan medicinal tars need to be further analysed for toxic elements and effects. Evaluation needs to be done as soon as possible. Another reason for concern are the reported adverse reactions to medicinal tars. The adverse reactions may have been caused by admixture or adulterated tars, but as quality-control is difficult, it is probably wise to prevent possible exposure or incidents.

One more positive conclusion of this study is that none of the samples that we gathered contained any mixed-in used engine oil. This would clearly have shown levels of PAH as high as 1,5 mg/kg (Grimmer et al. 1981). This does not rule out additives, but only confirms that these particular samples were not mixed. There still may be admixtures at different times, and seasonal variation of ingredients, due to high retail demand or scarcity of raw material could occur.

Hydro-distillation obviously changes the composition of the tar. But since the GC-MS analyses came out negative for PAHs in both the crude tar and the hydro-distilled derivative, we do not know if they would cause the DNA adducts mentioned by Shocket et al. (1990). We can therefore not say whether or not the distillates are carcinogenic. Hydro-distillation as a refinement of the crude tars can therefore not be evaluated at this point. This does not rule out the method. It only states that further studies need to be done.

The difference in tar composition is also a medicinal question. The traditional Cade oil from *J.oxycedrus* has documented effect, but the tars from *J. phoenicea, J. thurifera, Tetraclinis articulata* and *Cedrus atlantica* are not as thoroughly analysed. In want of these medicinal facts one can only look at the research done on essential oils of the different species: The oil of *J. thurifera* is antimicrobial (Barrera et al. 2005). *J. phoenicea* subsp. *turbinata* has good antimicrobial activity in Sardinian genotypes (Cosentino et al. 2003). *J. oxycedrus* methanol extracts of Turkish origin, had inhibitory effects on the growth of 57 strains of 24 bacterial species in the genera of *Acinetobacter, Bacillus, Brevundimonas, Brucella, Enterobacter, Escherichia, Micrococcus, Pseudomonas, Staphylococcus* and *Xanthomonas*. In addition 11 *Candida albicans* isolates at a concentration of 31.25-250 micro g/ml were also inhibited (Karaman et al. 2003). *J. oxycedrus* oil has shown to be analgesic and anti-inflammatory (Moreno et al. 1998). Essential oils from *Tetraclinis articulata* have proven to be effective against various cancer strains in that it induces apoptosis. (Buhagiar et al. 2000).

The process of making medicinal tar is based on traditional knowledge, but the process needs to be refined if we are to have a safe Moroccan medicinal tar, safe to both the users and the producers. The large scale process will have to be made into a more efficient and clean one. Today a large amount of crude tar is lost due to evaporation; and the tar that is extracted is also very contaminated by soot particles and soil. Safety aspects also include the health of the tar producers who inhale large amounts of smoke each time they produce their products and in doing so also take in considerable quantities of soot. Soot, being a known source of a number of PAHs, is a known health risk to workers inhaling it in various industrial environments (Barfknecht 1983). Some kind of filtering device on the actual production site would change the levels of tar vapour inhaled. Another approach would be for the workers to use filter masks. But as the process usually affects the whole village the filtering will probably have to be on the production units.

If the Moroccan medicinal tar is a health threat it needs to be replaced or refined in a way as to not be harmful, without endangering the traditional livelihoods of the producers. To exchange the traditional product is a rather difficult task. First of all you need to make the producers see that the new product can be beneficial to them, especially economically. New production methods require a certain investment of both economical and time-consuming nature. If, on the other hand, the new product can be shown to generate a larger income than the original one it is not likely that the producers will object.

The next obstacle to pass is a very important one: How does one pass the new product on to the users? The steam distillate has a smoky odour, a factor that will make it easier to pass it on to consumers since the quality of the medicinal tars are, according to both herbalists and producers, determined by their smell. However, the colour differs from the original product, but positive marketing with messages that this is a clean product compared to the original medicinal tar, which proved to be dirty, may resolve that issue. Another possible way is to use anti-mutagenic compounds, that is, use the medicinal tars together with something that has a high quantity of anti-mutagens. This will probably be easier to pass on to the general public, as the use of herbal remedies apparently is common in Morocco.

There is one threat that is more acute than the health issue. Due to ever increasing consumption of firewood, charcoal and material for making medicinal tar, deforestation and following desertification are important environmental issues to address as quickly as possible (Julin 2007). Exchanging medicinal tars for an alternative product may be one of the ways to lower the threats to the Moroccan environment, but the subsistence of the producers must not be jeopardized.

The crude Moroccan medicinal tars are mentioned to be exported to Spain. But what happens with them as they get there? The main hypothesis is that they are rectified and sold as Cade oil. This suspicion comes from the fact that Spain is an exporter of Cade oil but the resources are unavailable in Spain. *Juniperus oxycedrus* is included in the Red Book of Threatened Wild flora of Andalusia as endangered and in the Red List of Spanish Vascular flora as critically endangered (Redondo & Saavedra 2004). What difficulties can this lead to? Firstly the tar exported from Morocco is very likely not from *J.oxycedrus*, as the dominating trees in the area are *J.phoenicea* and only a few specimens of *J.oxycedrus* were found in the location mentioned by the producer. The companies selling the tar under the name Cade oil are therefore selling a product that is not thoroughly tested for content, and not to mention safety and efficacy, and at the same time they are not acting in an ethical way in as they are indirectly responsible for reducing the stands of important forest trees in Morocco.

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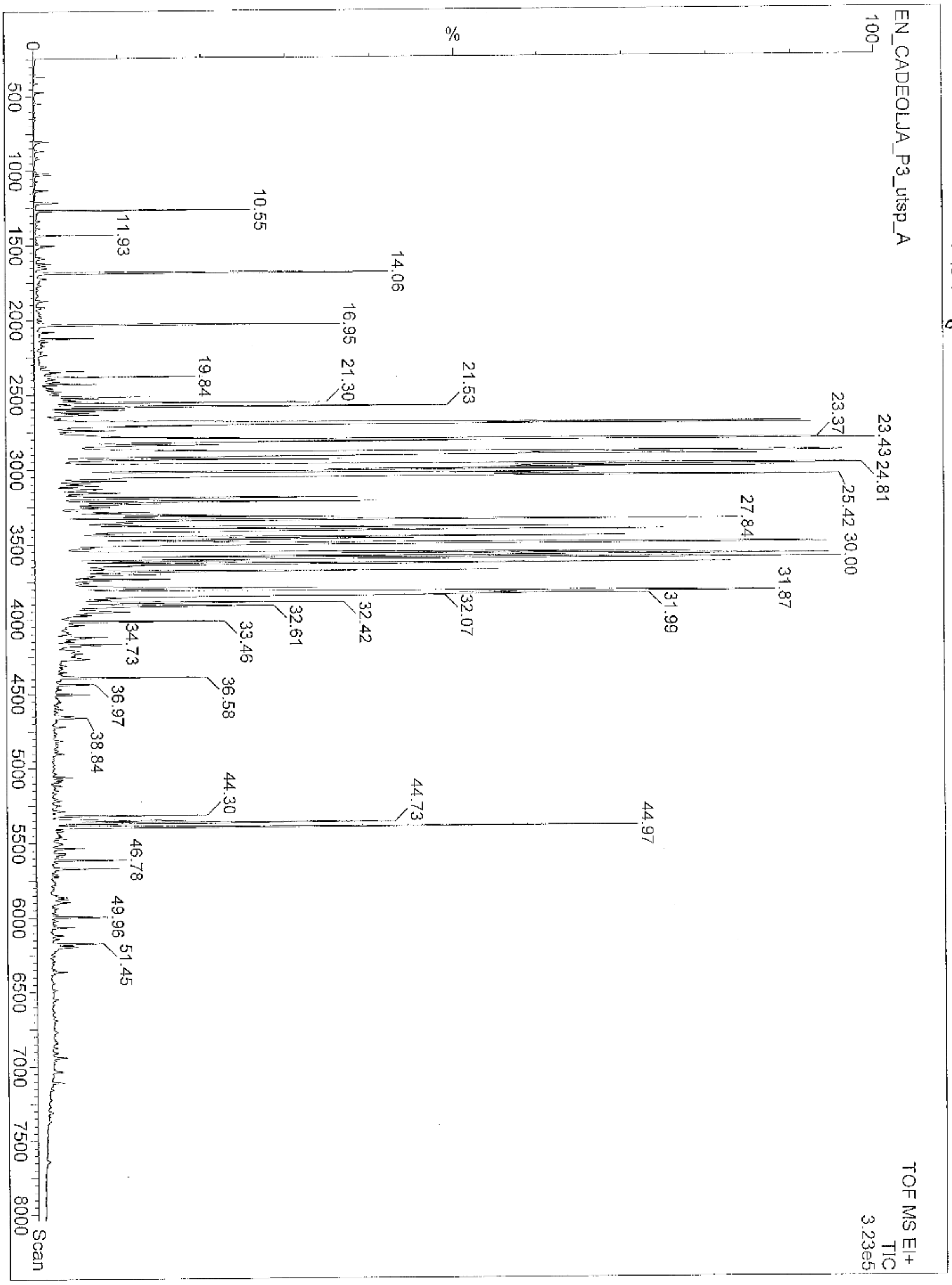
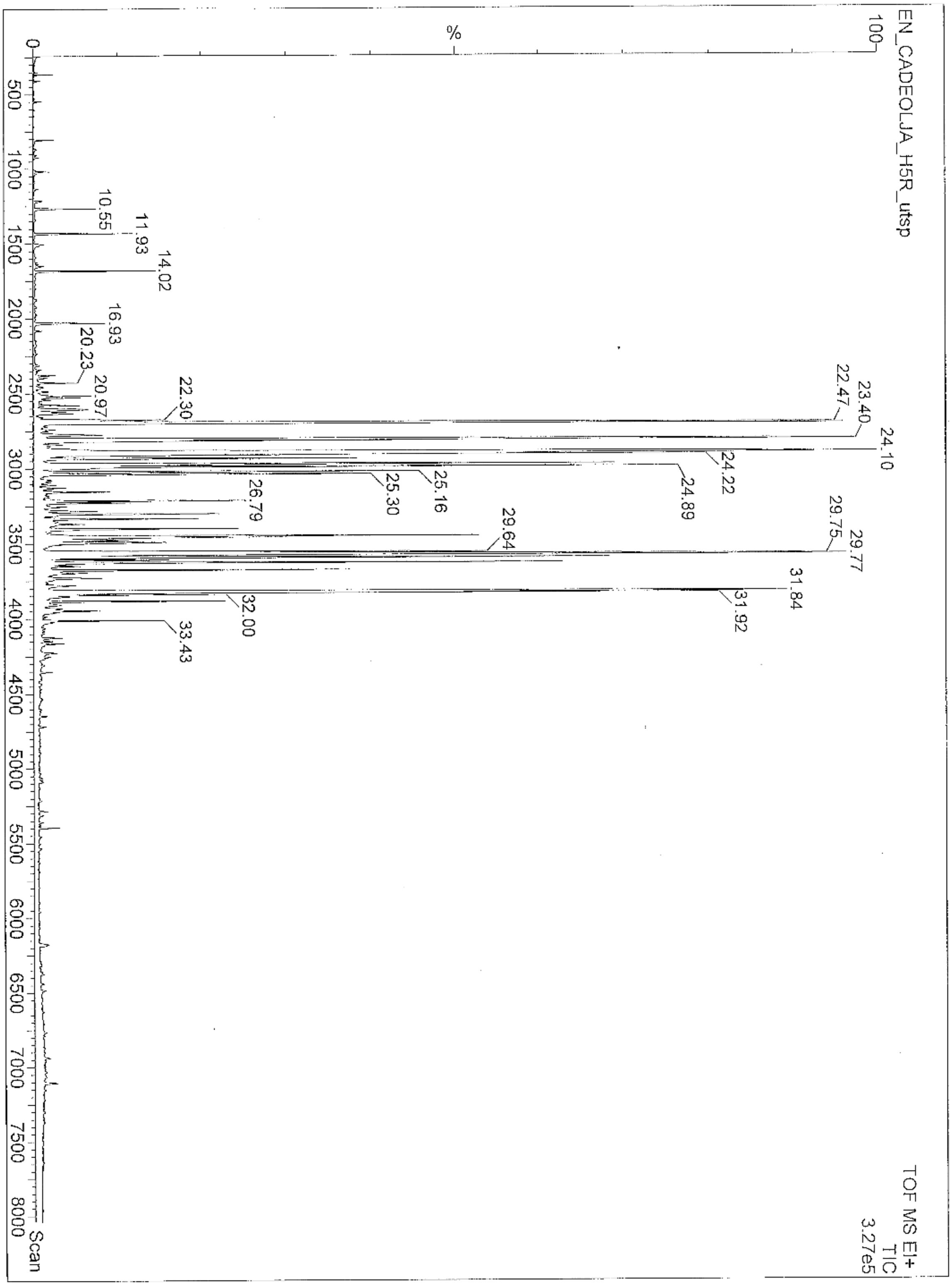
Appendix I: Gas Chromatograms

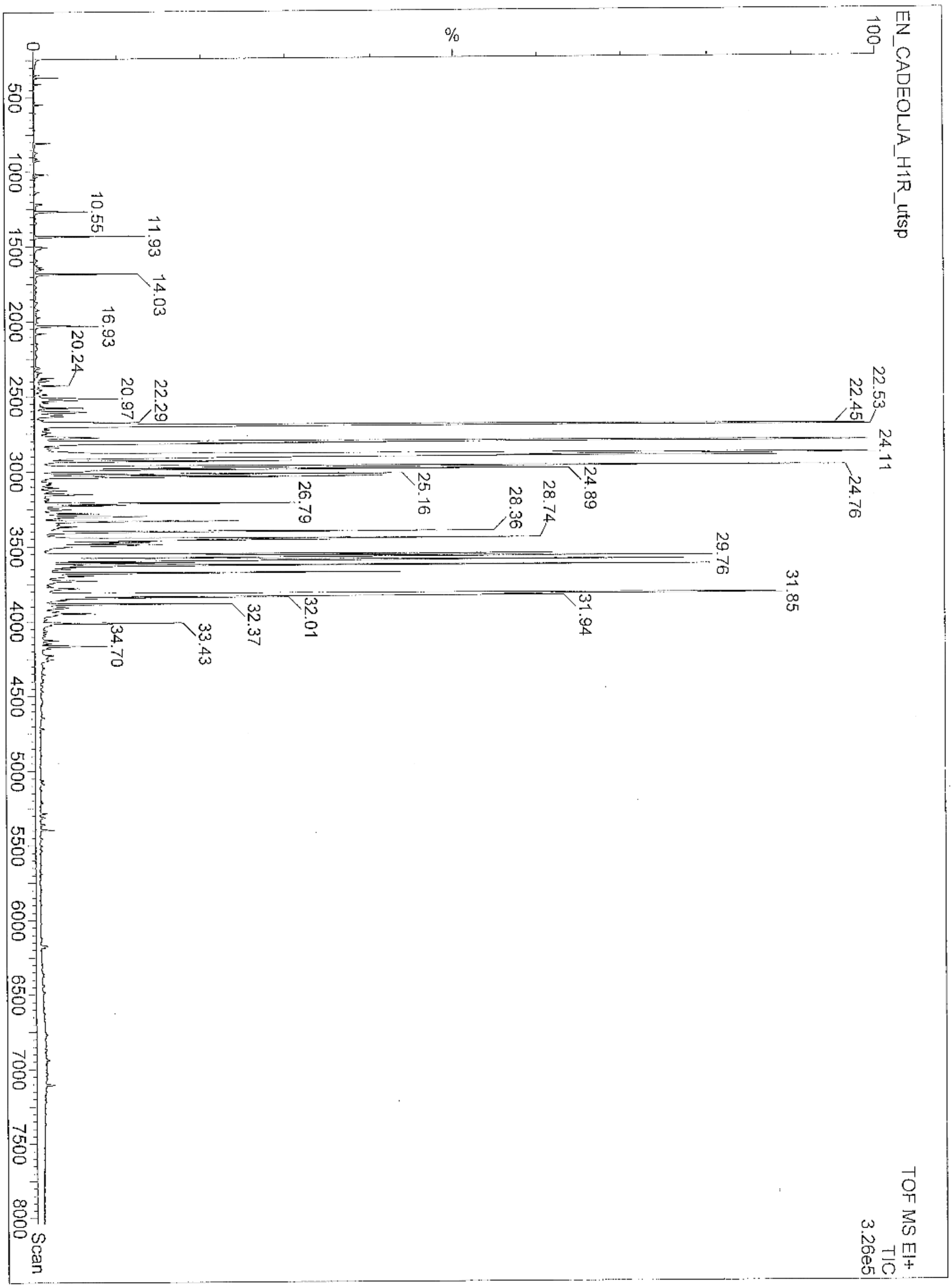


Sample collected from producer in the High Atlas Mountains Source is probably J.oxycedrus.

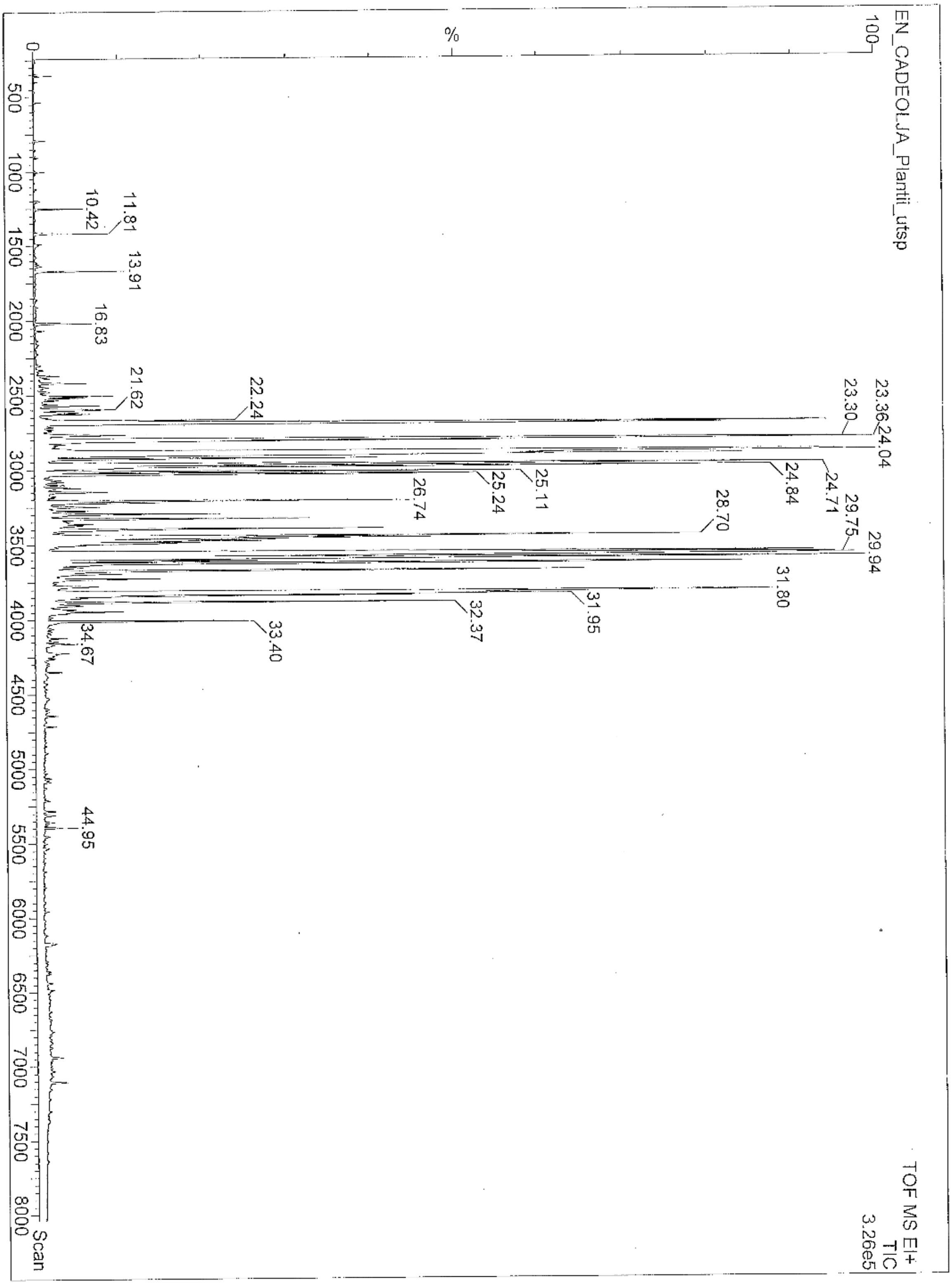
Appendix I



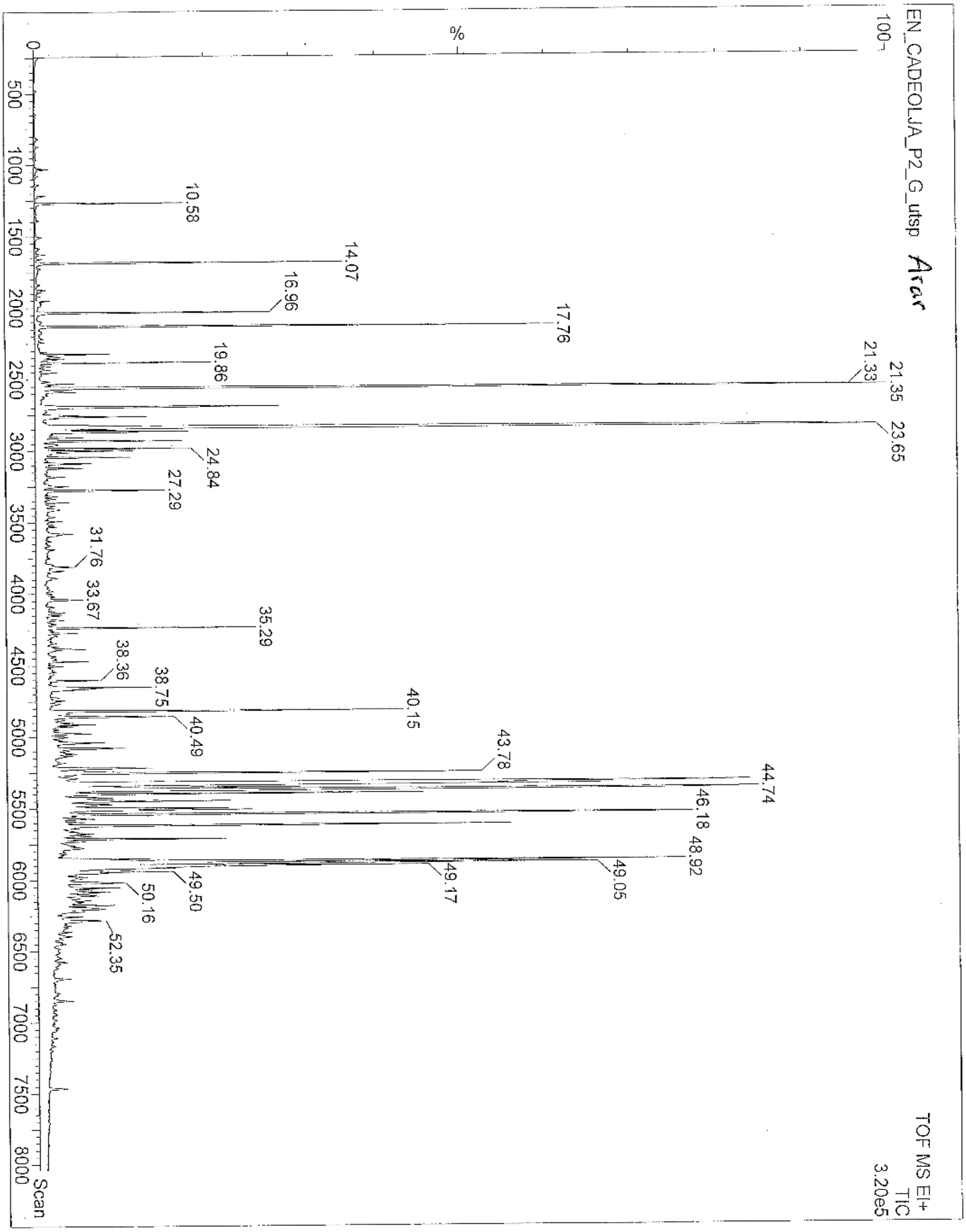
Sample collected from herbalist in Marrakesh.



Sample collected from herbalist in Marrakesh.

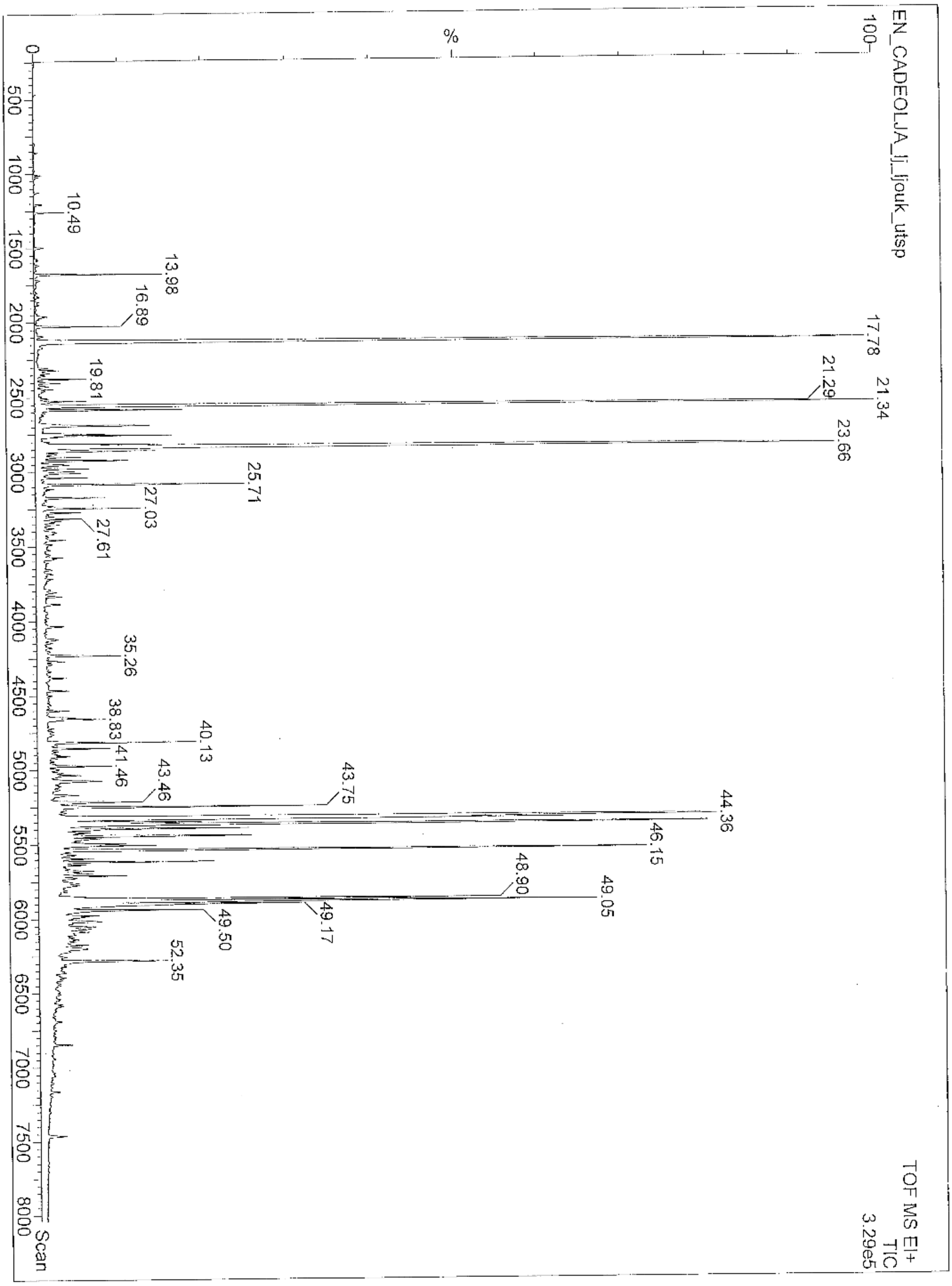


Commercial sample from herbalist.

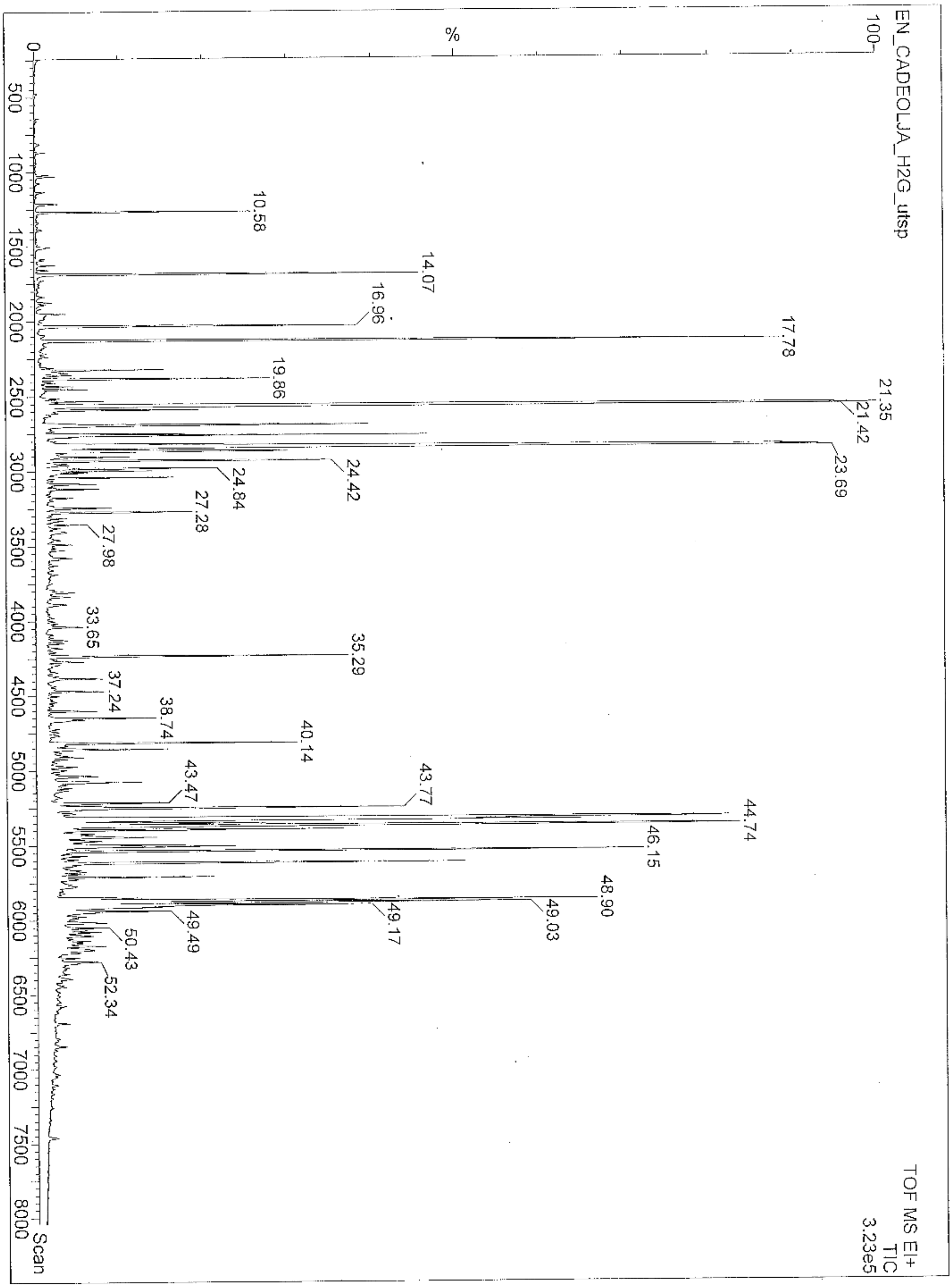


Sample collected from producer in the High Atlas Mountains. Source is probably J.phoenicea or T.articulata.

Appendix I

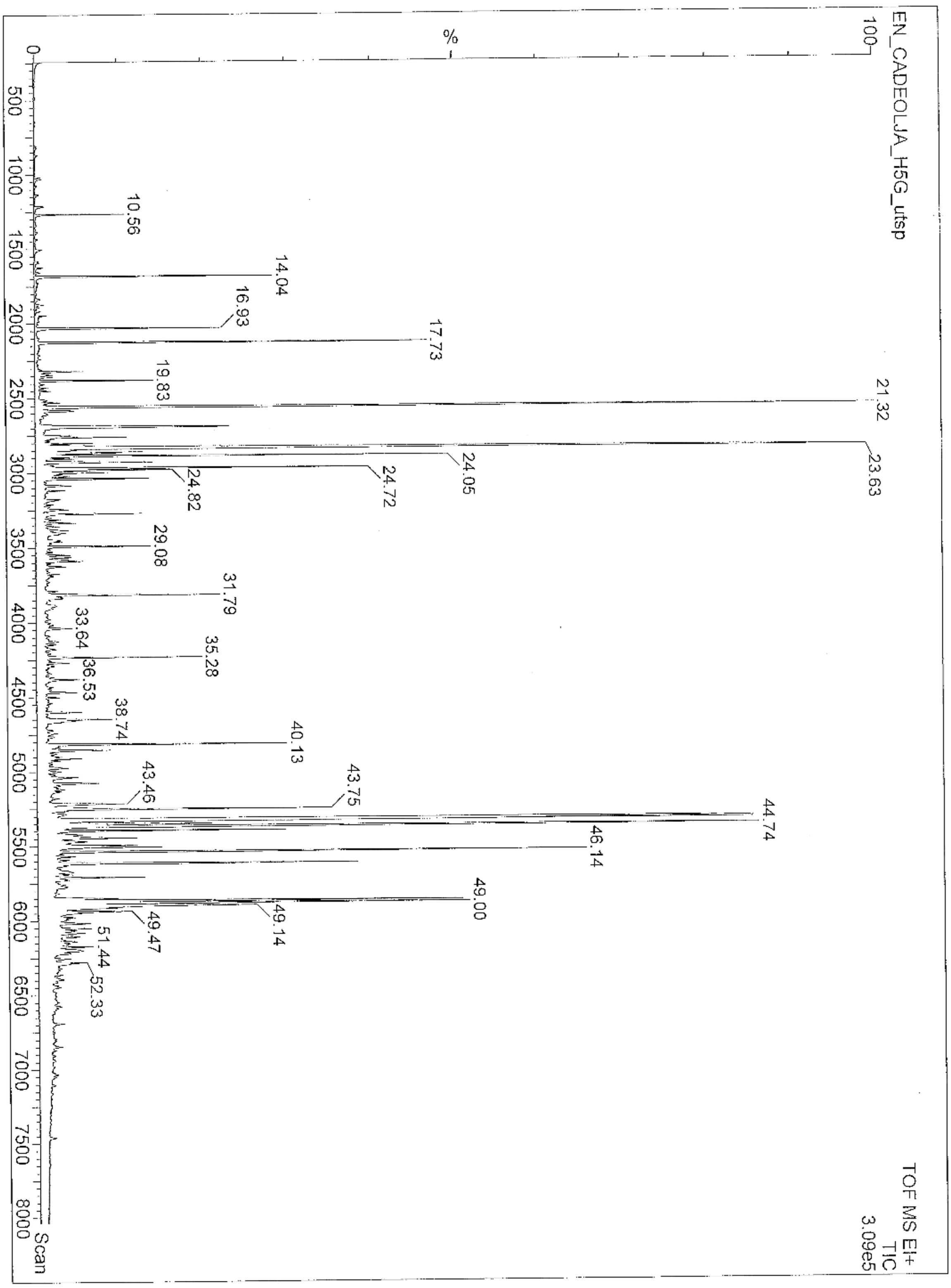


Sample collected in Ijoukak.

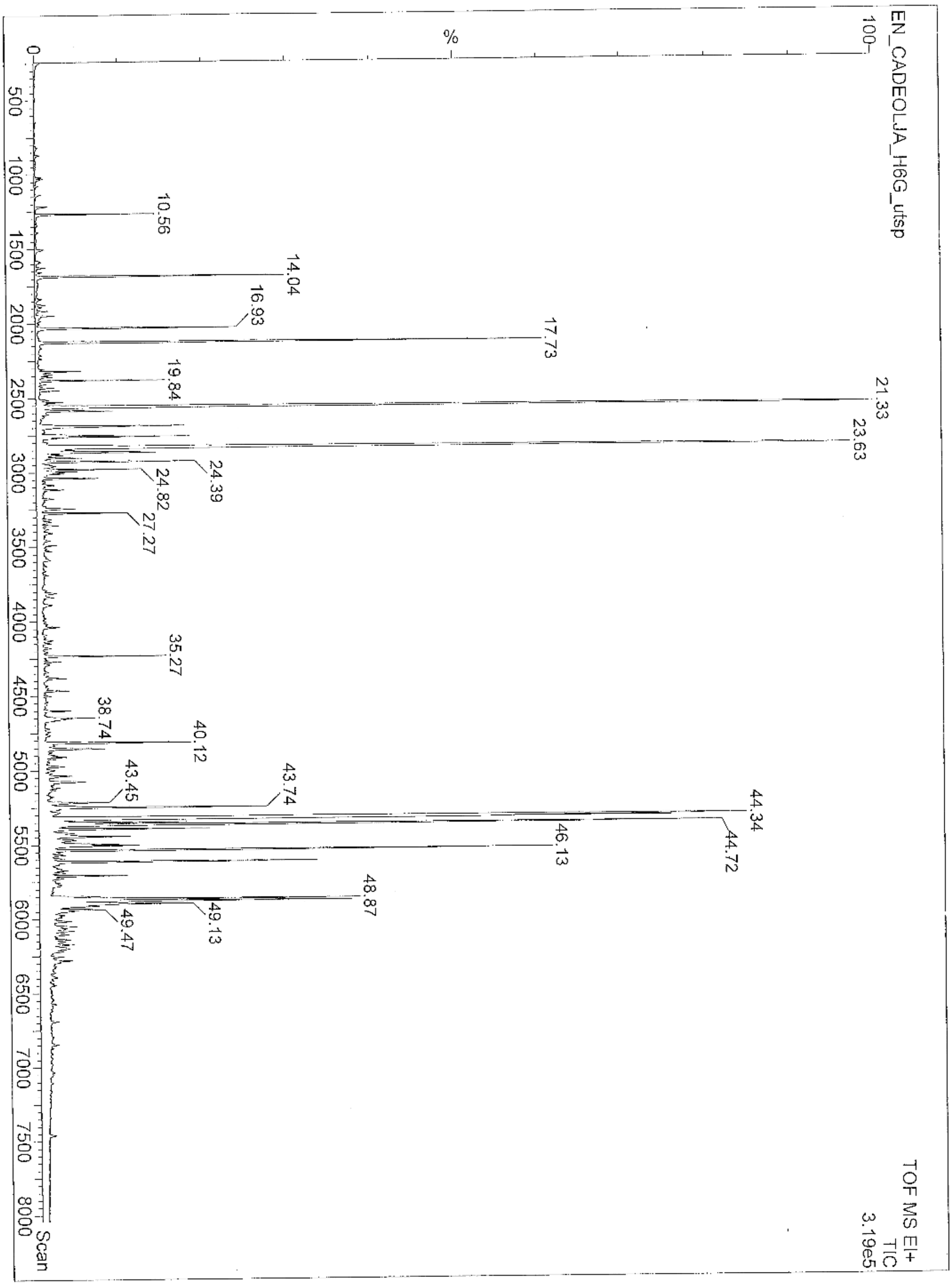


Sample collected from herbalist in Marrakesh.

Appendix I

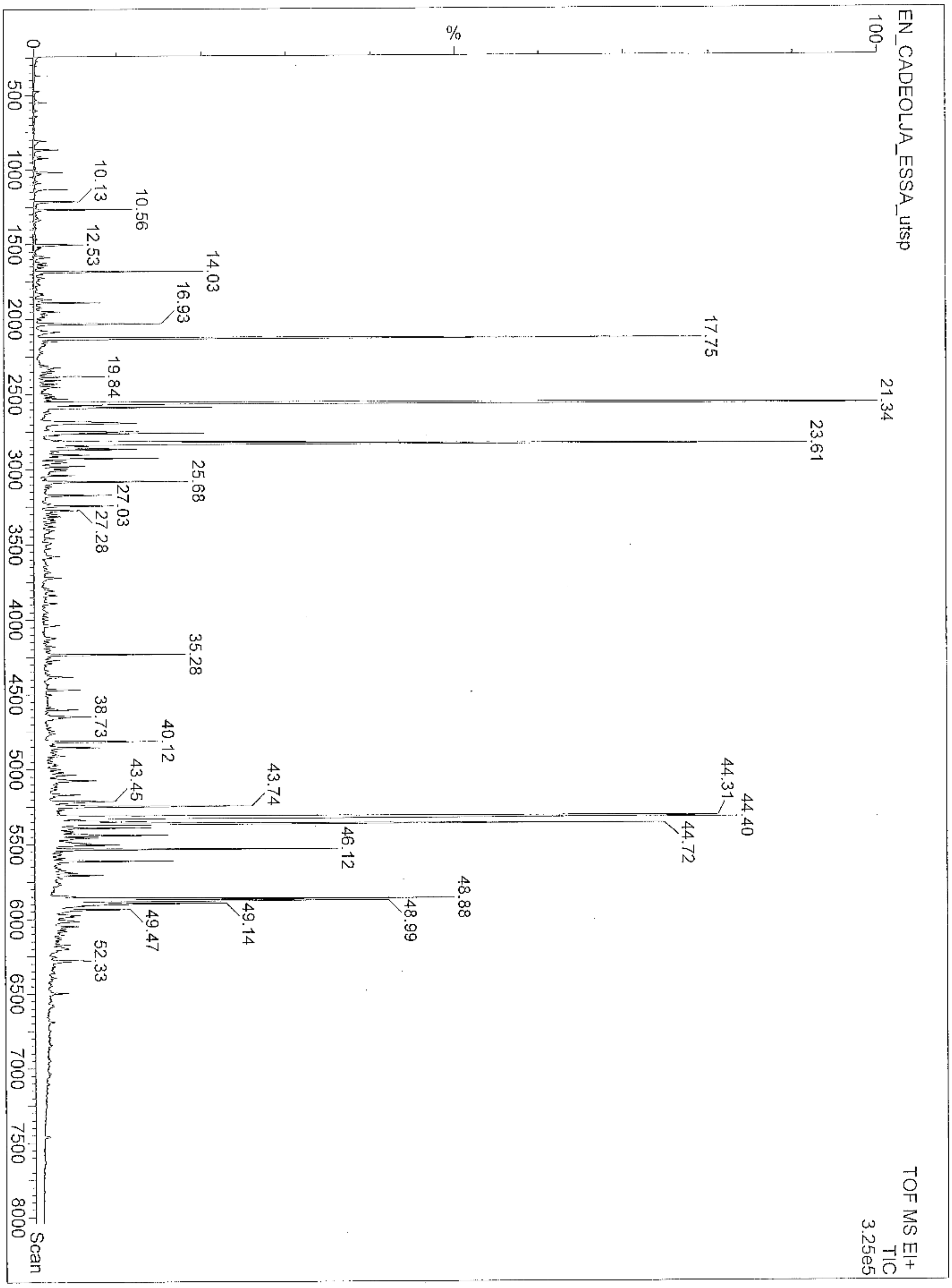


Sample collected from herbalist in Marrakesh



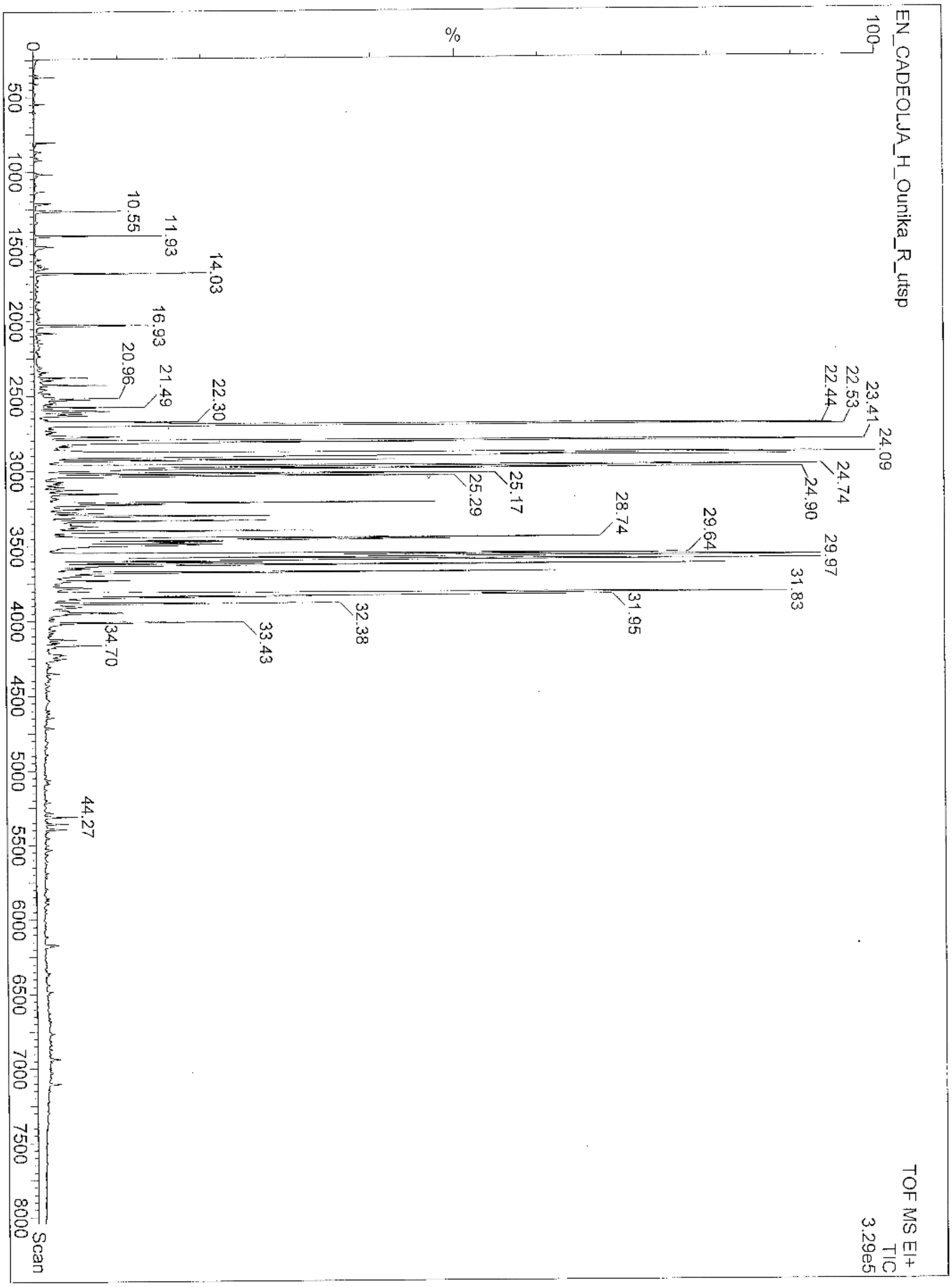
Sample collected from herbalist in Marrakesh.

Appendix I

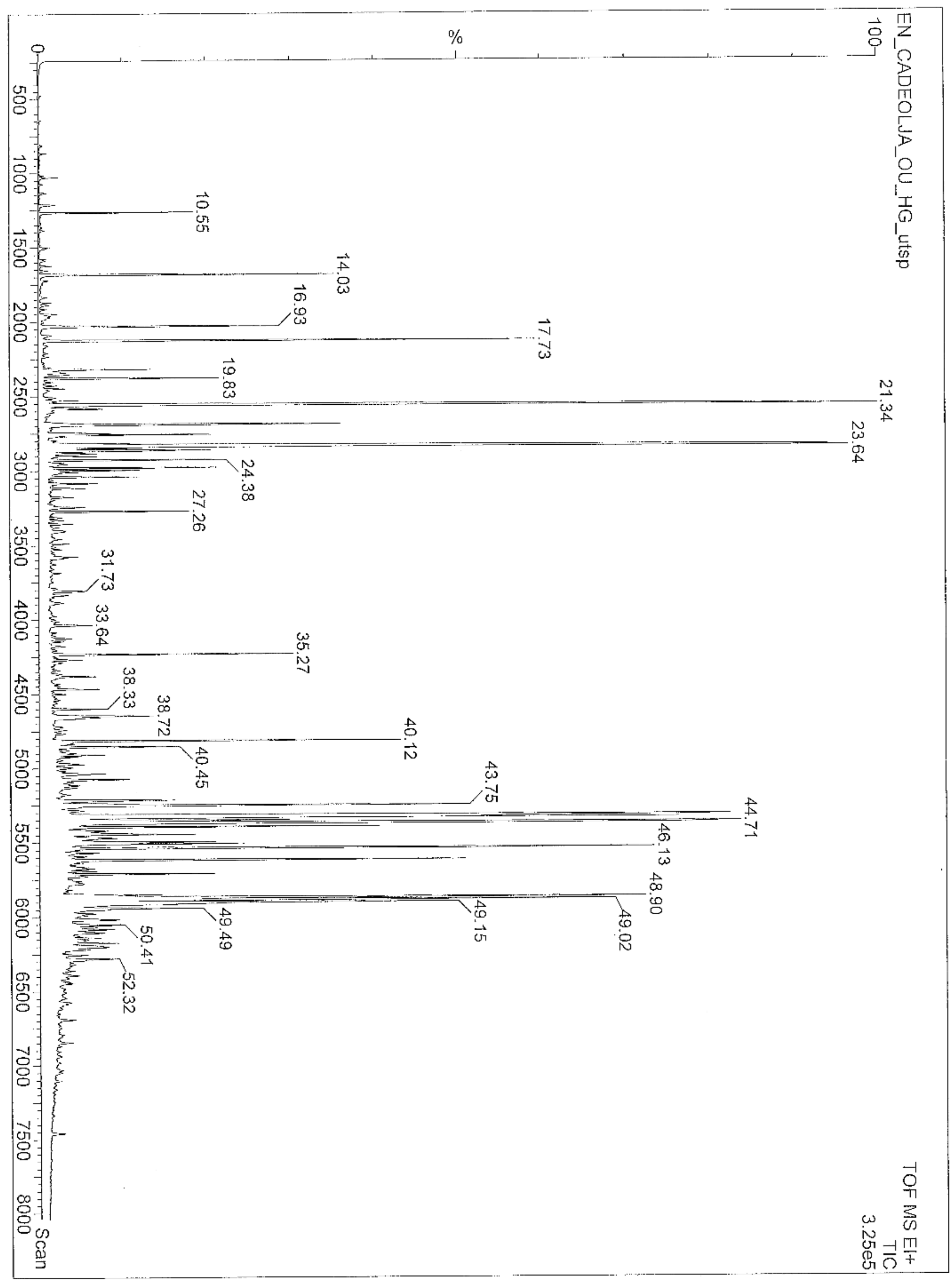


Sample collected from herbalist in Essaouira.

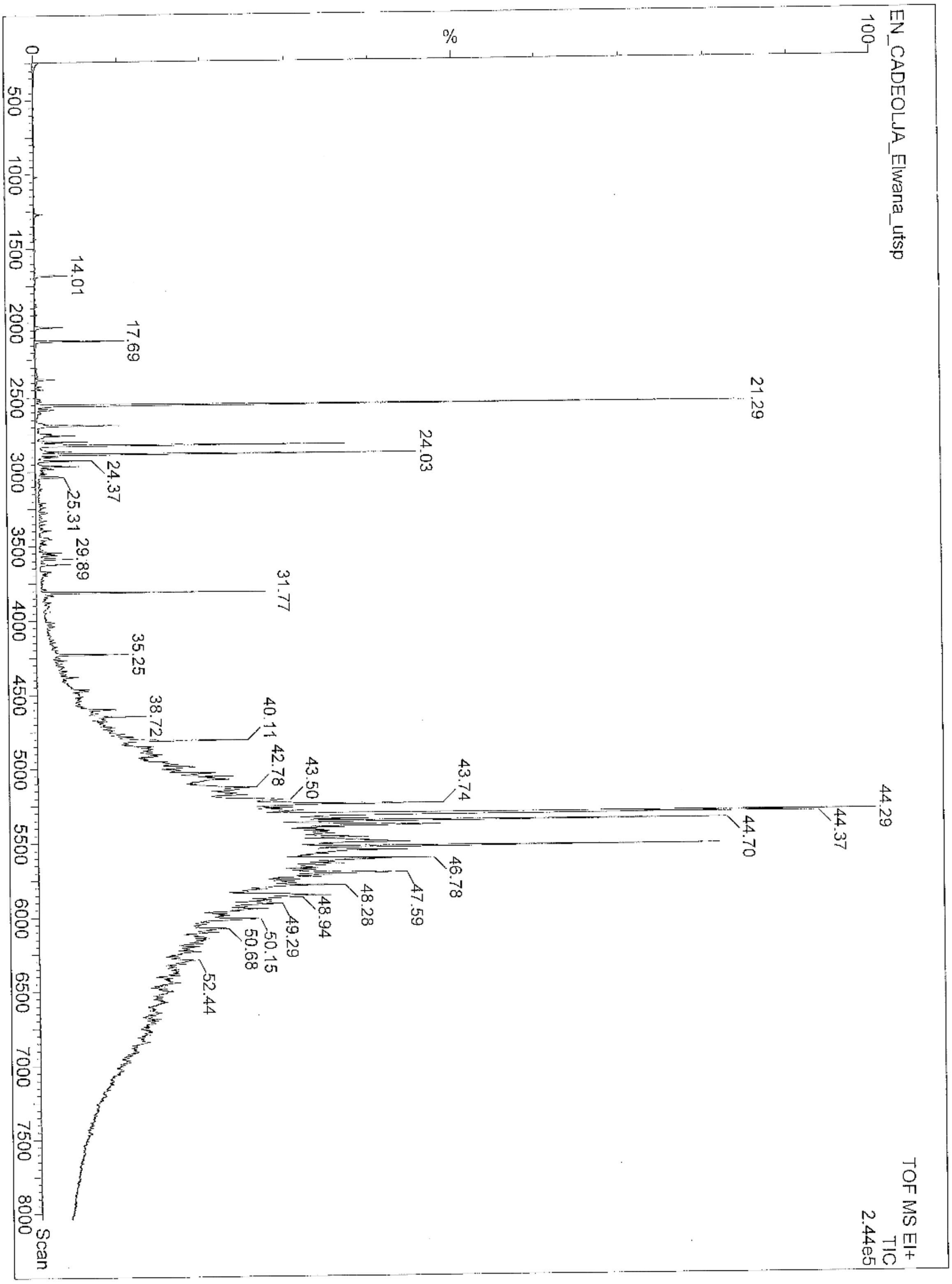
Appendix I



Sample collected from herbalist in Ourika.

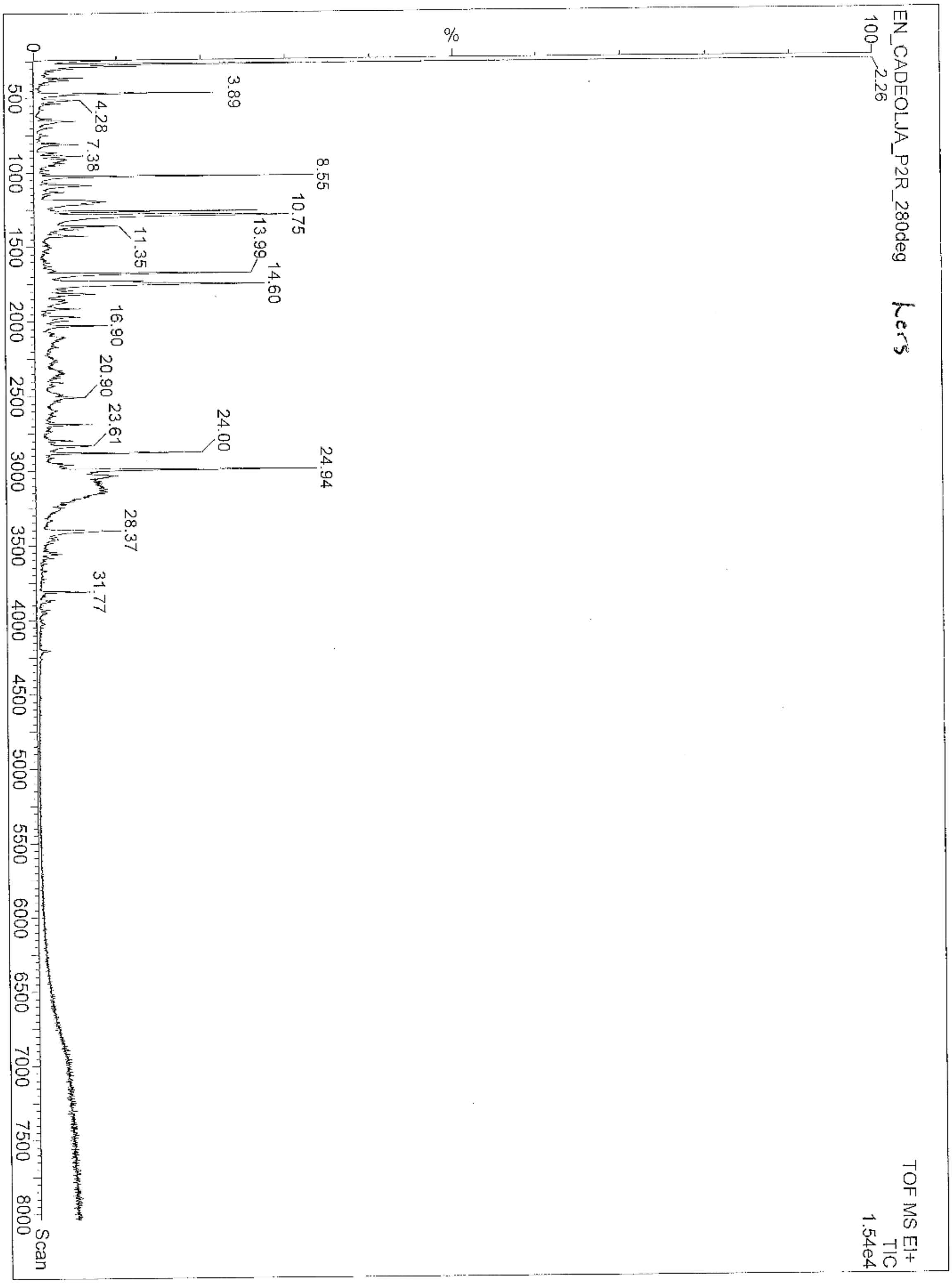


Sample collected from herbalist in Ourika.



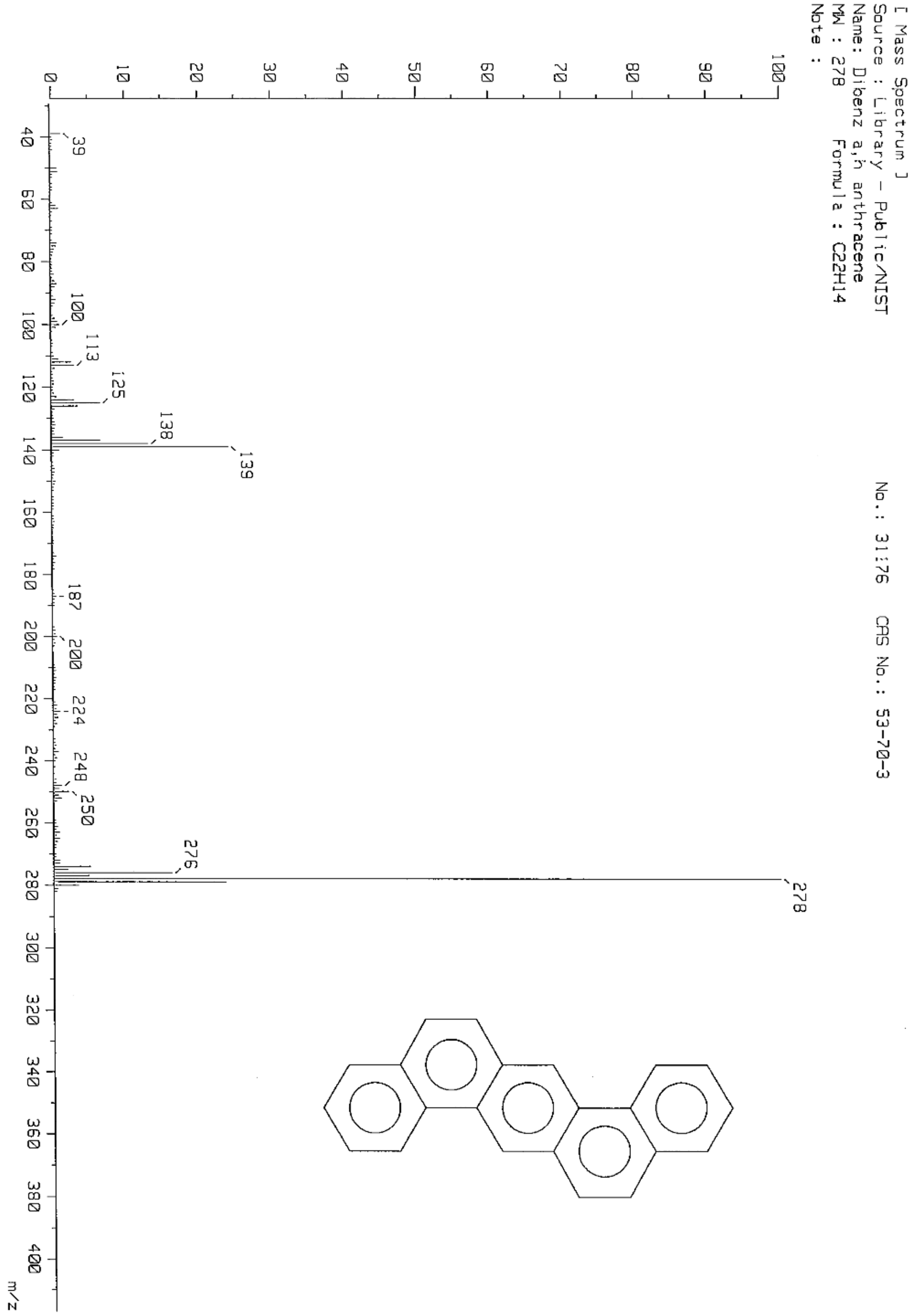
Commercial tar/vegetable oil mix collected in Essaouira.

Appendix I



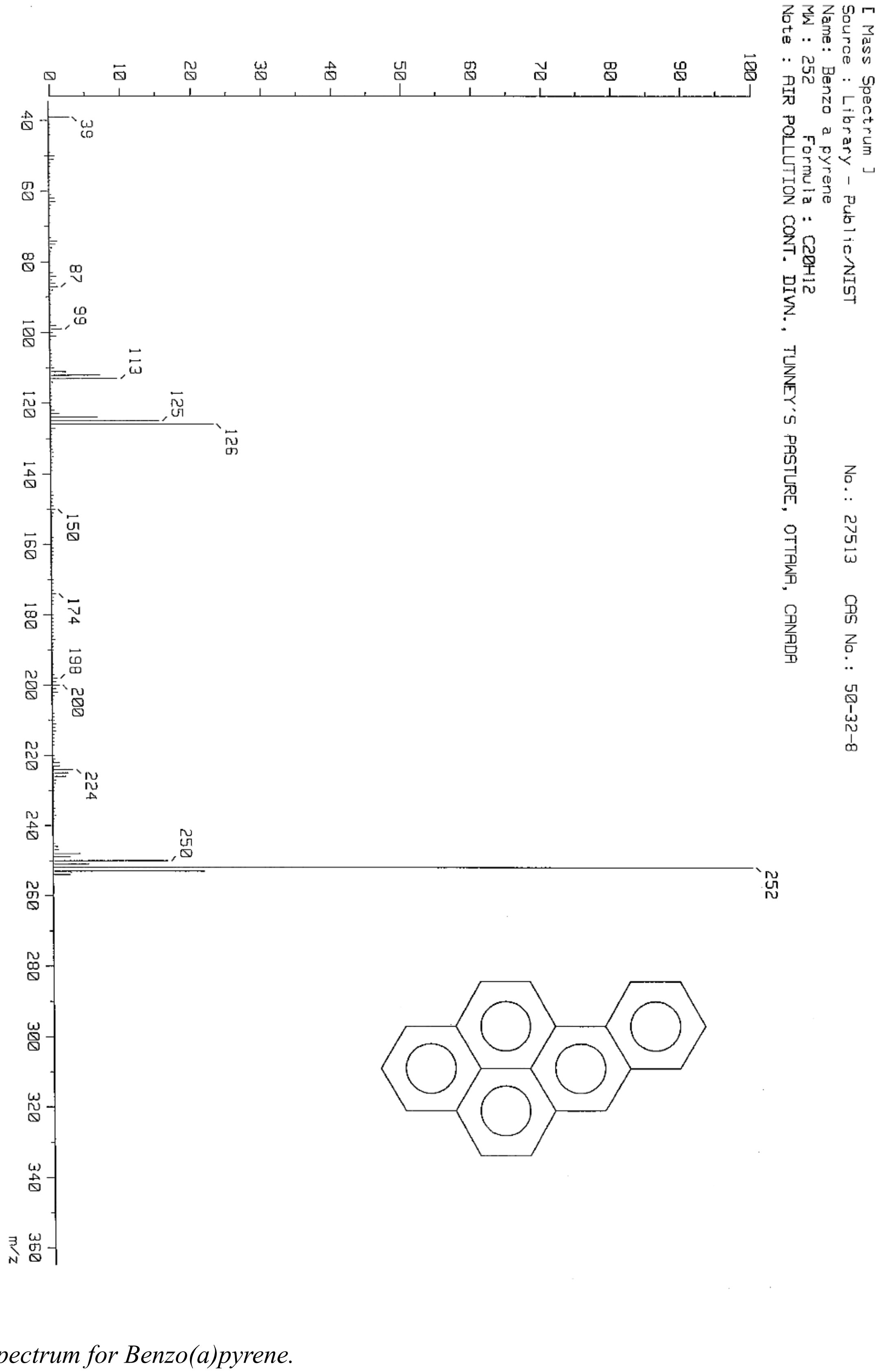
Sample from producer, probably from C.atlantica.

Appendix II: PAH Mass spectra



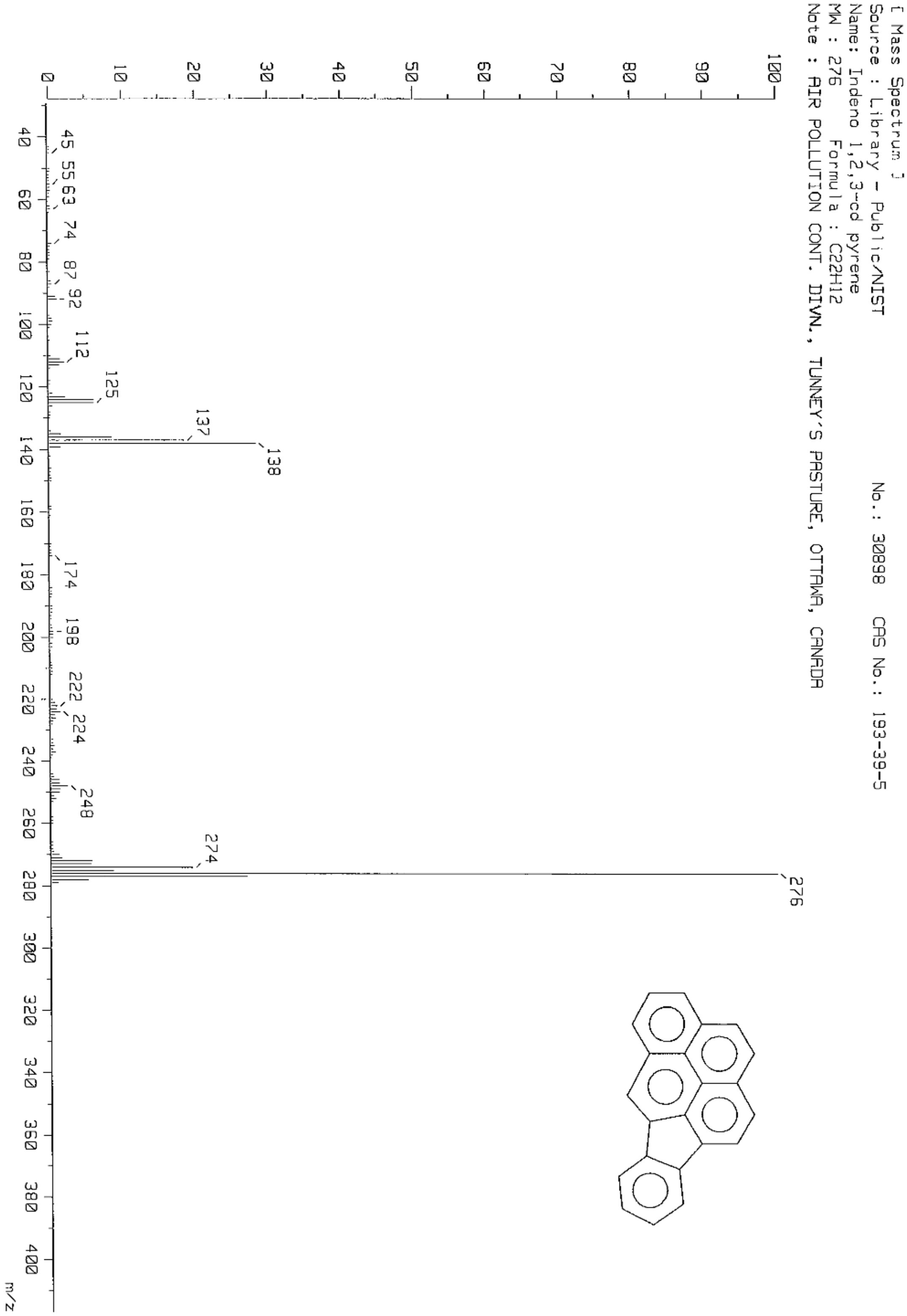
Mass spectrum for Dibenzo a,h anthracene.

Appendix II



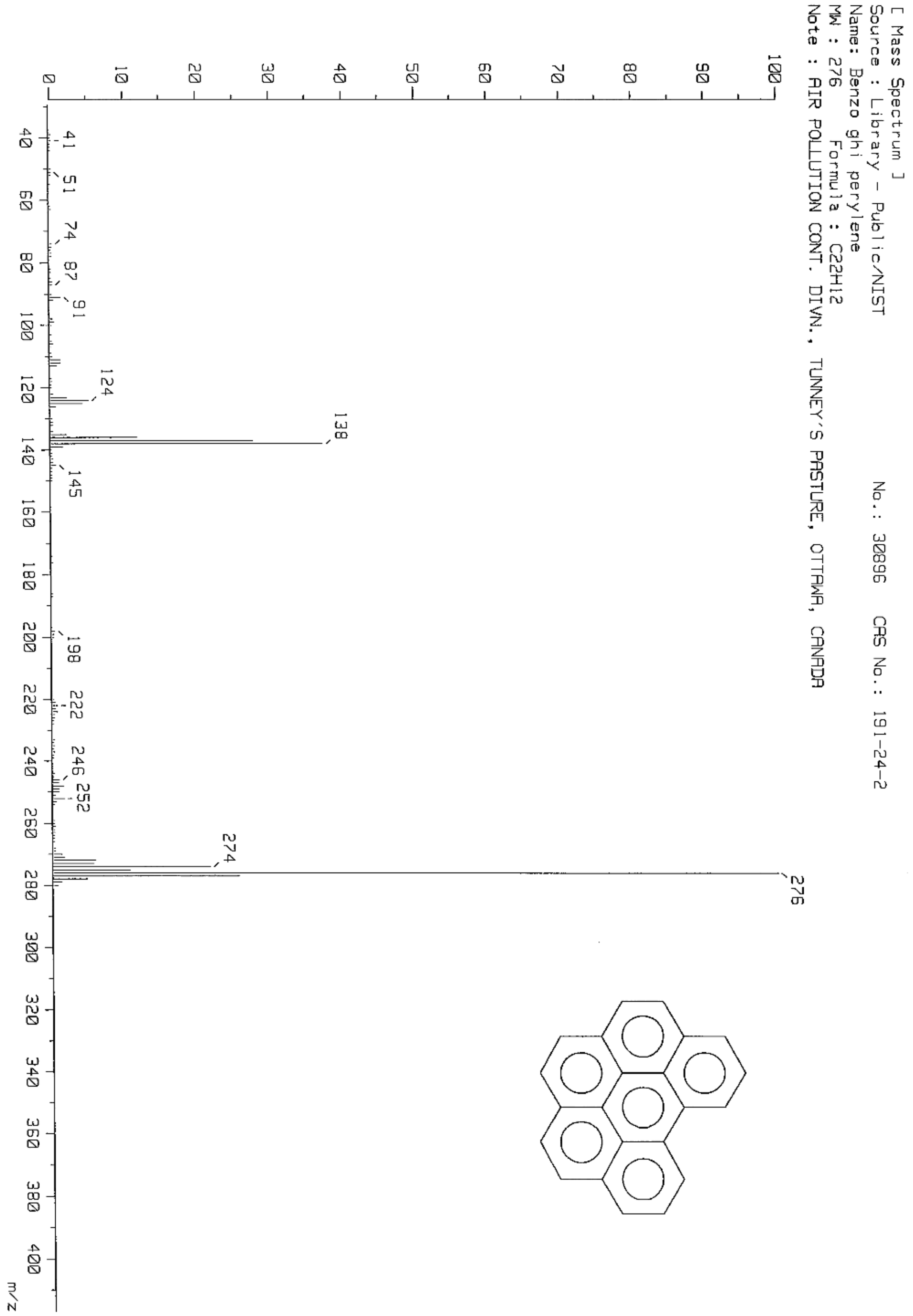
Mass spectrum for Benzo(a)pyrene.

Appendix II



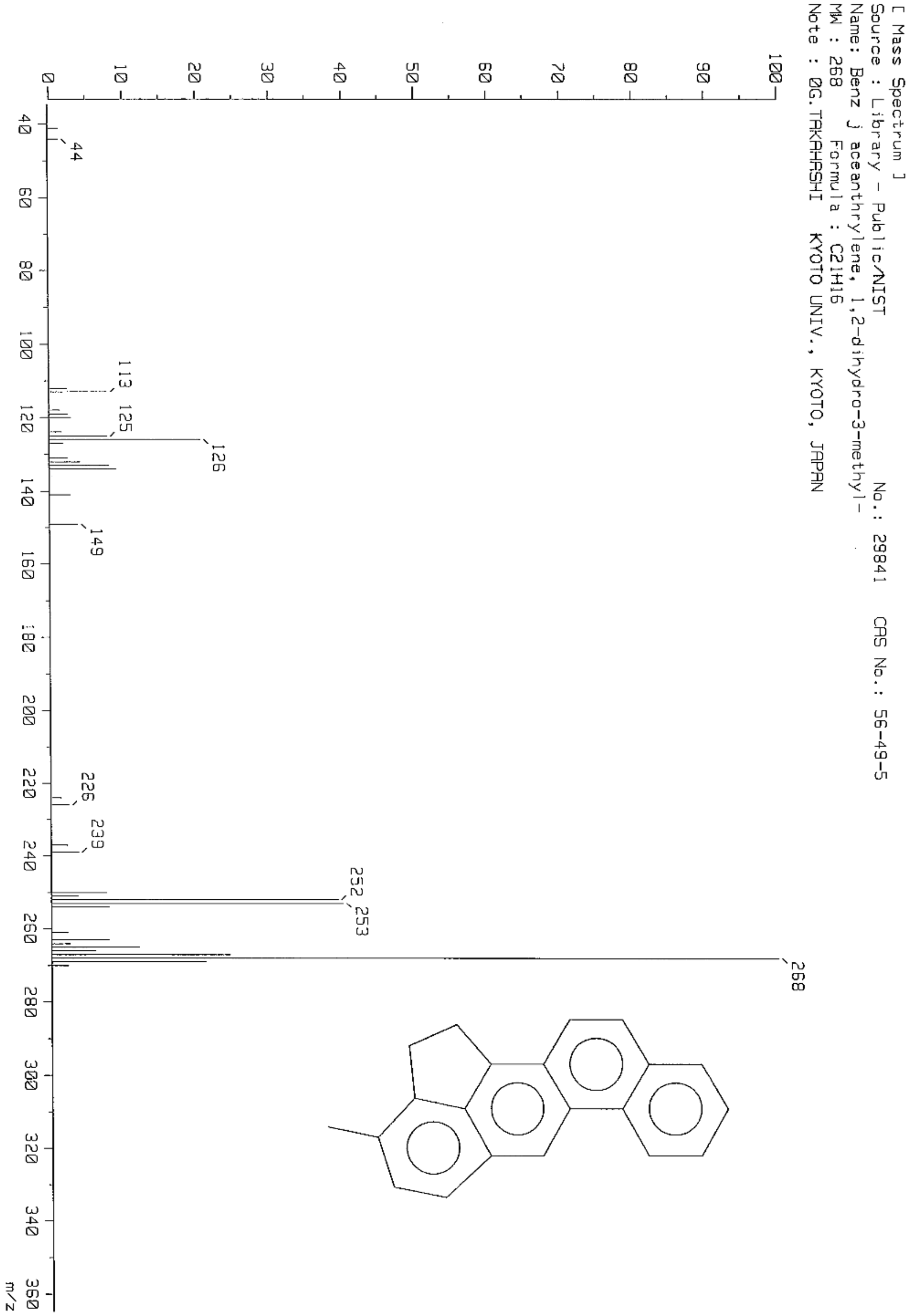
Mass spectrum for Indeno 1,2,3-cd pyrene.

Appendix II



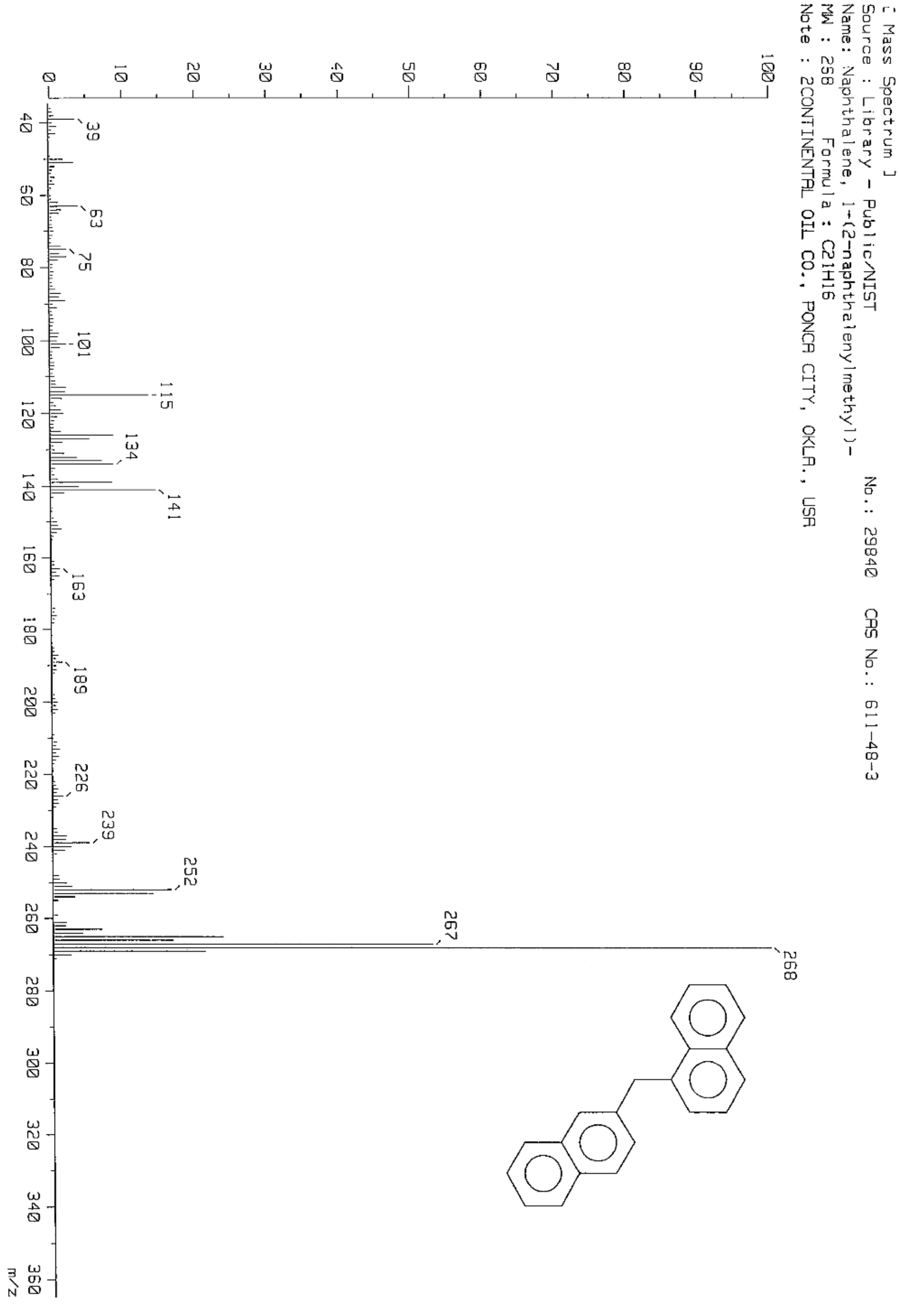
Mass spectrum for Benzo ghi Perylene.

Appendix II



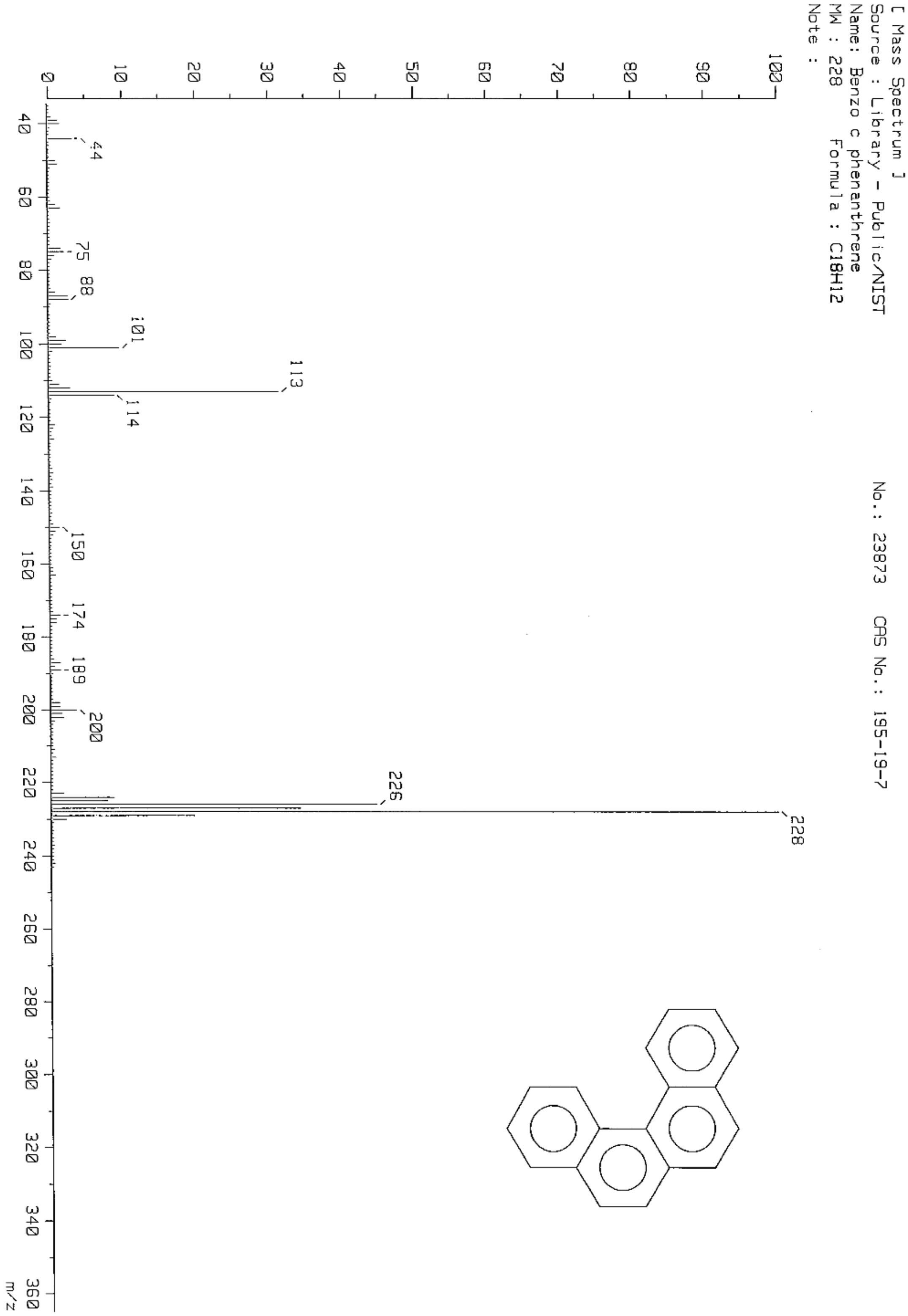
Mass spectrum for 1,2-dihydro-3-methyl-Benz [j] aceanthrylene.

Appendix II



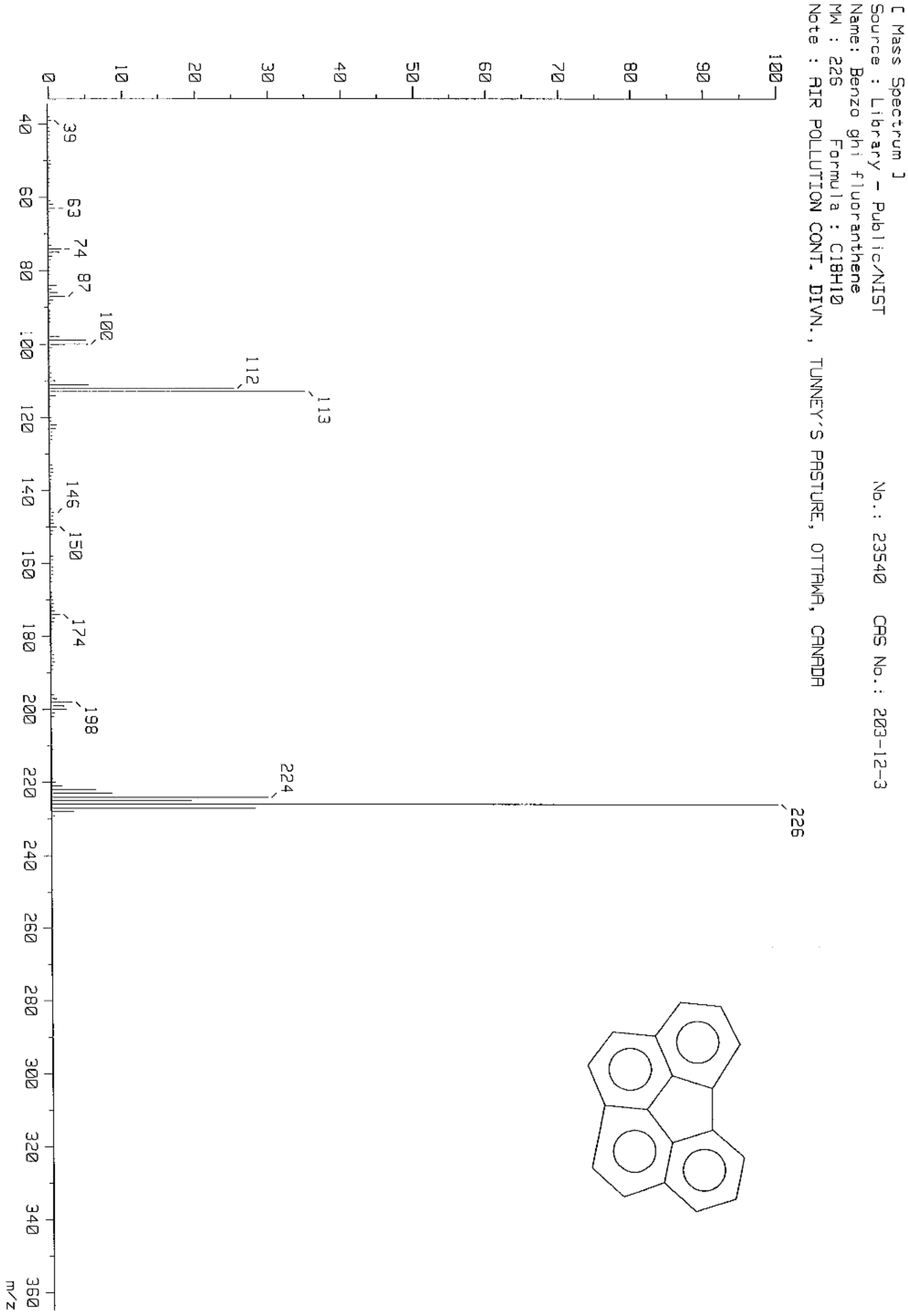
Mass spectrum for 1-(2-naphtalenenylmethyl)-Naphtalene.

Appendix II



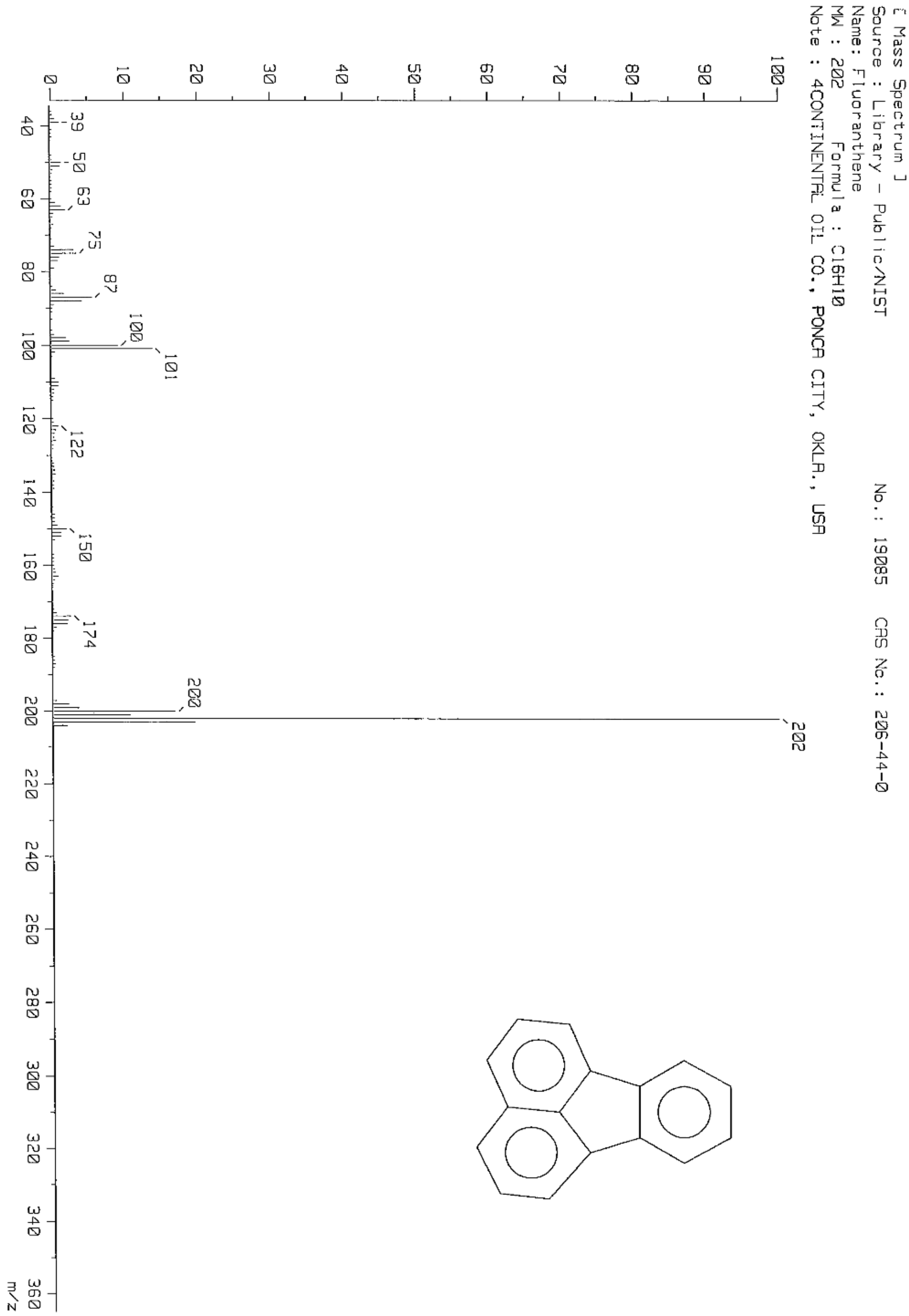
Mass spectrum for Benzo c Phenanthrene.

Appendix II



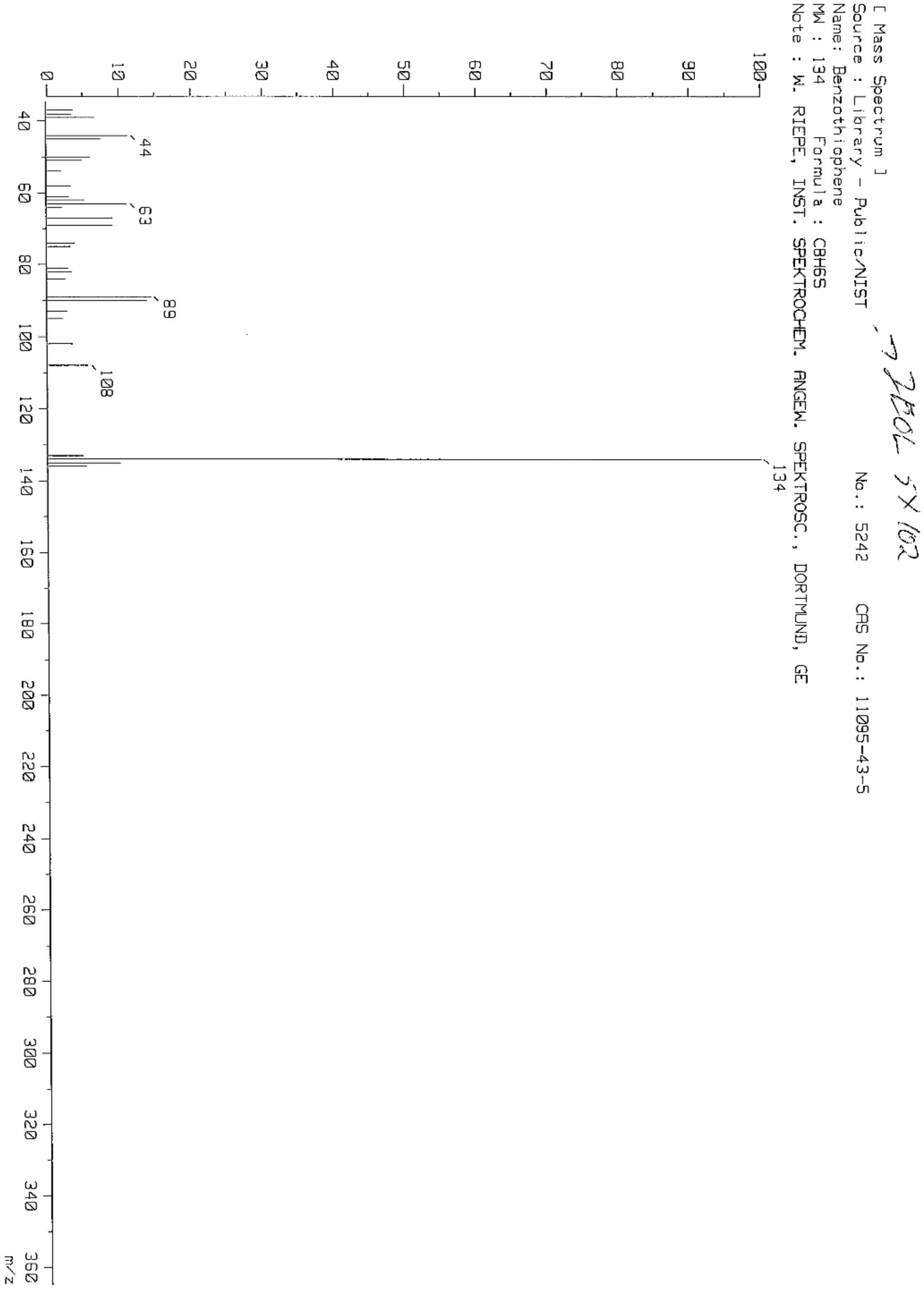
Mass spectrum for Benzo ghi flouranthene.

Appendix II



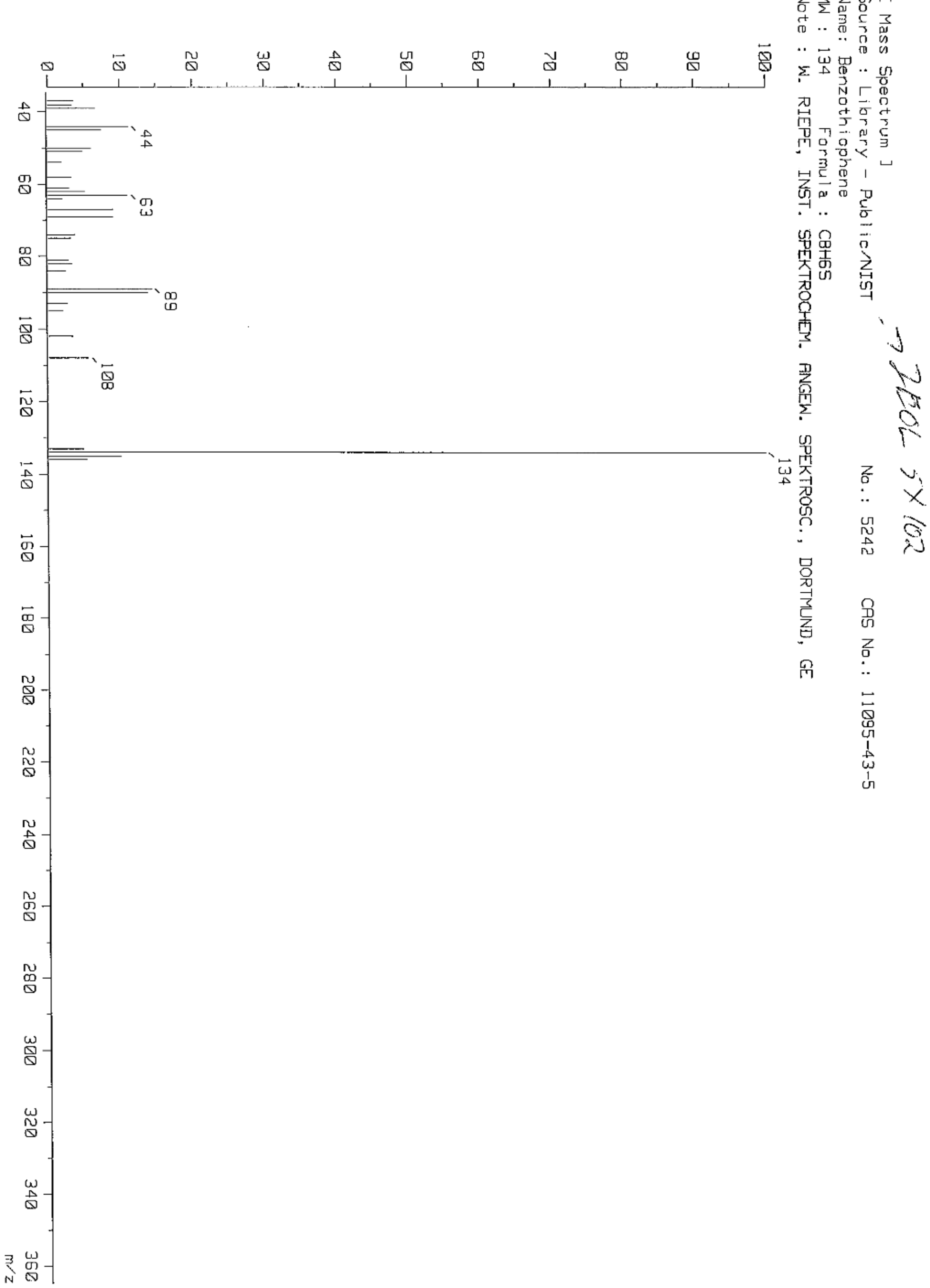
Mass spectrum for Fluoranthene.

Appendix II



Mass spectrum for Benzothiophene.

Appendix II



Mass spectrum for Benzothiophene.