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Availability and chemical composition of traditional eye cosmetics ("kohls") used in the United Arab Emirates of Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah, and Fujairah

ANDREW D. HARDY, *Centre for Medical History, School of Humanities and Social Sciences, University of Exeter, Exeter EX4 4RJ, Devon, UK;* RICHARD I. WALTON and KATHRYN A. MYERS, *Department of Chemistry, School of Biosciences, University of Exeter, Exeter EX4 4QD, Devon, UK;* and RAGINI VAISHNAV, *College of Medicine, Sultan Qaboos University, Box 35, Al-Khod 123, Sultanate of Oman.*

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Synopsis

This study was undertaken in order to determine the availability and chemical composition of potentially lead-toxic traditional eye cosmetics ("kohls") in six of the seven emirates of the United Arab Emirates (UAE). Thus of especial interest was the percentage of the purchased samples that contained the toxic element lead. A total of 53 observably different kohl samples were found to be available overall in the six emirates: Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah, and Fujairah. It was found that 19 of these samples had been previously analyzed by us in studies covering Oman, Abu Dhabi (city), and Egypt (Cairo). The techniques of X-ray powder diffraction (XRPD) and scanning electron microscopy (SEM) were used to analyze the remaining 34 samples. Overall, for the 53 kohl samples, it was found that 20 (38%) contained a lead compound (galena, PbS) as the main component. The other main components were found to be one of the following: amorphous carbon, calcite/aragonite ($CaCO_3$), goethite ($FeO(OH)$), hematite (Fe_2O_3), sassolite (H_3BO_3), talc ($Mg_3Si_4O_{10}(OH)_2$), or zincite (ZnO).

INTRODUCTION

As part of our continuing study of Middle Eastern traditional eye cosmetics ("kohls") we have now looked at the availability and chemical composition of such cosmetics in six of the seven emirates of the United Arab Emirates (UAE), with especial reference to determining those containing a lead compound. We have already published a study on the kohls of Abu Dhabi city (1). Thus the six remaining emirates of Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah (RAK), and Fujairah are covered here. For useful background information on eye cosmetics in general, and on Middle Eastern kohls in particular, the reader is referred to our previous publications (1–3) and references therein.

The older generation of Emirati men and women still use this traditional eye cosmetic for a variety of reasons: eye beautification, tradition, protection against the "evil eye," and as an ethnic medical remedy for eye strain/pain/soreness. In general, it is used more in the villages than in the urban areas of the UAE, and in the former it is still used on (very) young children as a perceived protection from the "evil eye"/the "evil one." Also, Bedu men wear it as a protection against the fierce desert sun. However, most of the middle-aged and younger generations of urban-living Emirati females now use the readily available modern eye pencils. Amongst the expatriates of the UAE, kohl is still used by (predominantly middle-aged) Indian ladies and also by Pakistani and Afghani middle-aged men.

In our prior studies on the kohls of Oman, Abu Dhabi city, and Egypt (Cairo) (1–3), we found the toxic element lead (usually as the compound lead sulfide, PbS) to be present in some of the samples. The biohazards of lead are well known and were documented in the first century BCE by Vitruvius (4) and, as one example of several recent such studies, in a comprehensive study of its negative effects on the intellectual abilities of young children (5). Presented here, as part of our ongoing study into the presence of lead in Middle Eastern kohls, is a study of the availability and chemical composition of them in the emirates of Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah (RAK), and Fujairah.

MATERIALS AND METHODS

MATERIALS

The souks (local markets) of Dubai, Sharjah and Ajman were all visited several times and were very thoroughly investigated for the availability of traditional eye cosmetics (kohls). A later visit to the most remote (north) emirate of Ras Al-Khaimah (RAK), via the smallest emirate of Umm Al-Quwain, was sufficient to allow a reasonably thorough investigation of the main souk of RAK. However, the short time spent in Umm Al-Quwain was only sufficient for a limited investigation in its main shopping area. Unfortunately the final emirate, Fujairah, could not be visited by us and a "selection" of the available kohls in the Fujairah city souk was purchased by a colleague at a slightly later date.

Initially all available kohl samples were purchased, but in our later souk visits only those kohl samples *not* seen before in this study were purchased, but with a careful record being made of the details of these "seen only" samples. The price per kohl sample, after bargaining, was usually between 1 and 5 dirhams (where 5.6 dirhams was 1 GBP and where 3.5 dirhams was 1 US$), but occasionally the price was 10, 15, 20, or even 30 dirhams. For the six emirates investigated, the numbers of kohl samples purchased and "seen only" were: Dubai, 33 purchased and 1 more seen; Sharjah, 23 purchased and 9 more seen; Ajman, 7 purchased; Umm Al-Quwain, 3 purchased and 4 more seen; RAK, 9 purchased and 16 more seen; Fujairah, 5 (a "selection") purchased. Thus, overall, 80 samples were purchased and a further 30 "seen only."

Of these 80 purchased samples it was found that 53 were observably different; the remaining 27 were identical to one of these 53 samples. Furthermore, on later comparison of these 53 samples with the kohl samples previously studied by us (1–3), it was found that 19 of them had been analyzed in these prior studies. It had been decided by us that if a kohl sample's name, origin, and container were all found to be *identical* to those of a sample already purchased (i.e., in this study) or already analyzed (i.e., in one of our previous publications), then we would assume that the samples had identical chemical compositions. However, as a check on this (i.e., consistency of composition with variation of locations of purchase), it was decided to analyze eight of the 19 samples already done by us in previous studies. Thus a total of 42 (34 plus 8) kohl samples were examined by the analytical techniques of X-ray powder diffraction (XRPD) and scanning electron microscopy (SEM) with an attached energy dispersive X-ray (EDX) microanalyzer.

X-RAY POWDER DIFFRACTION (XRPD)

For XRPD, the kohl samples were, where necessary, ground to a powder and then mounted in an aluminum holder. Diffraction data were collected using a Siemens D500 X-ray diffractometer operating with CuKα radiation. A step scan, using a step size of 0.0256 degree and a time of 1 s/step, was done over a 2-theta range of 8–70 degrees for each of the samples. These data sets were then used to determine the major and minor components (phases) present in the samples by comparing the obtained data to the reference data in the 2000 JCPDS (Joint Committee for Powder Diffraction Standards) database. The major phase was usually defined to be that phase which had a presence estimated to be $\geq$90%; any variation from this percentage is mentioned in the later Results section. The minor phases given in parentheses (in Tables I and II) are those estimated to be $\leq$5% of the sample. Also, each group of minor phases are listed in these tables in decreasing order of their estimated percentage presence. Results for the 34 samples not seen before are given in Table I, and those for the eight samples re-analyzed (i.e., seen and analyzed by us before, but selected to be checked for consistency of composition for different locations of purchase) are given in Table II along with all relevant previous-study results.

SCANNING ELECTRON MICROSCOPY (SEM)

For SEM EDX, each sample was mounted on an aluminum stub using an adhesive carbon tab. It was then examined in a JEOL JSM 5300 LV SEM with an attached Rontec EDX microanalyzer. This LV (low vacuum) SEM is designed so that the specimen chamber is differentially evacuated to low vacuum. The electric charge on the specimen is neutralized, thus allowing nonconductive specimens to be studied without coating. Elements lighter than carbon (i.e., $Z \leq 5$) cannot be detected using this equipment. Detection was qualitative, and the element peaks that were only just above the background are given in brackets in Tables I and II.

RESULTS

The results, including both chemical composition and availability, are given in Tables I and II. The kohl samples are listed in alphabetical order of their names (or translated

Table I
Kohl Samples That Have Not Been Analyzed Previously

Sample name[a]	Texture	Color	Available in	Made in	XRPD Main phase	XRPD Minor phase(s)[b]	SEM[c]	Data on contents?	Data on medical effects?
"Al-Almeerah Kajal"	Greasy	Black	Dubai[d] Sharjah[e] RAK[f]	Pakistan (Karachi)	Amorphous carbon	(Paraffin wax)	C, O	N	N
"Al Athmad" ("Cold")[g]	Powder	Orange	RAK[f]	Saudi Arabia (Medina)	Hematite (Fe_2O_3)	Geothite (FeO(OH)) Quartz (SiO_2)	C, O, Fe, Si (N)	N	N
"Al Haramen Ethmed"	Powder (shiny)	Grey-black	Sharjah[e] RAK[f]	Syria (Aleppo)[g]	Galena (PbS)	(Cerussite ($PbCO_3$)) (Anglesite ($PbSO_4$))	Pb, S, C, O	Y	Y
"Alfa Libra Kailas Kajal"	Greasy	Black	Sharjah[e] RAK[f]	India (Bombay)	Amorphous carbon	(Paraffin wax)	C, O, (N, S)	N	N
"Al-Mumtaz"[g]	Greasy	Black	Sharjah[e] RAK[f]	Pakistan	Amorphous carbon	(Paraffin wax)	C, O (S)	N	N
"Budhia Surma" ("No. 7 Black Surma")	Powder (shiny)	Grey-black	Sharjah[e]	India (Bombay)	Galena	Camphor ($C_{10}H_{16}O$) (Anglesite) (Cerussite)	Pb, S, C, O	Y	N
"Hamid Al-Misk" ("Original Athmad with Zam Zem water[h]")[g]	Powder	Red-orange	RAK[f]	Saudi Arabia	Geothite	Hematite Quartz	C, O, Fe, Si (N)	N	N
"Hasmi Kajal" (pencil)	Greasy	Black	Sharjah[e]	Pakistan (Karachi)	Zincite (ZnO)	Galena (Amorphous carbon)	C, Zn, O, Pb, S	N	N
"Hashmi® Kajal" (tube)	Greasy	Black	Sharjah[e] Ajman[i] UAQ[j] RAK[f]	Pakistan (Karachi)	Amorphous carbon	(Paraffin wax)	C, O (S)	Y	N
"Joy Kajal"	Greasy	Black	Sharjah[e] RAK[f]	India (Bombay)	Amorphous carbon	(Paraffin wax)	C (O)	N	N
"Khojati® Mumtaz® Deluxe Kajal. The Eye Definer."	Greasy	Black	Dubai[d] Sharjah[e] RAK[f]	India (Bombay)	Amorphous carbon	(Paraffin wax)	C, O	Y	N
"Khojati® Surma No. 13® (Export Quality)"	Powder	Grey-black	Dubai[k] Sharjah[e] RAK[f]	India (Bombay)	Zincite	(Camphor) (Amorphous carbon) (Quartz)	Zn, O, C, Fe (Si, S)	N	N
"Khojati® Toop Anjan®"	Greasy	Black	Sharjah[e]	India (Bombay)	Amorphous carbon	(Paraffin wax)	C, O	Y	Y
"Kohl Original Stone. With Zam Zem water[h]. Cold."[g]	Powder (shiny)	Grey	RAK[f]	Saudi Arabia	Galena	Cerussite (Anglesite)	C, Pb, S, O (N)	N	N
"Nimco No. 96 Neem Ka Tez Surma (Special)"	Powder	Grey-black	Dubai[d]	India (Bombay)	Talc ($Mg_3Si_4O_{10}(OH)_2$)	Dolomite ($CaMg(CO_3)_2$) Galena	C, Si, Mg, O, Ca, Pb, S (Zn, Cl)	N	Y

None (4)	Lump	Silver-grey	Dubai[d] Sharjah[e] RAK[f]	Iran/Morocco Iran Iran	Galena	(Anglesite) (Cerussite)	Pb, S, C (O)	N	N
None	Greasy	Black	Dubai[d]	Iran (Bandar Abbas)	Amorphous carbon	(Paraffin wax) (Rutile (TiO_2))	C, O, Fe (S, Ti)	N	N
None	Powder	Black	Sharjah[e]	Iran	Amorphous carbon	(Graphite) (Rutile)	C, O (Ti)	N	N
None	Powder (shiny)	Grey-black	RAK[f]	Iran	Galena	(Anglesite)	Pb, S, C (O)	N	N
"Salma Surma Special"	Powder (shiny)	Grey-black	Dubai[d]	Pakistan	Galena	(Cerussite) (Anglesite)	Pb, S, C, O	N	N
"Samir"[g]	Greasy	Black	Dubai[d] RAK[f]	Pakistan	Amorphous carbon	(Paraffin wax)	C, O (Zn)	N	N
"Shabnami Surma tark Chashma"[l]	Powder	White	Sharjah[e]	Pakistan (Karachi)	Sassolite (H_3BO_3)	Unknown	O, C	N	Y[l]
"Summayyah Kajal" ('For Children'[n])	Greasy	Black	Dubai[d]	Pakistan	Amorphous carbon	(Paraffin wax)	C, O	N	N
"Summayyah Kajal" ('For Adults'[n])	Greasy	Black	Dubai[d]	Pakistan	Amorphous carbon	(Paraffin wax)	C, O	N	N
"Surma" ('Very good for sore eyes'[n])	Powder	White	Fujairah[p]	Pakistan	Calcite ($CaCO_3$)	(Quartz)	C, Ca, Si, O, Al, Mg, Fe (Na, S, Cu)	N	N
"Surma Farid Ara"[m]	Powder	Black	Sharjah[e]	Iran (Mashid)	Amorphous carbon	(Rutile)	C, O (Ti)	Y[m]	N
"Surma Harmain Al Sherfain. Cold."	Powder (shiny)	Grey-black	Sharjah[e]	Pakistan (Karachi)	Galena	(Cerussite) (Anglesite)	Pb, S, C, O	Y	Y
"Surma Harmain Al Sherfain. Hot."	Powder (shiny)	Grey-black	Dubai[d]	Pakistan (Karachi)	Galena	(Anglesite)	Pb, S, C, O	Y	Y
"Surma Noor-Ul-Ain"	Powder	Black	Dubai[d]	India (Bombay)	Calcium carbonate (Calcite + Aragonite ($CaCO_3$))	Zincite (Kaolinite ($Al_2Si_2O_5(OH)_4$)) (Graphite) (Magnetite (Fe_3O_4)) (Quartz)	C, Ca, Al, Si, O, Zn, Fe, S	N	Y
"Surma Noor-Ul-Ain" ('Hot'[n])	Powder	Black	Sharjah[e]	India (Bombay)	Zincite	Galena (Amorphous carbon) (Quartz)	C, Zn, O, Pb, S (Si)	N	Y
"Zikra Al Haramain" ("Mountainous Arabic Ethmed Kohel")	Powder (matte)	Grey-black	Dubai[d] Sharjah[e] RAK[f]	Dubai	Galena	(Anglesite) (Cerussite)	Pb, S, C, O	N	Y

[a] The name of the sample, in English (sometimes translated). In alphabetical order. [b]Those phases in brackets are estimated to be each less than 5% level in the sample. [c]Those elements given in brackets were judged to be only just above background level. [d]Dubai Deira souk [e]Sharjah Iranian souk. [f]Ras Al-Khaimah main souk. [g]Translated from Arabic. [i]Ajman Iranian souk. [j]Umm Al-Qawain. [k]Bur Dubai souk. [l]Translated from Urdu. [m]Translated from Farsi (Persian). [n]Said by the shopkeeper. [p]Fujairah city souk. ® Word(s) preceding this symbol are registered trade names.

Table II
Kohl Samples That have Been Analyzed Previously

Sample name[a]	Texture	Color	Available in	Made in	XRPD Main phase	XRPD Minor phase(s)[b]	SEM[c]	Data on contents?	Data on medical effects?
"Hashmi Kajal" (round, gold-colored, container)	Greasy	Black	Dubai[d] Sharjah[e] UAQ[j]	Pakistan (Karachi)	Zincite (ZnO)[n]	(Amorphous carbon)[n] (Paraffin wax)[n]	Zn, O, C[n]	N	N
			RAK[f] Fujairah[s]		Zincite	(Amorphous carbon) (Paraffix wax)	Zn, C, O		
"Hashmi Kajal" (round, pink-colored, container)	Greasy	Black	Dubai[d] Sharjah[e] RAK[f]	Pakistan (Karachi)	Zincite[n]	(Amorphous carbon)[n] (Paraffin wax)[n]	Zn, O, C (Si)[n]	N	N
"Hashmi Kajal" (tube)	Greasy	Black	Dubai[d]	Pakistan (Karachi)	Zincite[n]	(Amorphous carbon)[n] (Paraffin wax)[n]	Zn, O, C[n]	N	N
"Hind Ka Noor Eye Liner"	Powder	Black	Dubai[d] Sharjah[e] Ajman[i]	India (Bombay)	Amorphous carbon[q]	(Talc ($Mg_3Si_4O_{10}(OH)_2$))[q] (Quartz (SiO_2))[q]	C, Si, Mg, O, Cl (S)[q]	N	Y[g]
			RAK[f]		Amorphous carbon	(Tale) (Quartz)	C, Si, O, S, Mg (Ca)		
"Hashmi ® Kohl Aswad"	Powder (matte)	Black	Dubai[d] Sharjah[e] Ajman[i] UAQ[j]	Pakistan	Galena (PbS)[n]	(Cerussite) ($PbCO_3$)[n] (Anglesite) ($PbSO_4$)[n]	Pb, S (Mg, Ca, K, O, Zn)[n]	N	N
			RAK[f] Fujairah[s]		Galena	(Cerussite) (Anglesite)	Pb, S, C, O (Zn)		
"Hashmi Surma Asmar"	Powder (matte)	Grey-black	Dubai[d] Sharjah[e]	Pakistan (Karachi)	Galena[n]	(Cerussite)[n] (Anglesite)[n]	Pb, S (Si, O)[n]	N	N
"Hashmi Surma Sunef"[l]	Powder (matte)	Grey-black	Sharjah[e] RAK[f] Fujairah[s]	Pakistan (Karachi)	Galena[n]	(Anglesite)[n] (Cerussite)[n] (Zincite)[n]	Pb, S (Si, Zn, O)[n]	Y[l]	N
					Galena	(Anglesite) (Zincite) (Cerussite)	Pb, S, C, O (Zn)		
"Kamal Kajal"	Greasy	Black	Dubai[d]	India (Bombay)	Amorphous carbon[p]	(Paraffin wax)[p]	No peaks seen[p]	Y	N
					Amorphous carbon	(Paraffin wax)	C, O (Si)		
"Khol Noori"	Powder (shiny)	Grey-black	Dubai[d] Sharjah[e] Ajman[l] RAK[f]	France	Galena[n]	(Cerussite)[n] (Angelsite)[n]	Pb, S (Si, O, Na, Ca)[n]	N	N

"Kohl Original Stone (with Zam Zem water[h])"[g]	Powder (shiny)	Grey-black	Dubai[k]	Saudi Arabia	Galena[n]	(Cerussite)[n] (Anglesite)[n]	Pb, S (O, C, K, Si)[n]	N	N
					Galena	(Cerussite) (Anglesite)	Pb, S, C, O		
"Khojati® Surma Deluxe"	Powder	Grey-black	Dubai[d] Sharjah[e]	India (Bombay)	Zincite[n]	(Calcite/Aragonite ($CaCO_3$))[n] (Quartz)[n] (Graphite)[n]	Zn, O (Si, Ca Fe)[n]	Y	N
					Zincite	Calcite/Aragonite (Amorphous carbon) (Quartz) (Magnetite (Fe_3O_4))	Ca, Zn, C, O Si, Al, Fe (S)		
"Khojati ® Surma Sada Aswad"	Powder (matte)	Black	Dubai[d] Sharjah[e] Ajman[i]	India (Bombay)	Galena[n]	Zincite[n] Cerussite[n]	Pb, S, Zn, O[n]	Y	Y
"Khojati ® Surma Sada"	Powder (matte)	Grey-black	Dubai[d] Sharjah[e] RAK[f]	India (Bombay)	Galena[q]	(Anglesite)[q] (Cerussite)[q]	Pb, S, C, O[q]	Y	N
"Lateef Surma Namirah"	Powder	Grey-white	Dubai[k] Sharjah[e] UAQ[j] RAK[f]	Pakistan (Lahore)	Sassolite (H_3BO_3)[n]	(Zinc borate hydrate (Zn $(BO_3)_2H_2O$))[n] (Graphite)[n]	O, Zn[n]	N	Y
"Lateef Surma 'sukh chen sada'[l]"	Powder	Black	Dubai[d] Sharjah[e] Ajman[i] UAQ[j] RAK[f]	Pakistan (Lahore)	Sassolite[p]	(Zinc borate)[p] (Amorphous carbon)[p]	Zn[p]	Y[l]	N
"Lateef Surma 'surma sada mix'[l]"	Powder	Black	Dubai[d] Sharjah[e] UAQ[j]	Pakistan (Lahore)	Sassolite[p]	(Zinc borate)[p] (Amorphous carbon)[p]	Zn[p]	Y[l]	N
"Lateef Surma"	Powder	Grey-black	Dubai[d] UAQ[j] RAK[f] Fujairah[s]	Pakistan (Lahore)	Sassolite[n]	(Zinc borate mono-hydrate)[n] (Graphite)[n]	Zn, O (C, Cl)[n]	N	Y
					Sassolite	(Graphite)	Zn, O, C		
"Surma Al-Sherifain"	Powder (matte)	Black	Dubai[d] Sharjah[e] Ajman[i]	India	Galena[n]	(Anglesite)[n] (Cerussite)[n]	Pb, S (O, Si, K, Ca, C)[n]	Y	Y
"Special Hayati Surma (Export Quality Surma No. ●13)"	Powder	Black	Dubai[d]	India (Bombay)	Amorphous carbon[n]	Calcite[n] (Portlandite)[n,r] (Graphite)[n]	C, Ca (Mg, Cl, Si)[n]	Y	Y

[a] The name of the sample, in English (sometimes translated). In alphabetical order. [b]Those phases in brackets are estimated to be each less than 5% level in the sample. [c]Those elements given in brackets were judged to be only just above background level. [d]Dubai Deira souk. [e]Sharjah Iranian souk. [f]Ras Al-Khaimah main souk. [g]Translated from Arabic. [h]Zam Zem water is holy water from Mecca, Saudi Arabia. [i]Ajman Iranian souk. [j]Umm Al-Qawain. [k]Bur Dubai souk. [l]Translated from Urdu. [n]From a previous study on kohls from Abu Dhabi city (1). [p]From a previous study on kohls from Oman (2). [q]From a previous study on kohls from Cairo (3). [r]Portlandite is a mixture of approx. 75% calcite and 25% aluminum silicates. [s]Fujairah city souk. ® Word(s) preceding this symbol are registered trade names.

names) in both tables, Table I for the 34 samples not seen before and Table II for the 19 samples analyzed by us in previous studies (1–3). A total of eight samples had trade names, and after these names, in Tables I and II and in the text, is placed the "®" symbol. Also, seven samples had no name. They are listed as "None" for their sample names and are here regarded as all being observably different from one another. Also, for the few occasions where the same sample name occurred more than once, on observably different samples, extra descriptive information on their containers is given in parentheses after each of the listed names. Also, any additional useful information given to us by the shopkeeper, on the kohl concerned, is given after the name (in parentheses and using ". . ."). Table II contains, in addition to the results from our previous studies, the results of XRPD and SEM EDX on eight samples selected in this study for the checking of consistency of composition with variation in locations of purchase. Also given in these tables, on a simple Y/N basis, is whether any information is given (on the container or on an enclosed leaflet) on the chemical contents of the sample or on the medicinal effects of using the kohl sample. Figure 1 shows the percentages of the main elements of the major phases in the combined (53) samples from Tables I and II. Similarly, in Figure 2 is shown the (percentage) origins of all the samples listed in Tables I and II.

For the 34 samples listed in Table I the main component of 12 was found to be galena (lead sulfide, PbS). In a further three samples it was present as a minor phase. Four of these 15 samples were silver-grey lumps, ten were grey-black (eight) or black (one) or grey (one) powders, and one was black and greasy. The associated minor phases, when galena was the major phase, were the lead compounds anglesite ($PbSO_4$) and/or cerussite ($PbCO_3$). These were usually present in small amounts (i.e., 1–2%) that suggested they were solely weathering products of the galena ore. In one sample, camphor ($C_{10}H_{16}O$)

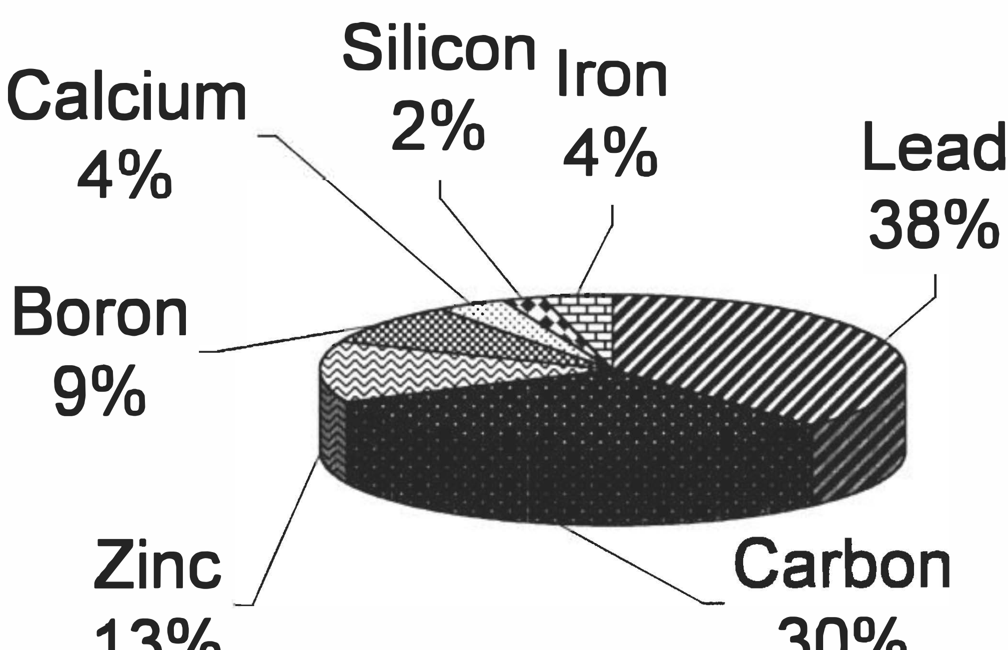

Figure 1. Main elements of the major phase in the kohl samples listed in Tables I and II.

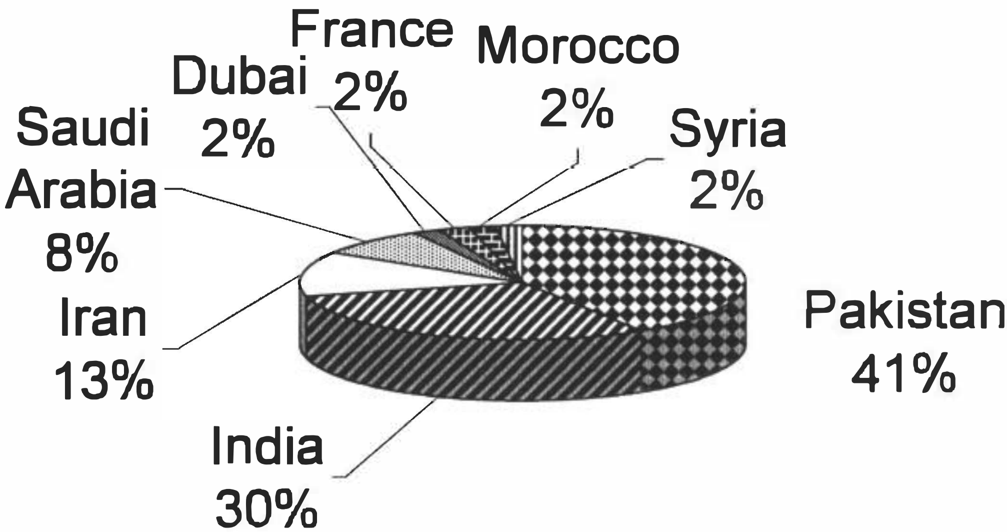

Figure 2. Origins of the kohl samples listed in Tables I and II.

was also present (at >5 %), and in another sample (which was grey in color) cerussite had almost certainly been deliberately added, as it was present at >5 %.

Thirteen of the samples were found to have amorphous carbon as their major phase. Two were powders and eleven greasy; all were black in color. Additionally, three samples had amorphous carbon present as a minor phase. Three samples had (white) zincite (ZnO) as their major phase, with their black or grey-black colors deriving from the addition of amorphous carbon (one sample) or amorphous carbon and galena (two samples) as the minor phases. One sample had zincite as a minor phase, but at >5%. Four samples had one each of the following white/grey-white compounds/mixtures as its major phase: calcium carbonate ($CaCO_3$, once as calcite only and once as a mixture of calcite and aragonite), talc ($Mg_3Si_4O_{10}(OH)_2$), and sassolite (H_3BO_3). The second and third of these four samples were colored black and grey-black respectively—from the presence of minor phases of graphite and magnetite (Fe_3O_4) in one sample and of galena in the other sample. Finally, two orange/red-orange powder samples were found to be based on mixtures of the iron compounds hematite (Fe_2O_3) and goethite (FeO(OH)).

As already stated, the major phase listed in Tables I and II usually had a presence in the sample of ≥90%. However, for 8 of the 42 samples analyzed, the major phase listed was in fact less than 90% (where all percentages given below are estimates). One sample in Table II, "Khojati ® Surma Delux," had its major phase of zincite present at only 70%. Its minor phases were the two forms of calcium carbonate (calcite and aragonite) present at a total of 25%, with the remaining 5% covering the combined minor phases of amorphous carbon, quartz, and magnetite. Seven more such samples are present in Table I. The sample "Kohl Original Stone" was found to contain only 85% of the major phase (galena), its minor phases of cerussite plus anglesite having percentages of 10% and 5%, respectively. Both "Surma Noor-Ul-Ain" (the sample said to be "hot" by the shopkeeper) and "Hashmi Kajal" (in the form of a blue-colored pencil) had their major phases (zincite) at only 80% each, with minor phases of galena (16%) plus amorphous carbon (2%) plus quartz (2%), and galena (17%) plus amorphous carbon (3%), respectively.

The other (i.e. "cold") "Surma Noor-Ul-Ain" sample had calcium carbonate in two forms (calcite and aragonite) as its major phase at a combined percentage of only 60%. Its minor phases were zincite (25%), with the remaining 15% covering the combined minor phases of kaolinite, graphite, magnetite, and quartz. The red/red-orange samples, "Hamid Al-Misk" and "Al Athmad," had major phases of goethite and hematite, respectively (each at 60%), and minor phases (totalling the remaining 40%) of quartz plus hematite and quartz plus goethite, respectively. The last of these seven samples in Table I was "Nimco No. 96. Neem Ka Tez Surma (Special)," which had a combination of talc and dolomite (at a total of 87%) listed as the major phase(s) and a minor phase of galena (13%).

Many of the 53 samples in Tables I and II originated in Pakistan (22) or India (16). The remainder came from Iran (7), Saudi Arabia (4), and Dubai, France, Morocco, and Syria supplying one each. Three of the samples from Iran, which had amorphous carbon as their major phases, unexpectedly had the mineral rutile (impure TiO_2, often having a reddish coloration from the presence of small amounts of hematite) as a minor phase.

DISCUSSION

TOXICOLOGY OF LEAD

Lead compounds are toxic by ingestion, inhalation, and skin exposure. Children are more susceptible than adults to lead intoxication. Adults absorb 5–15% of ingested lead while children can absorb as much as 41% of ingested lead. The toxic effects of lead form a continuum from clinical or overt effects to more subtle ones (6). The critical effects in infants and children involve the nervous system. Blood lead levels once thought to be safe have been shown to be associated with intelligence quotient deficits, behavioral disorders, slowed growth, and impaired hearing (7,8). Blood lead levels in children that are greater than 10 μg/dl are now considered abnormal (9), and recently it has been shown that significant intellectual impairment occurs in young children who have blood lead levels *below* 10 μg/dl (5).

Severe lead poisoning, resulting in encephalopathy, can result when blood lead levels are greater than 70 μg/dl. A recent report has demonstrated that young infants exposed to lower levels of lead following the use of traditional medicines can also present with encephalopathy (10). Reported cases of acute encephalopathy in infants that are *directly linked* to excessive use of a lead-based kohl are now fewer than several decades ago, but unfortunately do still occur (11).

Frequently, mothers apply kohl to infants and children as a traditional measure to beautify and to protect the child from the "evil eye." Lead-containing kohls can be easily ingested by these infants, who may wipe their eyes and face, and subsequently lick their fingers. Earlier (animal) studies (12) have shown that trancorneal transport is *not* a significant contributory mechanism for absorption of lead from lead-based eye cosmetics.

More than 90% of lead in blood resides in the red blood cells. The total body burden of lead can be divided into two kinetic pools, which have different rates of turnover. The largest pool is in the skeleton, which has a very slow turnover (a half life of more than 20 years) (9). The other pool is in the soft tissue, where it is much more labile. Lead in trabecular bone is more labile than in cortical bone, and trabecular bone has a shorter turnover time. Lead in the bone may contribute up to 50% of blood lead. During pregnancy and lactation, mobilization of lead from maternal bone is a cause for concern. Strong correlations between maternal and umbilical cord blood lead levels demonstrate that lead is transferred from the mother to the fetus (13). Cumulative effects of low levels of lead exposure *in utero* and after birth can have similar detrimental effects. An increase in the maternal-blood lead level may contribute to a reduction in gestation period and low birthweight. The fetal brain may also be particularly sensitive to the toxic effects of lead because of the immaturity of the blood-brain barrier.

In an adult population, the most critical adverse effect of lead is probably hypertension. Other toxic effects of concern are peripheral neuropathy, lead-induced anemia, and lead nephropathy.

In a previous publication (3) we discussed galena's (lead sulfide, PbS) particle size with respect to the associated kohl powder being "shiny" or "matte" in texture and with respect to its rate of dissolution in gastric fluid. It was found by us that at a mean particle size for galena of about ≤ 10 µm, the kohl powder (with galena as the major phase) became totally matte in texture. It had previously been found (12) that reducing the particle size of galena leads to a significant increase in its rate of dissolution (in gastric fluid). So, in a very simplistic toxicology sense, it can be said: "shiny is good and matte is bad" (as the latter would be much more easily dissolved in gastric fluid than the former, with the former perhaps going straight through the body with minimum absorption and negligible toxicity). Thus in Tables I and II we have stated if the powder is "shiny" or "matte" in texture when galena is the listed major phase. In Table I only one such sample is matte, but in Table II six are matte in texture. While the Table I sample "Zikra Al Haramain" is available in three of the six emirates studied here, it is also very expensive (30 dirhams) and so is therefore unlikely to be bought extensively by the local populace. However, the six such samples in Table II have one available in two, four in three, and one in all six emirates, with their prices ranging from 1 to 4 dirhams. Thus these six samples are, unfortunately, much more likely to be purchased extensively by the local populace and so could give rise to significant lead toxicity if used in such a way that adsorption can readily occur (e.g., if used on the conjunctiva of the eye).

In view of all the above-mentioned toxic effects and the still widespread use of kohls in at least parts of the present-day Middle East, it follows that children who have a lead-based kohl regularly applied to them are at risk of serious and fatal toxicities of the nervous system and also to more subtle, subclinical, long-term effects.

WRITTEN INFORMATION ON CONTAINER PACKAGING

Eleven of the samples listed in Tables I and II have detailed (i.e., quantitative "contents data" provided with the sample (usually on an enclosed leaflet). Table III lists this detailed "contents data," our best translations/interpretations, and the (most likely) associated chemical/mineral names. There are still some "formula names" that we have been unable to translate and others with a degree of uncertainty in their translation (i.e., those with a "?" added). Most of the major phases found match a "formula name" in the "contents data," usually one with a high given percentage.

Additionally, there are six more samples where qualitative "contents data" are given. For three of these samples, the information given is vague: (made with) "almonds" (trans-

Table III
Kohl Samples That Had (quantitative) "Contents Data"

Sample name	Made in	Available in	XRPD major phase	XRPD minor phase(s)	Contents data	(%)	Translation/ interpretation	(Most likely) Chemical/mineral name
Table I samples:								
"Budhia Surma" ("No. 7 Black Surma")	India (Bombay)	Sharjah	Galena	Camphor	Filfile-Sufed	0.1%	"White pepper"	A white pepper
				(Anglesite)	Kibabeh	0.1%	" '?' Pepper"	A pepper
				(Cerussite)	Kafoor	25.0%	Camphor	Camphor
					Shab-E-Yama Ni	0.2%	"Lucky evening"?	Unknown
					Surma	74.0%	Kohl	Galena
					Murkwarid	0.2%	"Very dark '?' "	Unknown
					Sankha	0.4%	Conch shell	Calcite
"Khojati ® Mumtaz ® Deluxe, Kajal. The Eye Definer"	India (Bombay)	Dubai/Sharjah/Ras Al-Khaimah	Amorphous carbon	(Paraffin wax)	Cow's ghee	17.000%	Cow's ghee	A clear butter
					Coconut oil	24.000%	Coconut oil	Coconut oil
					Tel	2.000%	(An) Oil	(An) Oil
					Sufoof-e-Syah	6.000%	"Black from oil of almond"	Amorphous carbon
					Waxy base	51.00%	Wax	Wax
"Khojati ® Toop Anjan ®"	India (Bombay)	Sharjah	Amorphous carbon	(Paraffin wax)	Sufoof-e-syah	1.00%	"Black from oil of almond"	Amorphous carbon
					Beeswax	40.00%	Beeswax	Beeswax
					Bhimseni Kafoor	39.00%	Camphor	Camphor
					Cow's ghee	15.00%	Cow's ghee	A clear butter
					Ark Phudina	5.00%	Extract of mint	Extract of mint
"Surma Harmain Al-Sherfain" "Cold"/"Surma Harmain Al-Sherfain" "Hot"	Pakistan (Karachi)	Sharjah/Dubai	Galena	(Anglesite)	Surma Black	70%	Black kohl	Galena
				(Cerussite)/ (Anglesite)	Kafe Darya	15%	Unknown	Unknown
					Phitakari Pure	13%	"Pure potassium"?	A potassium salt?
					Kafoor Bhim Seni	2%	Camphor	Camphor

Table II samples:								
"Kamal Kajal"	India (Bombay)	Dubai	Amorphous carbon	(Paraffin wax)	Karpur	2%	Camphor	Camphor
					Kajali	5%	Kohl	Amorphous carbon
					Caster oil	65%	Castor oil	Castor oil
					Madh wax base	28%	"Madh" wax	Beeswax
"Khojati ® Surma Deluxe"	India (Bombay)	Sharjah/Dubai	Zincite	(Calcite + Aragonite)	Sange Basari	83.962%	"Stone from Basra"	Calcium/Iron/Zinc mineral
				(Amorphous carbon)	S. Syah	12.642%	"Black from oil of almond"	Amorphous carbon
				(Quartz) (Magnetite)	Gile Aurkh	3.396%	"Wet and red"?	Unknown
"Khojati ® Surma Sada Aswad"	India (Bombay)	Ajman/Dubai/ Sharjah	Galena	Zincite Cerussite	Asmad	68.807%	"A (crushed if a powder) rock from Saudi Arabia"	Galera
					Sange-e-Basari	20.184%	"Stone from Basra"	Calcium/Iron/Zinc mineral
					Sufoof-e-Syah	11.009%	"Black from oil of almond"	Amorphous carbon
"Khojati ® Surma Sada"	India (Bombay)	Dubai/Sharjah/Ras Al-Khaimah	Galena	(Anglesite) (Cerussite)	Asmad ("Ground in different natural extracts")	100%	"A (crushed if a powder) rock from Saudi Arabia"	Galena
"Surma Al-Sheri-fain"	India	Dubai/Sharjah/ Ajman	Galena	(Anglesite) (Cerussite)	Surma Black	70%	Black kohl	Galena
					Kafe Darya	15%	Unknown	Unknown
					Phaitkarishudh	13%	"White potassium"?	A white potassium salt?
					Kafoor BhimSemi	2%	Camphor	Camphor
"Special Hayati Export Quality Surma No. 13"	India (Bombay)	Dubai	Amorphous carbon	Calcite (Portlandite) (Graphite)	Camphor (Kaphoor)	6%	Camphor	Camphor
					Boric acid powder	5%	Boric acid	Boric acid/sassolite
					Gulab Jal (Rose-water)	19%	Rose-water	Rose-water
					Carbon black	70%	Black carbon	Amorphous carbon

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lated from Farsi for sample "Surma Farid Ara") and "rose water" and "Greek herbs and rose water" (both translated from Urdu for samples "Lateef Surma 'surma sada mix' " and "Lateef Surma 'sukh chen sada,' " respectively). The other three with qualitative "contents data" are more specific about their contents (but give no amounts/percentages). Extra information/translation/interpretation is given in *italics* (in parentheses) after the (below) "contents data" of these three samples. For the sample "Al Haramain Ethmed": "It is the natural Ithmed stone powder, sulphur of Antinion (black and red)" (*this is referring to the often-quoted, but never yet seen by us, idea that antimony sulphide—the mineral stibnite—is the main component of the sample:* ***none*** *was found in this sample, the major phase found being* ***lead*** *sulphide*). For the sample "Hashmi ® Kajal" (in tube form, with a cardboard holder on which is printed its "contents data"): "Ingredients: Zinc oxide (B.P.) (*zincite, none found*), waxes (B.P.) (*paraffin wax was found*), processed carbon black (*amorphous carbon was found*), herbs, clarified butter, cinnamomun, camphora (*camphor, none found*)." For the sample "Hashmi Surma Sunef" (translated from very fine-print Urdu on its box lid): "Surma Black" (*often meaning galena, which was the major phase found here*), "Kushta-just" (*probably a zinc compound, zincite was found*), "Kafoor" (*camphor, none found*), "Warq Naqra" (*coconut, possibly the ground husk*), "Arq Badyan" (*currently of unknown meaning*) and "Mameera-o-deger Jary Bootiyam" (*mixture of herbs*).

As regards data on the medicinal effects from using a particular kohl sample, it was found that a total of fifteen samples (nine in Table I and six in Table II) had this written information (usually on an enclosed leaflet). Five of the six samples from Table II have had their medicinal effects of usage data discussed in a previous publication (1) and, with one exception (the sample "Surma Al-Sherifain," see below), will not be repeated here. The sixth sample from Table II, "Hind Ka Noor Eye Liner," had a leaflet inside its box that gave some medicinal effects of usage data in (colloquial) Arabic. On translation it was found to say: (this kohl is extremely useful for/against) "reducing cold," "eye ache," "all diseases of the eye," "heat in the eye," "improves eye-sight and strengthens vision," and also "can be used by adults and children." As this sample consists of amorphous carbon (the major phase), talc, and quartz (minor phases)—none of which are likely to give toxicity—the use of this kohl would be unlikely to make matters worse if used (externally) for the above "conditions." This kohl sample has been seen by us in many Middle Eastern souks, and only in two cases were enclosed leaflets found (in this study and in our Cairo study (3)).

Three of the nine such samples in Table I gave only limited information on their medicinal effects of usage. Such phrases occur as: "It glazes the vision and helps the eyelashes to grow better, treats and removes redness" (sample "Zikra Al Haramain," which has galena as its major phase); "Extremely soothing to the eyes. . . . . It also works as an antidote to eye irritation due to pollution and dust particles. . . . . It is an extremely beneficial tonic for weak eyes" (sample "Khojati® Toop Anjan®," which has amorphous carbon as its major phase); and "Most useful for the diseases of the eye" (translated from Urdu for sample "Shabnami Surma tark Chashma," a white sample with sassolite as its major phase). Commenting on the above it must be said that neither (matte) galena or amorphous carbon (or their associated minor phases) will give the above-stated medicinal effects of usage for the first two of the above samples, and while sassolite is both a mild antiseptic and a bacteriostatic material, its ability to be "useful" for all diseases of the eyes is questionable. A fourth sample from Table I, "Al Haramen Ethmed," has on an enclosed leaflet (in English and Arabic) a lot of information on the positive (and mostly correct) medicinal effects of antimony. However, as already stated, this sample has *no* antimony (sulphide) present, only lead sulphide—which most certainly does *not* have the stated positive medicinal effects mentioned (i.e., acting as an anti-parasitic/bacterial material).

The remaining five such samples from Table I (i.e., "Nimco No. 96. Neem Ka Tez Surma (Special)" and two each of the "Surma Harmain Al Sherfain" and "Surma Noor-Ul-Ain" samples), plus the sample "Surma Al-Sherifain" from Table II, were all found to have the *same* statement of medicinal effects on usage: "Most helpful in the treatment of all kinds of eye troubles such as: eye weakness, haziness, tears, eye dirt, burning eyes, scratching and redishness etc. Strengthens the vision and gives a cooling effect to the eyes while it fights disease. Used daily or once a week, helps keep eye ailments away in both young and old alike." Four of these six samples are made in India (by three apparently different companies) and two are made in Pakistan (by the same company). Having identical medicinal effects of usage "statements" implies either common ownership of the various companies and/or common employment of the same "copywriter." Also, three of these six samples have galena present as the major phase and another two have it present as a minor phase. Thus for the three samples with galena as the major phase, the above-listed medicinal effects are highly suspect, and for the other three samples (having talc, calcium carbonate, or zincite as their major phases), they are merely very questionable. Additionally, the sample named "Surma" in Table I was said (by the Fujairah city souk shopkeeper) to be "very good for sore eyes." It was a white powder whose major and minor phases were calcite and quartz, respectively. Even given the general non-toxicity of these compounds, we would question this therapeutic claim.

Four samples had the words "hot" or "cold" on their labels, and another, while not so labelled, was said by the shopkeeper to be "hot" (one of two "Surma Noor-Ul-Ain" samples purchased). A "hot" symbol (in Arabic) or word (in English and/or Arabic) on the sample's container/box is often used to indicate that the kohl can be used as an eye medicine and so will sometimes be placed *inside* the eye, while a "cold" symbol/word indicates that it is to be used solely for beautification and so is usually placed on the outside of the eye. The "hot" kohl often contains, or is thought to contain, a special "active ingredient" that acts as the eye medicine. This "active ingredient" is often stated (verbally by the shopkeeper or in writing on an enclosed leaflet) to be antimony sulphide (stibnite), but is nearly always found to be lead sulphide (galena) when the sample is chemically analyzed. The sample "Al Athmad" ("Eyes Kuhl." "Cold") contains no galena as expected, but "Kohl Original Stone. With Zam Zem water. Cold" *does* contain galena as its main phase. Also, for our only clearly labelled pair (i.e., one labelled "hot" and one "cold" on their container boxes) of samples ("Surma Harmain Al-Sherfain"), *both* were found to contain galena as their major phases and to have identical minor phases (anglesite and cerussite, both lead compounds). Also, these two samples had *identical* quantitative "contents data" on enclosed leaflets (see Table III). However, the two samples of "Surma Noor-Ul-Ain," which had containers that were almost identical and were labelled neither "hot" nor "cold," *were* found to have different chemical compositions. The sample stated to be "hot" by the shopkeeper *was* found to contain galena as a minor phase (zincite being the main phase), and the other sample (by implication "cold") had no galena present (calcium carbonate being the main phase). On the basis of these findings, it should be clear that such labelling is *not* to be trusted when trying to determine if an "active ingredient" is actually present in a sample purchased in the UAE. By contrast, in a very recent study in Saudi Arabia (14), all the samples labelled "hot"/"cold" did/did not have lead present.

COMPARISON WITH OTHER STUDIES

Of the 53 observably different kohl samples available in the six emirates studied here, it was found that twenty (38%) contain a lead compound (galena, PbS) as the major phase. This percentage is identical to that found for lead-containing samples in all the samples available in the souks of both Dubai and Sharjah; it is slightly higher than that found (36%) for the souk of RAK and is substantially different from the values found for the much smaller souks of Umm Al-Quwain (14%) and Ajman (57%). For the Fujairah city souk, it was found that while 40% of the samples purchased contained galena as a major phase, this value was calculated for only two of five samples purchased (a "selection"), and so is possibly not a true representation for that emirate.

The overall percentage (38%) is also smaller than that found by us for Abu Dhabi city (50% (1)), but is higher than our values found for Oman (32% (2)) and Cairo (33% (3)). By comparison, the lead-containing percentages given in Table IV, for other previous publications where kohl samples were analyzed, are almost all ≥50% (the one exception being the kohls purchased in Bahrain, where only 33% of the samples studied contained lead). The fifteen studies listed in Table IV, done over the twenty-five year period 1979–2004, have a range of 32% to 100% for those samples that contain lead. The "average" is 63% of samples found to contain lead.

The non-lead elements or compounds found in our present study (Figure 1 and Tables I and II) are broadly similar to those found in the previous studies of Table IV. However, several authors (14–17) did find antimony (usually in small/very small amounts) in some of their kohl samples, whereas we found no antimony whatsoever despite the verbal assurances of several Emirati shopkeepers and from information on enclosed leaflets.

Also, in the fifteen previous studies listed in Table IV it can be seen that India and/or Pakistan are mentioned as the origin of at least some of the kohl samples in ten of the studies. In Abu Dhabi city the percentage of samples originating in India and Pakistan was 89%. This value is similar to the values found in this study for five of the individual emirates: 81% each for Dubai and Sharjah, 86% for Ajman, 100% for Umm Al-Quwain, and for RAK only 68%. In Fujairah city souk's "selection," all (100%) originated in Pakistan, but this is probably not a true representation for that emirate. By contrast, the percentages in Oman and Egypt (Cairo) were only 40% and 22%, respectively. The reason for this difference in values between the UAE and these other two Middle Eastern countries is that samples were made locally in both Oman (38%) and Egypt (61%), unlike the UAE where only one such sample ("Zikra Al Haramain," which was made in Dubai) has ever been encountered.

The eight samples seen before by us in previous studies, but re-analyzed here (Table II), were all found to have essentially the same chemical composition regardless of locations of purchase.

CONCLUSIONS

In the 53 observably different kohl samples, found overall in the six emirates covered in this study, the main component of twenty was determined to be galena (with three more

Table IV
Other Analyses of Kohl Samples

n	Made in	Purchased in	No. containing lead (%)	Non-lead elements/compounds	Method(s) used	Year and reference
11	India and Pakistan	Midlands (UK)	6 (55%)	Zn,C/Menthol, Herbs, Pearls	AA, XRPD	(1979) (18)
13	Not given	Kuwait	11 (85%)	C/$Fe_2O_3.H_2O$, Herbs	AA, XRPD, SEM	(1981) (19)
17	Nigeria	Nigeria	17 (100%)	C/Herbs	AA, XRPD, SEM	(1984) (20)
21	Saudi Arabia and India	Saudi Arabia	14 (67%)	C,O,S,Si,Ca,Fe,Al,Ti,Sb,Na,Zn,Cl,K	SEM	(1995) (15)
47	Mostly India, Pakistan and Oman	Mostly Oman (39)	15 (32%)	Mostly compounds based on Fe, Ca, Zn, and B. Also, various C compounds.	XRPD, SEM	(1998) (2)
23	Mostly India and Pakistan	United Arab Emirates (Mostly Abu Dhabi, 18)	11 (48%)	Various; largely as above.	XRPD, SEM	(2002) (1)
18	Egypt (11), India (4), China, Sudan and Saudi Arabia	Cairo	6 (33%)	Various; largely as above.	XRPD, SEM	(2004) (3)
Kohl analyses using only AA (atomic absorption):						
22	Mostly India, Pakistan and Morroco	World-wide[b]	13[a] (59%)	Not given	AA	(1991) (21)
21	Mostly India, Pakistan and Saudi Arabia	Bahrain	7[a] (33%)	Not given	AA	(1992) (22)
6	Mostly India and Saudi Arabia	Saudi Arabia	4[a] (67%)	Sb (at less than 10%) in five samples	AA	(1993) (16)
10	Pakistan	Pakistan (Karachi)	8 (80%)	Zn (in the 2 non-lead samples), SiO2 (all)	AA	(1994) (23)
8	Mostly Saudi Arabia	Saudia Arabia	6[a] (75%)	Sb, As, Cd and Pt (all at less than 1%)	AA	(1995) (17)
28	Egypt (18), imported (10)	Egypt (Greater Cairo)	14[a] (50%)	Not given	AA	(1997) (24)
10	Morocco (6), imported (4)	Morroco (Marrakech)	10 (100%)	Not given	AA	(2001) (25)
107	Saudi Arabia, India, Pakistan, Iran	Saudi Arabia	62 (58%)	Al, Sb (each at less than 1%) and Camphor/Menthol found in a few samples	AA	(2004) (14)

[a] Above 1% lead.
[b] America, UK, Morocco, and Mauritania.

samples having it present as a minor phase). Therefore, almost half (43%) of these 53 available samples contain a lead compound. Sixteen more were based on amorphous carbon, seven on zincite, five on sassolite, two on the iron compounds hematite and goethite, two on calcium carbonate, and one on talc.

This study shows that traditional eye cosmetics, "kohls," are still readily available in the souks of Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah, and Fujairah and that, unfortunately, many do still contain the toxic element lead (as PbS). The largest three emirates (Dubai, Sharjah, and RAK) have, as expected, the largest souks and thus the largest number of available kohl samples for purchase. If three kohl samples were bought in any one of these three emirates' souks, then there would be a high probability that one would contain lead, and in all likelihood there would be *no* clear indication of this on its container or enclosed leaflet. Moreover, some of the most available kohls not only contain lead, but contain it in a form (i.e., small particle size) that makes it more easily absorbed into the human gut. Finally, we can only reiterate that this element has no known biological value and is an insidious cumulative poison having potentially devastating cognitive effects if applied regularly to young children.

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