Minions and Caradon Hill

Minions and Caradon Hill is the second Bodmin Common which we have investigated. This area is also referred to as St Cleer. This is another enclosed area of moorland—the two areas are linked by a road which allows access (including by the ponies) to both areas. Ponies are reported in emaciated condition both in the winter and summer. As this is another area which experiences persistent welfare problems, we also conducted environmental sampling in this area. Once our investigations began, a hair sample was obtained from a pony from this area which had just died. It was in emaciated condition. After receiving the results of this pony, we then tested ponies which had been removed from the Moor in emaciated condition. They had been cared for off of the Moor and were now in good body score condition. It should be noted that “Bodmin ponies” are not a native breed of pony to the UK.

This is an area from which ponies are known to be entering into the human food chain.

Example of the emaciated condition of moorland ponies removed from the Minions area in previous years.

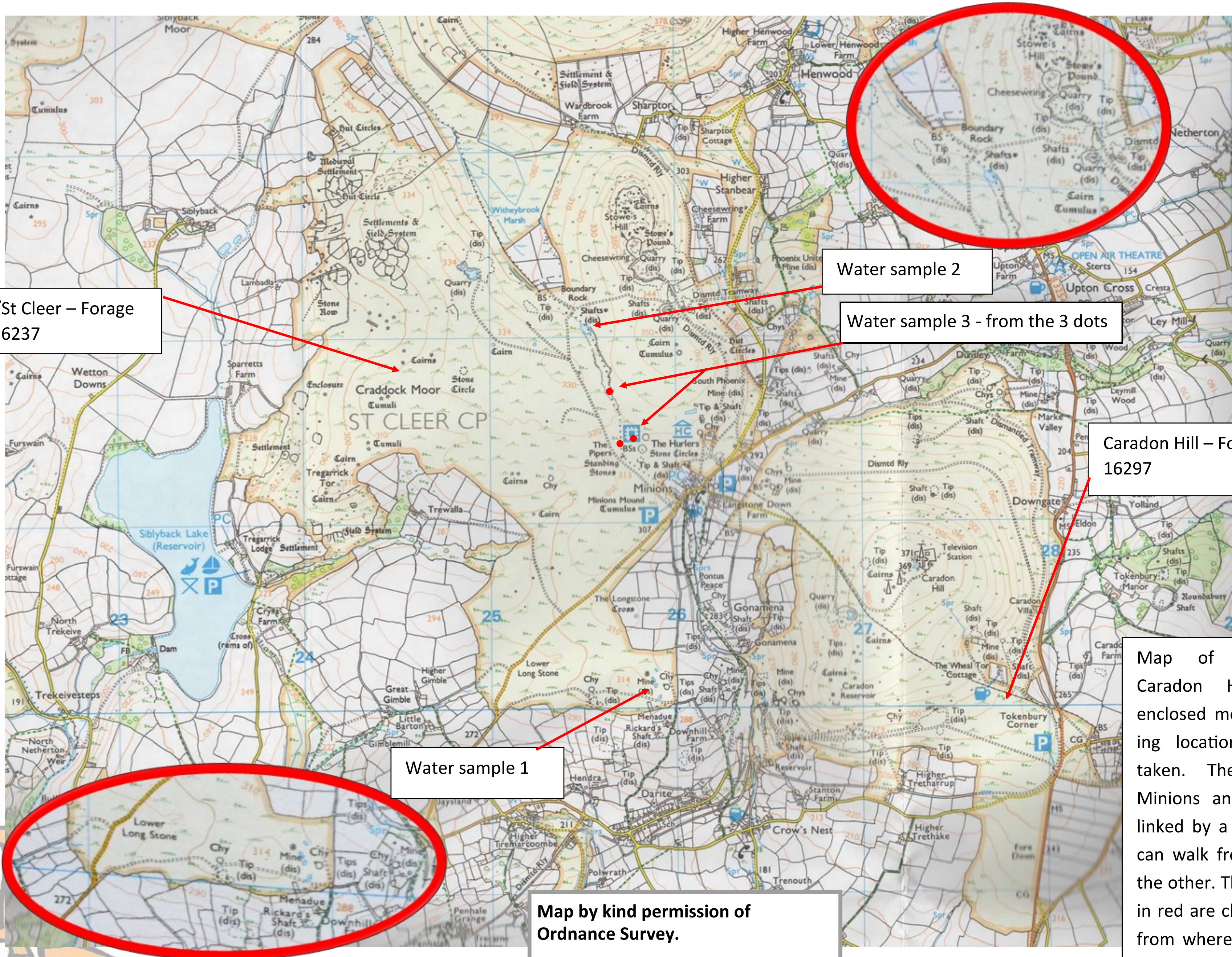
Previous Land Use

The Minions/Caradon Hill/St Cleer moorland area is part of an area designated as a UNESCO World Heritage Site because of its mining history. Of approximately 100 engine houses built around Minions, evidence is said to remain for 42 of them. (Herring, P. 2008: Bodmin Moor, An Archaeological Survey, Volume 2. English Heritage, page 66). Industrial activity has included copper, tin, and manganese mining as well as granite quarrying. The area around Phoenix United mine is designated a Site of Special Scientific Interest (SSSI) under section 28 of the Wildlife and Countryside Act 1981. The Natural England citation states “ The ecology of the site is strongly influenced by the presence of heavy metals in the mine waste and soils which have severely restricted the growth of vascular plants, favouring colonisation by bryophytes and lichens”. “Open water habitats include small pools and derelict mine leats in addition to the fast-flowing stream rich in dissolved metals.“ “The mine spoil tips, associated mine buildings, tracks and the stream banks support a specialised flora of rare mosses and liverworts which are tolerant of the high levels of toxic metals, particularly copper. This contamination has severely restricted the growth of vascular plants, favouring colonisation by specialised mosses and liverworts. To date a total of three nationally rare mosses, three nationally rare liverworts and one nationally scarce liverwort have been recorded at Crow’s Nest”. One particular type of moss is restricted to copper-rich mine waste at two Cornish sites, Crow’s Nest and a site near to Minions on the north side of Caradon Hill. (http://www.sssi.naturalengland.org.uk/citation/citation_photo/2000114.pdf, http://www.sssi.naturalengland.org.uk/citation/citation_photo/2000274.pdf)

Industrial activity has taken place in this area since prehistoric times. The earliest workings appear to be on the site of Witheybrook Marsh to the north-west of Minions. By the Middle Ages the most notable stream works in the area were at Witheybrook, Tremar Coombe, Tregarrick and Trewalla on Craddock Moor to the west of Minions, and Gonamena. (Gillard, B. 2004: Cornwall Industrial Settlements Initiative, Minions. Truro, page 8). In the 16th century, tin streamworks were in operation to the north of Caradon Hill (SX2571) and contained some of the richest and most accessible tin lodes on the moor and became some of the most successful deep mines in later centuries.

“Large reserves of copper were discovered under Caradon Hill in 1836. The major copper mines of the Caradon area produced about 600,000 tons of ore during their 50-year lifespan; the output figures for the remaining moorland copper mines were small. The figures for tin are more difficult to summarise, given that early production figures are virtually non-existent”. (Herring, P. 2008: Bodmin Moor, An Archaeological Survey, Volume 2. English Heritage, page 18)

Arsenic was considered a valuable by-product of tin and copper mining in Cornwall and was used in a variety of industries.



Map by kind permission of Ordnance Survey.

OS Explorer 109 scale 1:25000.

Map of Minions and Caradon Hill areas of enclosed moorland, including locations of samples taken. The two areas of Minions and Caradon are linked by a road so ponies can walk from one side to the other. The insets circled in red are close-up sections from where water samples have been taken. These water sources are former mining pits and shafts.

By the mid 1890s almost all mining on Bodmin ceased due to falling ore prices.

Of interest is this quote from 1844, which states that 'The moors in the parish of St Cleer, barren and desolate in the extreme, on which nothing useful to the purposes of man was found, but huge masses of granite, or scanty sheep pasture, and which were as silent as they were desolate, have assumed a cheerfulness and activity, the result of noisy and busy labour' (Mining Journal, 8 May 1844).

The moor today is used to graze animals—cows, sheep and ponies. It is also used for recreation purposes, promoted to tourists and to the general public who can access the moor and its prehistoric monuments under the Countryside and *Rights* of Way Act 2000 also known as the "Right to Roam". Minions has a visitor centre to promote its industrial heritage.

Heavy Metals

"The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain" (http://www.lenntech.com/processes/heavy/heavy-metals/heavy-metals.htm #ixzz4HdOtRa00).

Grasses and plants uptake heavy metals from soils that have been exposed to mining operations, pollutants, and contaminants (such as petroleum and associated by-products).

"Heavy metals are dangerous because they tend to **bioaccumulate**. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater" (http://www.lenntech.com/processes/heavy/heavy-metals/ heavy-metals.htm#ixzz4HdOtRa00).

Testing

Hair Tissue Mineral Analysis testing is the only accurate method for detecting heavy metals as toxic metals are not found in blood except immediately after acute exposure. " Hair has been accepted as an effective tissue for biological monitoring of toxic heavy metals by the U.S Environmental Protection Agency and is being used for this purpose throughout the world". "Hair tissue mineral analysis (HTMA) has been used to determine the impact of minerals found in the environment as well as studying archeological or historical specimens, pollution and correlation of soil mineral content in local populations, pre and postnatal effects of mercury exposure, the effects of dietary changes in healthy populations, and industrial pollution from accidental and intentional dumping" http://www.traceelements.com/docs/NewsletterMarch-April2016.pdf. The Journal of Equine Veterinary Science , vol. 35 Issue 4, April 2015, states that hair mineral analysis is a suitable tool for evaluating the mineral status in the horse and that hair is a better biological indicator than serum in assessing mineral status. Heavy metals cannot be detected in blood except after immediate, acute exposure.

Toxic metals accumulate in soft tissues not blood or urine. Once exposed to heavy or toxic metals, they remain in the blood for approximately 24 hrs. They then leave the blood and deposit in the soft tissues where they remain until exposure is discontinued or procedures are taken to remove them from the system. Once the source of toxicity is identified, a mineral balancing program is recommended and it takes between five to seven months to bring elevated heavy metals to an acceptable level.

Pony 4

The first pony Hair Mineral Tissue tested from this area (known as "Pony 4") had just died and was in emaciated condition. The pony was a young mare, approximately 2 years in age. An egg worm count returned a result of 700 eggs per gram—considered to be a medium count.

The results of the hair test were interpreted by agricultural scientist Kerry Marsh (B.Ed.B.Ag.Sc.). The results revealed the pony had toxic levels of arsenic, aluminum, and a level of uranium in her results. She also had toxic levels of iron and manganese. The cobalt and copper levels were high. Marsh stated that such elevated levels of these minerals and toxic metals are due to environmental exposure and this could be due to the water or soil as a source, or a combination of both. As this pony had not been fed or supplemented, the only route of such high levels of minerals and toxic metals is contamination. The additional elements show a very high level of lithium. Her sodium, potassium, zinc, selenium and sulphur levels were low with phosphorous and boron being in the very low range. The graphs displayed below show the results of the hair testing. Five of pony 4's results were beyond the limits of the top level of the graph. Iron is considered to reach a high level at a reading of 9.6 mg%, pony 4 returned a reading of 39 mg% (or 390 ppm—to convert mg% to ppm, multiply mg% result by 10). Manganese reaches a high level at 1.120 mg% and pony 4 returned a result of 2.568 mg%. Arsenic reaches a high level at .070 mg% and pony 4 returned a result of .432 mg%. Aluminium reaches a high level at 4.8 mg% and pony 4's result was 31.7 mg%. Lithium is high at .002 mg% and pony 4's result was .086 mg%.

Marsh stated that arsenic, depending on the form, is deadly to horses. Generally, toxic levels of arsenic are due to long term environmental exposure. Arsenic and other toxic metals cross the placental barrier. So if the mare had a level of arsenic, the foal is also born with an arsenic level. Foals are more susceptible to arsenic poisoning. A small dose over a period of time will result in sub acute poisoning. At some stage, the liver fails causing death. Arsenic stores in the liver and "Pony 4" had chronic liver and kidney stress. One of the many symptoms of arsenic poisoning is anorexia. The aluminium level is also at a very high level and once again it depends on the form of aluminium. Nevertheless, aluminium toxicity causes serious health effects. Her nutritional mineral levels are severely imbalanced due to the excesses of iron, manganese, cobalt and copper. Excesses of these three minerals are not fatal. Interestingly there is a level of uranium present but it is not at such a level to cause serious health issues. If there was mining in this area, I would suggest that soil and/ or water be tested for arsenic and uranium on this site. Beryllium was present in the profile but within the acceptable reference range. The cause of death is not entirely clear but arsenic toxicity should be suspected as horses with toxic levels of arsenic have loss of appetite and eat little when food is offered.

Mineral ratio indicators suggested this pony had chronic kidney and liver stress, hormone imbalance, adequate bone density, adequate thyroid function and severely underactive adrenal gland function. There was an indicator that she may have been carrying a full blown infection that may not be obvious such as tooth abscess of hoof abscess etc, though this reading may be produced by the excess iron toxicity affecting the ratios.

Toxic elements are stored in body tissue, in the liver and in the brain. Whilst an animal is alive it is possible to release the toxicity but once an animal is dead, it is not possible to remove the toxicity stored in the body. When this is consumed by a human or animal, the toxicity is passed on and will be stored in the body of the consumer. When exposure ceases, the level of heavy metals may drop to a certain degree but particular antagonists are required to reduce/remove toxicity and it is not something that will be removed by changing pasture alone.

Aluminum (depending on the form) is generally found in contaminated water, poor, acidic soils, coal fired power plants, bauxite mining, some horse wormers as an anti caking agent, ulcer treatments. Symptoms may include: kidney and liver dysfunction, colic, dry skin and coat, hind incoordination neurological disturbance.

Lithium sources include contaminated water and soil. The contamination is usually due to lithium grease/oil from discarded drums or leakages. Symptoms may include: muscle tremors, stiffness, rapid respiration, diarrhea.

Pony 11 and Pony 12

As there was no further access to test horses currently on the moor, 2 further horses were tested which had been removed from the moor in emaciated condition during previous years. One male (now gelding), pony 11, rescued in 2014 as a yearling, and the second a filly, pony 12" rescued in 2015 as a yearling.

Marsh stated "Pony 11" had similar toxic elements and additional elements to Pony 4 also from Minions. Aluminium, arsenic and beryllium were on profile. Lithium and iron are also in the high range as they were on Pony 4's tissue test. The mineral ratio indicators for this pony also suggested loss of calcium from bone, and an indicator that he may have been carrying a full blown infection that may not be obvious such as tooth abscess of hoof abscess etc. This reading may also be due to iron toxicity which antagonises copper and zinc. This pony had good levels of boron, chromium, cobalt, copper, magnesium and manganese. Calcium and phosphorus were at a very low level. Pony 11 had low levels of molybdenum, potassium, selenium, sodium, sulfur and zinc. A toxic levels of iron and aluminum are recorded. Lithium is in the very high range.

Marsh stated the results of "Pony 12" were very similar to "Pony 11" in as much as arsenic and beryllium are present on the toxic elements and she has a very high level of aluminum and lithium. Iron is at the toxic level. It is quite obvious both ponies are from the same area and been exposed to the same heavy metals, excesses of iron and lithium. Pony 12 will also need supplements added to her diet as she too is very low on calcium and is losing calcium from bone. The calcium/phosphorous ratio is most important for horses to be in relative balance as the horse consists of so much bone. Indicators showed significant loss of calcium from bone, and an indicator that she may have been carrying a full blown infection that may not be obvious such as tooth abscess of hoof abscess etc, though again this reading may be produced by the excess iron toxicity. The indicators suggest overactive thyroid function and adrenal gland function. The

Hair Mineral Tissue Testing Results for Pony 4

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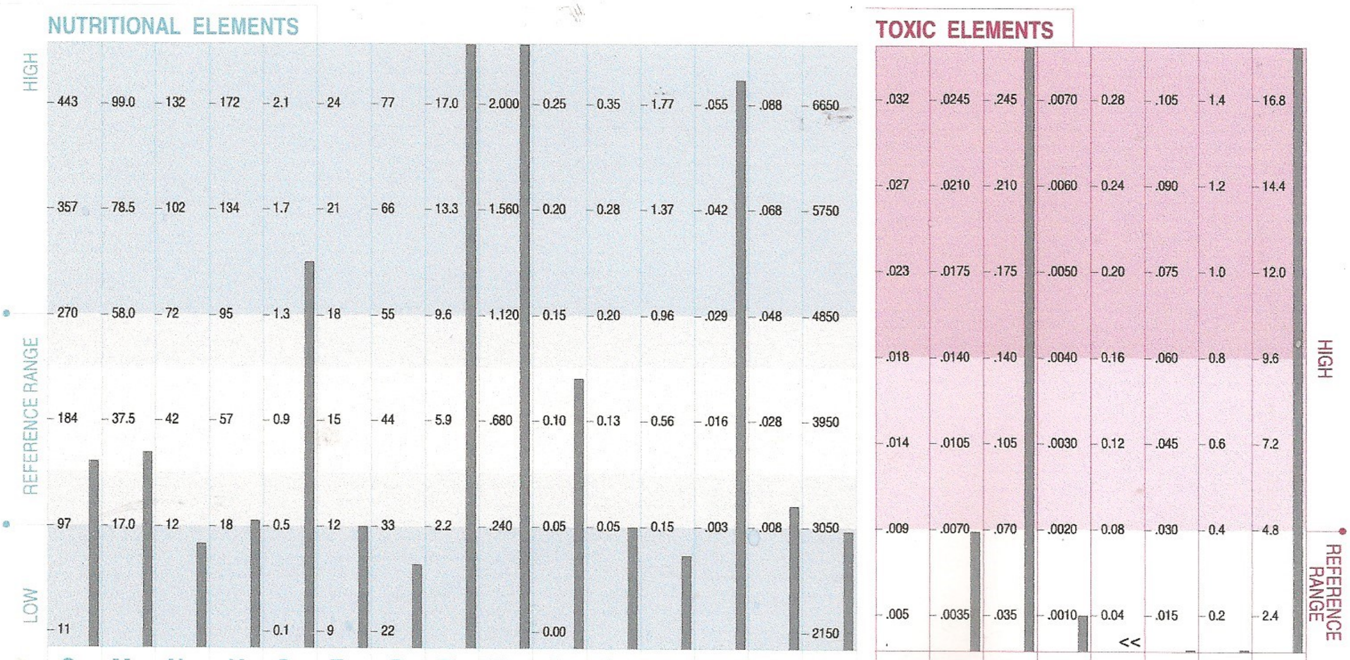
Email lab@interclin... 4301 Sunbelt Drive · Addison, Tx · 75001 · U.S.A.

LABORATORY NO.:	1305320
PROFILE NO.:	16
EQUINE:	PONY 4,
AGE:	2
SEX:	F
REQUESTED BY:	MARSH, K
ACCOUNT NO.:	2216
DATE:	20/04/2016

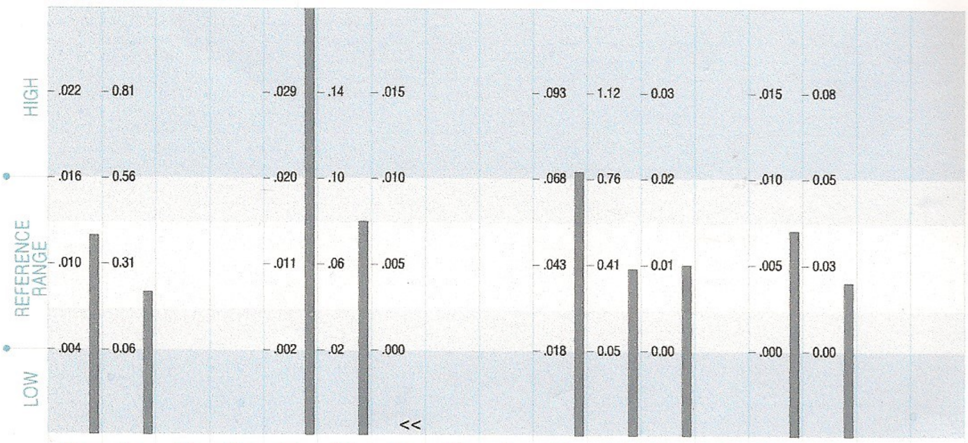
NUTRITIONAL ELEMENTS / TOXIC ELEMENTS



Ca	Mg	Na	K	Cu	Zn	P	Fe	Mn	Cr	Se	B	Co	Mo	S
Calcium	Magnesium	Sodium	Potassium	Copper	Zinc	Phosphorus	Iron	Manganese	Chromium	Selenium	Boron	Cobalt	Molybdenum	Sulfur
150	31.2	7	20	1.5	12	29	39.0	2.568	0.12	0.05	0.04	.058	.012	3017

Sb	U	As	Be	Hg	Cd	Pb	Al
Antimony	Uranium	Arsenic	Beryllium	Mercury	Cadmium	Lead	Aluminum
N/A	.0069	.432	.0010	0.01	.003	0.1	31.7

ADDITIONAL ELEMENTS



Ge	Ba	Bi	Rb	Li	Ni	Pt	Tl	I	V	Sr	Sn	Ti	W	Zr
Germanium	Barium	Bismuth	Rubidium	Lithium	Nickel	Platinum	Thallium	Iodine	Vanadium	Strontium	Tin	Titanium	Tungsten	Zirconium
.012	0.23	N/A	N/A	.086	.08	.001	N/A	N/A	.070	0.39	0.01	N/A	.007	0.02

"<<": Below Calibration Limit; Value Given Is Calibration Limit

"QNS": Sample Size Was Inadequate For Analysis.

"NA": Currently Not Available

Laboratory Analysis Provided by Trace Elements, Inc., an H. H. S. Licensed Clinical Laboratory. No. 45 D0481787

20/04/2016
CURRENT TEST RESULTS

PREVIOUS TEST RESULTS

'Welfare In Action'

Hair Mineral Tissue Testing Results for Pony 11

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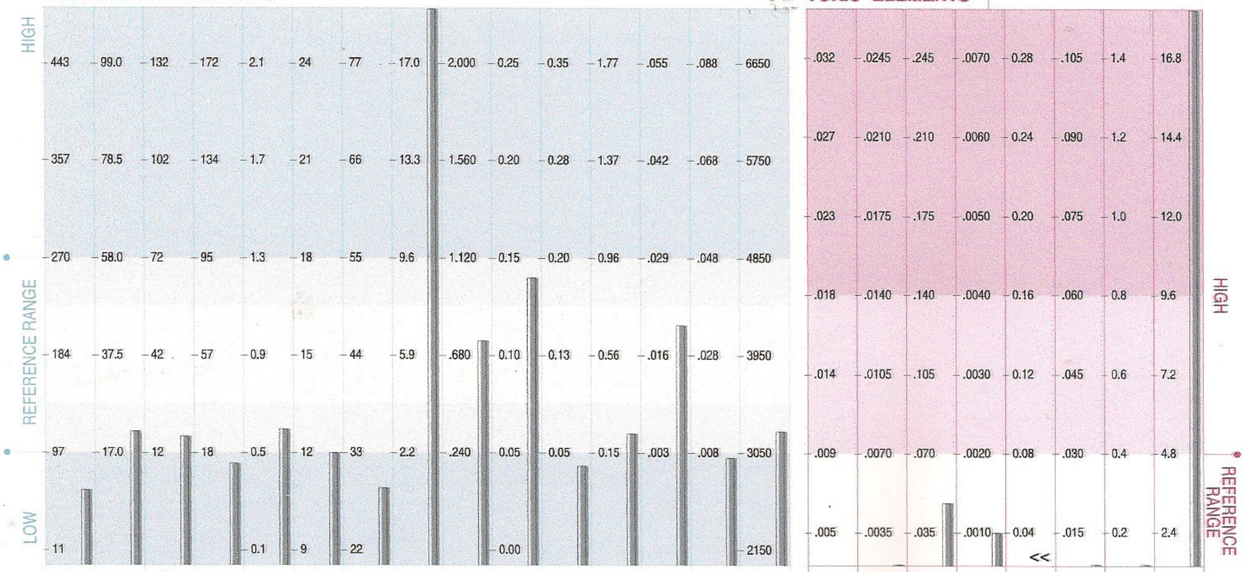
LABORATORY NO.:	1310974		
PROFILE NO.:	16		
EQUINE: PONY 11 - [redacted]	AGE: 3	SEX: G	
REQUESTED BY: MARSH, K	ACCOUNT NO.: 2216	DATE: 24/05/2016	

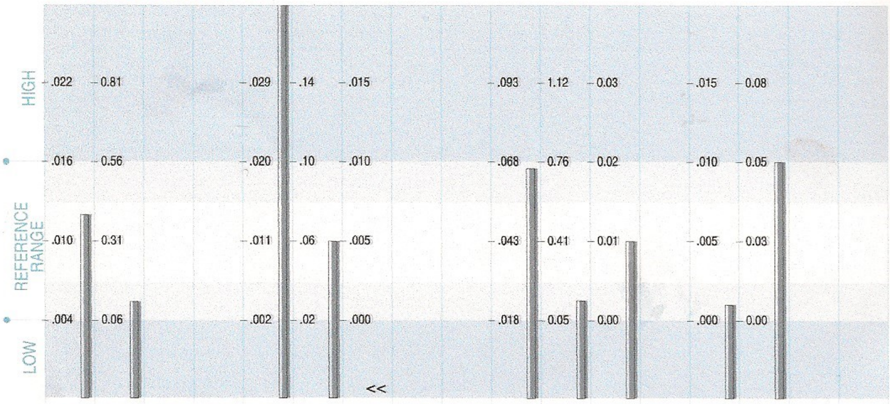
NUTRITIONAL ELEMENTS / TOXIC ELEMENTS



Ca	Mg	Na	K	Cu	Zn	P	Fe	Mn	Cr	Se	B	Co	Mo	S
Calcium	Magnesium	Sodium	Potassium	Copper	Zinc	Phosphorus	Iron	Manganese	Chromium	Selenium	Boron	Cobalt	Molybdenum	Sulfur
64	21.6	17	14	0.6	12	29	40.6	.747	0.14	0.04	0.23	.020	.007	3255

Sb	U	As	Be	Hg	Cd	Pb	Al
Antimony	Uranium	Arsenic	Beryllium	Mercury	Cadmium	Lead	Aluminum
N/A	.0010	.048	.0010	0.01	.001	0.1	23.7

ADDITIONAL ELEMENTS



Ge	Ba	Bi	Rb	Li	Ni	Pt	Tl	I	V	Sr	Sn	Ti	W	Zr
Germanium	Barium	Bismuth	Rubidium	Lithium	Nickel	Platinum	Thallium	Iodine	Vanadium	Strontium	Tin	Titanium	Tungsten	Zirconium
.012	0.12	N/A	N/A	.087	.06	.001	N/A	N/A	.066	0.14	0.01	N/A	.001	0.05

"<<": Below Calibration Limit; Value Given Is Calibration Limit

"QNS": Sample Size Was Inadequate For Analysis.

"NA": Currently Not Available

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24/05/2016
CURRENT TEST RESULTS

PREVIOUS TEST RESULTS

'Welfare In Action'

Hair Mineral Tissue Testing Results for Pony 12

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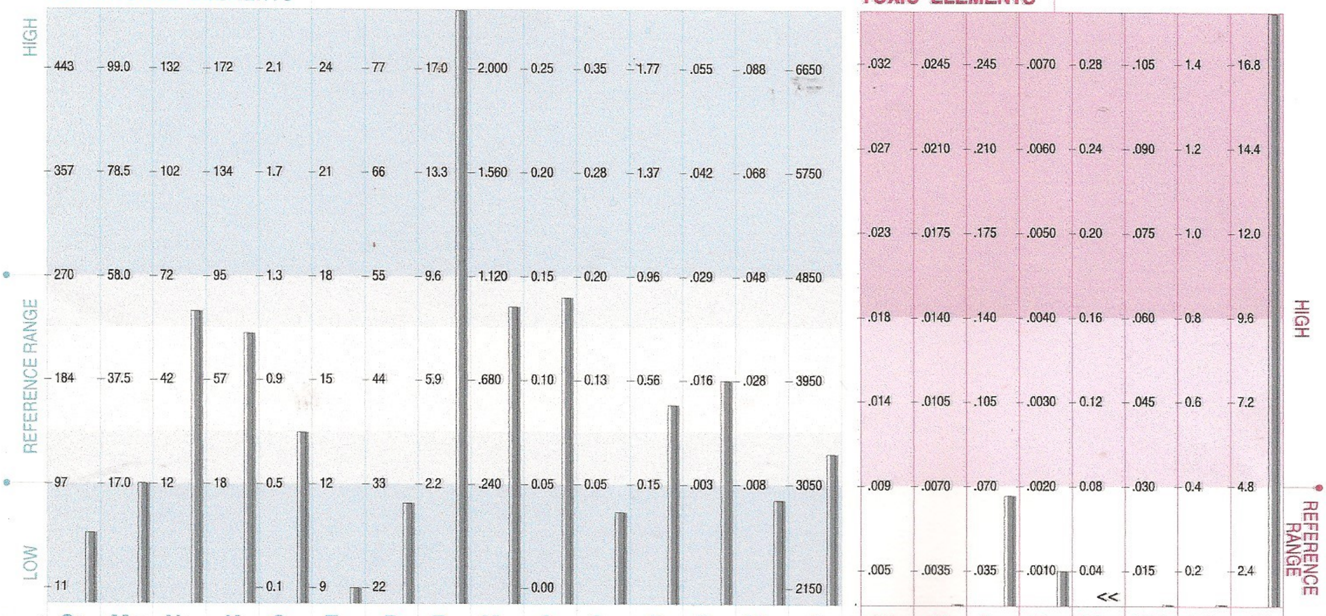
LABORATORY NO.: 1310975			
PROFILE NO.: 16			
EQUINE: PONY 12 - [redacted]	AGE: 2	SEX: F	
REQUESTED BY: MARSH, K	ACCOUNT NO.: 2216	DATE: 24/05/2016	

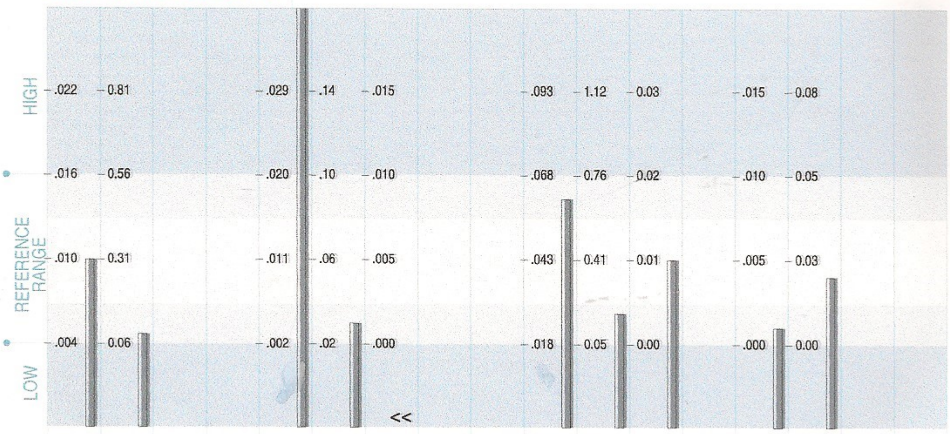
NUTRITIONAL ELEMENTS / TOXIC ELEMENTS



Ca	Mg	Na	K	Cu	Zn	P	Fe	Mn	Cr	Se	B	Co	Mo	S
Calcium	Magnesium	Sodium	Potassium	Copper	Zinc	Phosphorus	Iron	Manganese	Chromium	Selenium	Boron	Cobalt	Molybdeum	Sulfur
56	17.1	62	74	0.7	9	31	35.1	.991	0.14	0.03	0.46	.016	.005	3317

Sb	U	As	Be	Hg	Cd	Pb	Al
Antimony	Uranium	Arsenic	Beryllium	Mercury	Cadmium	Lead	Aluminum
N/A	.0013	.066	.0010	0.01	.001	0.1	21.6

ADDITIONAL ELEMENTS



Ge	Ba	Bi	Rb	Li	Ni	Pt	Tl	I	V	Sr	Sn	Ti	W	Zr
Germanium	Barium	Bismuth	Rubidium	Lithium	Nickel	Platinum	Thallium	Iodine	Vanadium	Strontium	Tin	Titanium	Tungsten	Zirconium
.010	0.09	N/A	N/A	.061	.03	.001	N/A	N/A	.061	0.18	0.01	N/A	.001	0.02

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Laboratory Analysis Provided by Trace Elements, Inc., an H. H. S. Licensed Clinical Laboratory. No. 45 D0481787

24/05/2016
CURRENT TEST RESULTS

PREVIOUS TEST RESULTS

Table comparing Hair Mineral Tissue Testing Results From Minions/Caradon Hill Ponies. From Kerry Marsh's Interpretation of Results.

	B	Ca	Cr	Co	Cu	Fe	Mg	Mn	Mo	P	K	Se	Na	S	Zn
Pony 4	Low	Good	Good	High	High	Toxic	Good	Toxic	Good	Low	Low	Low	Low	Low	Low
Pony 11	Good	Low	Good	Good	Good	Toxic	Good	Good	Low	Low	Low	Low	Low	Low	Low
Pony 12	Good	Low	High	Good	Good	Toxic	Low	High	Low	Low	Good	Low	High	Good	Critically low

(yellow) High	B	Boron	Fe	Iron	K	Potassium
(red) Low	Ca	Calcium	Mg	Magnesium	Se	Selenium
(green) Good	Cr	Chromium	Mn	Manganese	Na	Sodium
(black) Critically low	Co	Cobolt	Mo	Molybdenum	S	Sulphur
(blue) Non existent	Cu	Copper	P	Phosphorus	Zn	Zinc

	Aluminium	Lithium	Arsenic	Beryllium	Uranium
Pony 4	Toxic	Very High	Toxic	Present	Present - just within range
Pony 11	Very High	Very High	Present	Present	Trace
Pony 12	Very High	Very High	Present - just within range	Present	Trace

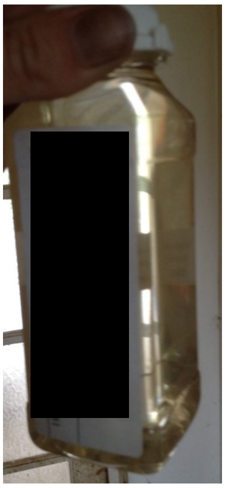
pony had good levels of boron, cobalt, copper, potassium and sulphur. She had a critically low level of zinc, a very low level of calcium, and low levels of magnesium, molybdenum, phosphorus, selenium. Pony 12 had a slightly high level of chromium, manganese and sodium, and a toxic level of iron. The arsenic level is at the upper end of the reference range, just below the high range.

Pony 11 and Pony 12 have been removed from the environment for a period of time. They have been nutritionally supplemented with balancers, good quality feed and hay, and they have regained weight and are now in good body condition but they have retained toxicities, and continue to have deficiencies in essential minerals.

Testing results from East Moor (approximately 5km north of Minions) showed no toxicity of aluminium or lithium. Toxic elements such as arsenic or beryllium were either non existent or at very low/trace levels. Only one pony at East Moor returned levels of toxic elements including toxicity of beryllium, uranium and aluminium - this pony must have either come from another area or been born to a mare which had already accumulated levels of toxicity.

The Environmental Testing

Water Sample 1



Water Sample 2

To see whether the deficiencies and toxicities discovered from the test results are present in the environment, testing was conducted. Two forage tests were conducted, one on the Minions common and one on Caradon Hill. There are multiple water sources available, some are pits/shafts from previous mining activity which are filled with water. The ponies are seen to drink from these sources. Whilst it would have been preferable to test all the water sources available, financial budget was a limitation. Two separate water sources were tested, both on the Minions common (see the map on page 2 for locations). ForagePlus provided the sterile bottles required for this water sampling and samples were analysed by NRM laboratories in Berkshire. One further test was taken as a combination of 3 water sources on this site and this was analysed by Lancrop Laboratories in York.

Bags were also supplied for forage sampling. Analysis was undertaken by ForagePlus. Grass samples were taken by roaming over the moorland area and taking forage from across the area. Forage tests measure mineral levels in the forage. The forage tests do not measure the presence of toxic elements such as arsenic or beryllium. The forage tests measure levels of the following minerals - phosphorus, magnesium, calcium, sodium, potassium, chloride, manganese, copper, zinc, selenium, cobalt, iodine, lead, iron, aluminium, molybdenum, and sulphur.

Livestock water quality reports measured levels of calcium, phosphorus, magnesium, sodium, potassium, chloride, copper, iron, lead, manganese, zinc, arsenic, beryllium, uranium, aluminium, ammonium nitrogen, nitrate nitrogen, electrical conductivity, and pH.

Water results Minions

Horses drink between 25 to 45 litres per day depending on size and can take on toxicity through their water supply. Many of the results from the water quality tests were within acceptable ranges. The table below highlights some of the levels that returned above the maximum acceptable levels of elements in drinking water.

	Livestock Limit	Human Limit	Sample 1	Sample 2	Sample 3
Iron (mg/l)	0.3	0.2	**12.1**	**0.47**	**3.6**
Manganese (mg/l)	0.05	0.05	**0.16**	0.03	**0.25**
Aluminium (mg/l)	0.5	0.2	0.29	0.17	0.243
Arsenic (ug/l)	25 - 200 depending on text/research	10	**1826**	2.97	<10

Table of water sample results displaying some of the levels that returned above the acceptable levels of elements in drinking water. Limits for humans obtained from Defra guidelines http://dwi.defra.gov.uk/consumers/advice-leaflets/standards.pdf Livestock limits obtained from David K. Beede Phd, 2006: Evaluation of Water Quality and Nutrition for Dairy Cattle. Michigan State University and table 2 of http://sheboygan.uwex.edu/files/2010/08/UMWaterQuality.pdf

Sample 1 —The level of iron at 12.1 mg/l (milligrams/litre) is above the livestock limit of 0.3 mg/l and the laboratory recommended that this water source should not be used. **The maximum level of arsenic in human drinking water is 10 ug/l (microgrammes/litre). Guidelines for the maximum acceptable level of arsenic in livestock water vary between 25 ug/l to 200 ug/l. The limit for concentrations of potentially toxic substances in drinking water for livestock recommended by the National Academy of Sciences 1974 states the limit for arsenic is 0.2 ppm, or 200 ug/l. The result of arsenic in sample 1 was 1826 ug/l. This is 182 times the acceptable level of human drinking water toxicity and well above the maximum limit for livestock.** This water source is open to access by animals and humans.

The manganese level is also above the recommended limit of 0.05 mg/l**.** Levels of beryllium, uranium and aluminium were recorded in the sample. Beryllium returned a result of 0.2 ug/l, uranium 1.82 ug/l both elements were present but within acceptable parameters. The level of aluminium was above human safety limits but below the maximum livestock limit. The sample had an acidic pH of 5.7.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units	Comments
Total Arsenic	1826	ug/l	
Total Beryllium	0.2	ug/l	
Total Uranium	1.82	ug/l	
Total Aluminium	0.29	mg/l	

Sample 2 — Iron returned a reading of 0.47 mg/l which is above the recommended limit for humans and livestock. The laboratory thought this would affect taste and could potentially cause staining but is not at a level to cause a health risk. The arsenic level was recorded at 2.97 ug/l, beryllium <0.1 ug/l, Uranium 0.09 ug/l and aluminium 0.17 ug/l. The sample had a pH of 5.6 which is classed as acidic.

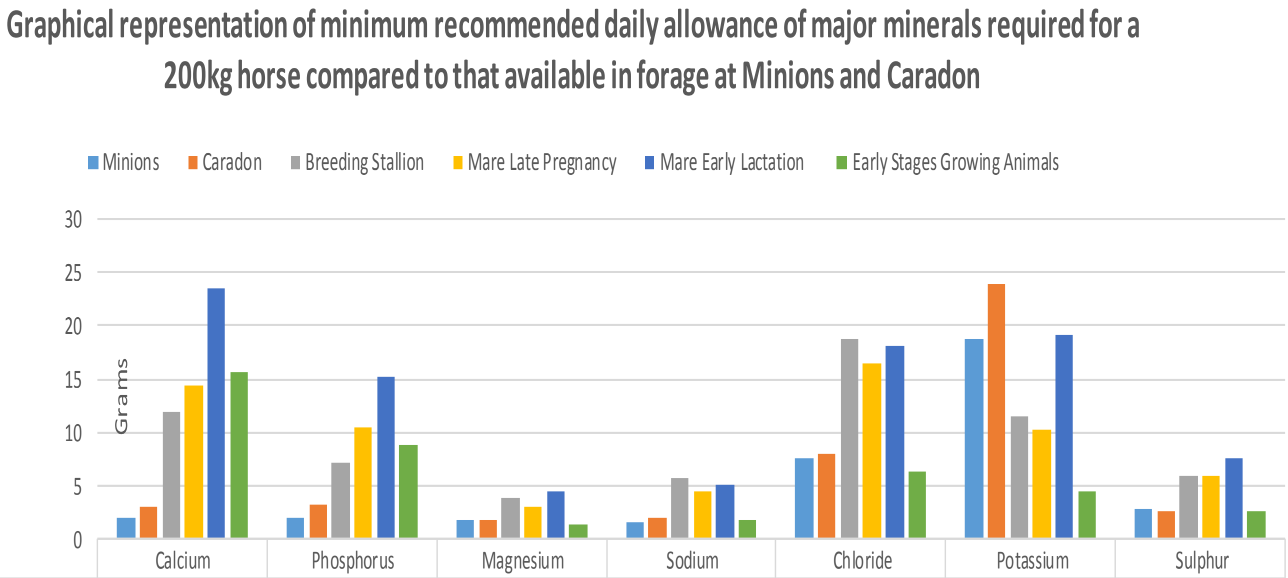
Sample 3 - was a combination of 3 water sources (2 pools, and a stream channel). The iron level was at 3.6mg/l which is above the recommended livestock and human maximum limit of 0.3 mg/l and 0.2 mg/l respectively. The manganese level is also above the maximum acceptable level of 0.05 mg/l. The level of aluminium was above the human limit but below the maximum livestock limit. The level of arsenic was below 10 ug/l. The sample was very acidic with a pH reading of 3.9. The guidelines on acceptable limits for pH are 5.6 to 9.0 (David K. Beede Phd, 2006: Evaluation of Water Quality and Nutrition for Dairy Cattle). Nitrates were at very high levels of 247 mg/l. Guidelines suggest a maximum limit of 100mg/l for livestock https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf, page 96). Separate samples would need to be taken from the separate sources to get accurate information on the toxicities/potential problems identified.

Forage Results:

Forage results reports were produced by ForagePlus. The ForagePlus site results are published alongside graphs displaying the recommended daily allowance recommendations for a 500kg horse in light work. The ponies in our area of interest are smaller in weight, and are working stallions, pregnant/lactating mares, or youngsters. The ForagePlus site results have been reproduced below alongside graphs displaying the recommended daily minimum mineral uptake of horses within the weight range of the ponies that reside on Minions and Caradon Hill. The minimum recommended daily intake figures for 200kg and 400kg horses were gained from the published tables "Daily Nutrient Requirements of Horses", "Nutrient Requirements of Horses: Sixth Revised Edition, 2007, chapter 16, published by the National Research Council". No chart was available for 300kg horses. As the horses at Minions/Caradon are approximately between 12 to 14 hands high they would fit within the 200-400kg weight range. The tables also show that the requirements for non-breeding horses that are not in work are the same as those for breeding stallions of each height range.

Although the graphs display the results for minimum recommended daily intake, ForagePlus recommends that values of 1.5 times each figure should be aimed for to achieve a healthy horse. One forage sample has been taken per area and it has to be acknowledged that there may be variations in levels in areas that were not sampled.

Forage Results Minions and Caradon:

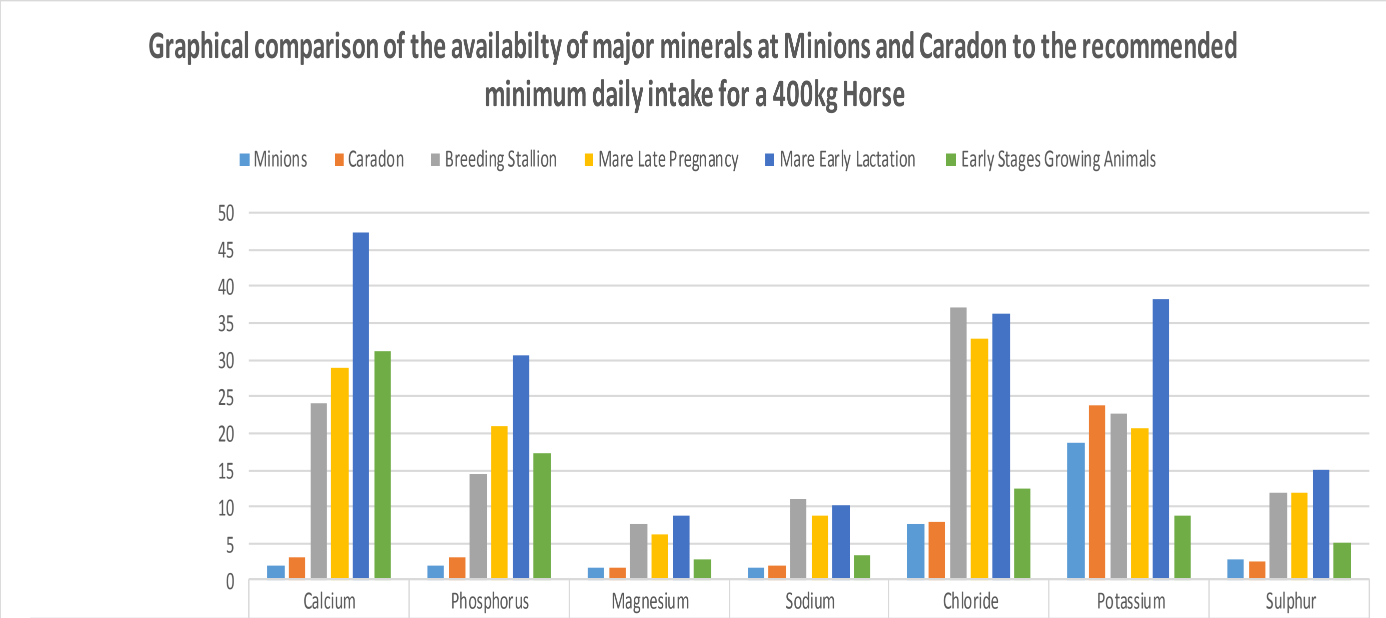


	Calcium	Phosphorus	Magnesium	Sodium	Chloride	Potassium	Sulphur
Minions	2	2	1.7	1.6	7.6	18.8	2.7
Caradon	3.1	3.2	1.8	1.9	8	23.9	2.6
Breeding Stallion	12	7.2	3.8	5.6	18.7	11.4	6
Mare Late Pregnancy	14.4	10.5	3.1	4.4	16.4	10.3	6
Mare Early Lactation	23.6	15.3	4.5	5.1	18.2	19.1	7.5
Early Stages Growing Animals	15.6	8.7	1.4	1.7	6.3	4.4	2.5

Major mineral RDA requirements in grams for 200kg horse compared with that available in forage at Minions/Caradon

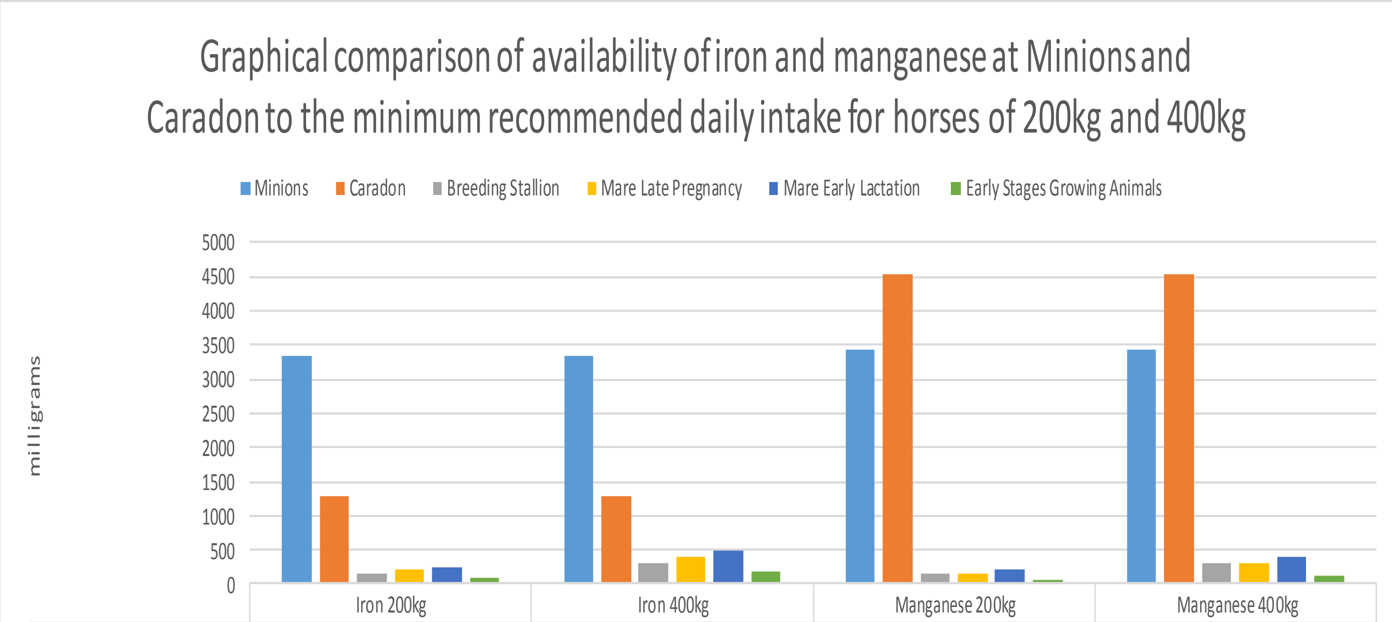
The results of the major minerals in forage show deficiencies at both Minions and Caradon, some of which are considerable. The pastures are deficient in calcium, phosphorus, magnesium, sodium, chloride and sulphur. The differences which are marked at 200kg weight become even more accentuated for ponies at the 400kg weight.

Potassium is more available for ponies at Minions and Caradon for horses at the lower end of the weight range, but at Minions the amount available is not sufficient for horses at the higher end of the weight range. Caradon has a slightly better profile but is still below the minimum requirement for a lactating mare of 400kg weight.



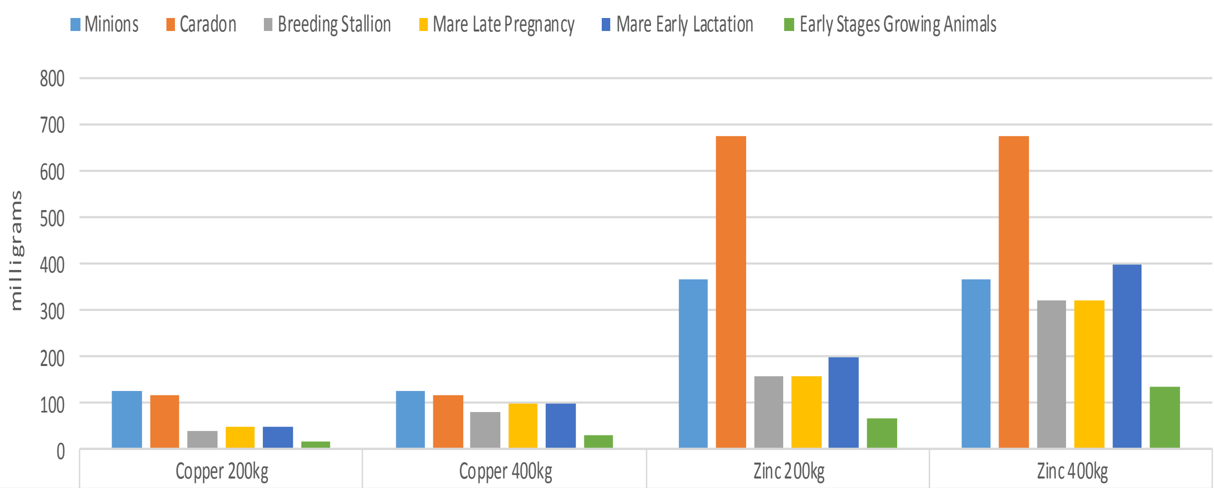
	Calcium	Phosphorus	Magnesium	Sodium	Chloride	Potassium	Sulphur
Minions	2	2	1.7	1.6	7.6	18.8	2.7
Caradon	3.1	3.2	1.8	1.9	8	23.9	2.6
Breeding Stallion	24	14.4	7.6	11.1	37.3	22.8	12
Mare Late Pregnancy	28.8	21	6.1	8.8	32.8	20.7	12
Mare Early Lactation	47.3	30.6	8.9	10.2	36.4	38.3	15
Early Stages Growing Animals	31.3	17.4	2.9	3.4	12.5	8.8	5.1

Levels of iron and manganese are in excess and far beyond the daily requirement for a 200kg horse and a 400kg horse, whether for a stallion, a mare, or a young growing pony.



	Iron 200kg	Iron 400kg	Manganese 200kg	Manganese 400kg
Minions	3340	3340	3418	3418
Caradon	1280	1280	4524	4524
Breeding Stallion	160	320	160	320
Mare Late Pregnancy	200	400	160	320
Mare Early Lactation	250	500	200	400
Early Stages Growing Animals	84.2	168.5	67.4	134.8

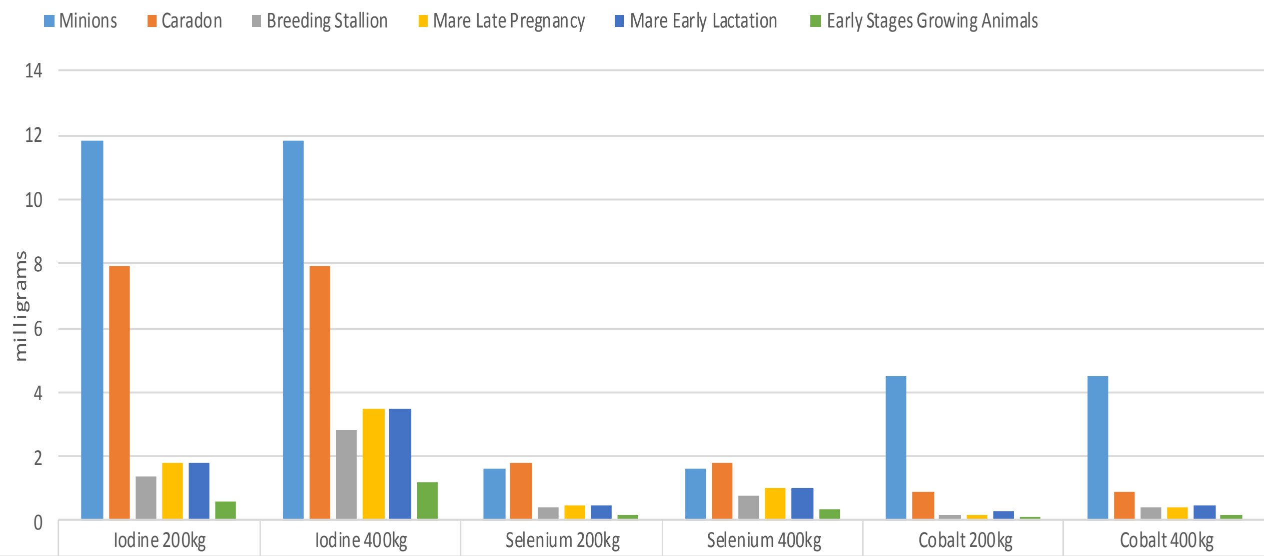
Graphical comparison of the availability of copper and zinc at Minions and Caradon to the minimum recommended daily intake for horses of 200kg and 400kg.



	Copper 200kg	Copper 400kg	Zinc 200kg	Zinc 400kg
Minions	125	125	369	369
Caradon	117	117	676	676
Breeding Stallion	40	80	160	320
Mare Late Pregnancy	50	100	160	320
Mare Early Lactation	50	100	200	400
Early Stages Growing Animals	16.8	33.7	67.4	134.8

Copper is available beyond the minimum level at Minions and Caradon for 200kg horses. The levels at both sites for a 400kg horse are just around the minimum level but would fall short if the 1.5x the minimum figure for nutrition was used. At Minions and Caradon zinc is also in excess compared to the minimum values for 200kg horses. For 400kg horses, there is just enough to meet the minimum value for breeding stallions and mares in late pregnancy but not enough for mares in the early stages of lactation. The levels of zinc at Caradon are in excess for a 400 kg horse.

Graphical display comparing iodine, selenium, and cobalt availability at Minions and Caradon to minimum recommended daily intake for 200kg and 400 kg horses



	Iodine 200kg	Iodine 400kg	Selenium 200kg	Selenium 400kg	Cobalt 200kg	Cobalt 400kg
Minions	11.8	11.8	1.6	1.6	4.5	4.5
Caradon	7.9	7.9	1.8	1.8	0.9	0.9
Breeding Stallion	1.4	2.8	0.4	0.8	0.2	0.4
Mare Late Pregnancy	1.8	3.5	0.5	1	0.2	0.4
Mare Early Lactation	1.8	3.5	0.5	1	0.3	0.5
Early Stages Growing Animals	0.6	1.2	0.17	0.34	0.1	0.2

Levels of iodine are in excess at both sites for both 200kg and 400kg horses. The level of iodine is in greatest excess at Minions. Levels of cobalt are also beyond daily requirements for 200kg and 400kg horses on both sites. The selenium levels are above requirements on both sites for 200kg horses. Selenium levels are just above requirements for 400kg horses - again this gap would be much narrower if the 1.5x figure was used for optimum health levels.

<u>Table comparing hair testing (from Kerry Marsh's interpretation of hair tissue testing results) and on-site forage results (colour based on results for adult ponies' requirements):</u>

	B	Ca	Cr	Co	Cu	Fe	Mg	Mn	Mo	P	K	Se	Na	S	Zn	Cl-	I
Pony 4						Toxic		Toxic								N/A	N/A
Pony 11						Toxic										N/A	N/A
Pony 12						Toxic										N/A	N/A
Minions 200kg	N/A		N/A						N/A								
Minions 400kg	N/A		N/A						N/A								
Caradon 200kg	N/A		N/A						N/A								
Caradon 400kg	N/A		N/A						N/A								

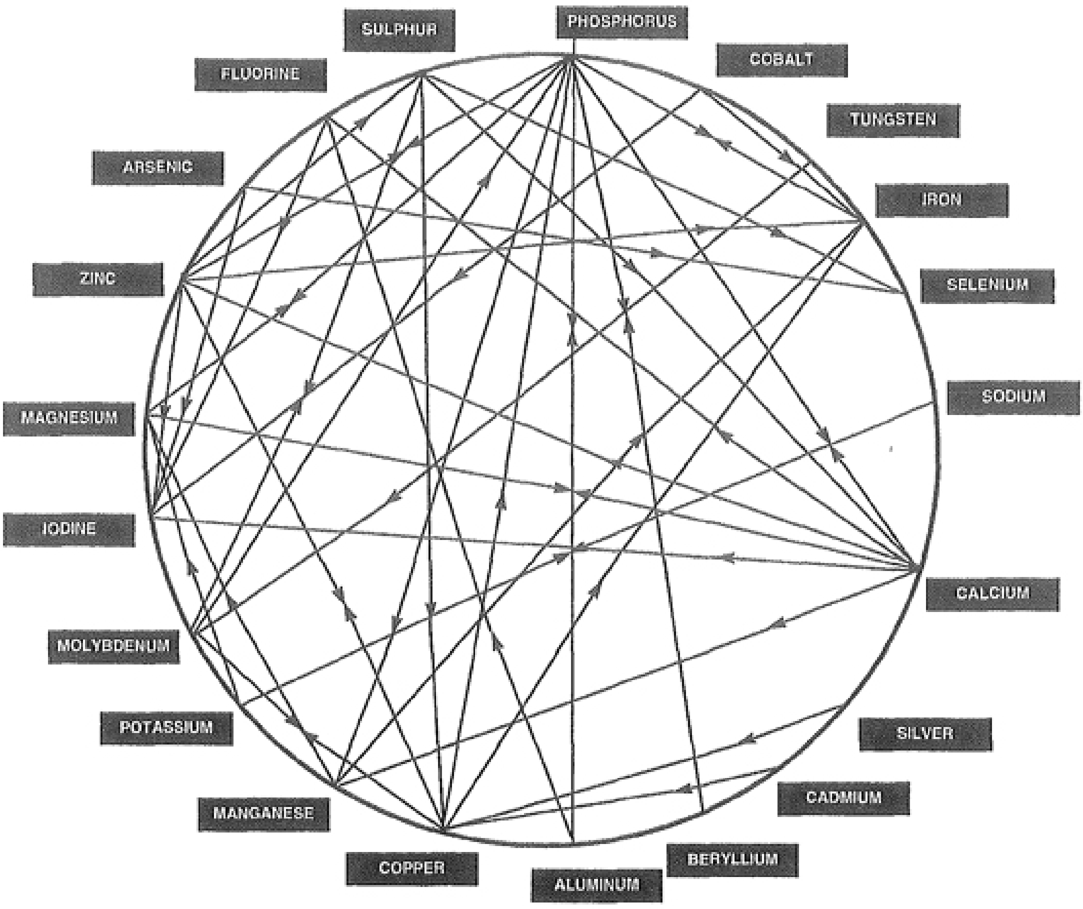
Key:

High	B	Boron	Mg	Magnesium	Na	Sodium
Low	Ca	Calcium	Mn	Manganese	S	Sulphur
Good	Cr	Chromium	Mo	Molybdenum	Zn	Zinc
Critically low	Co	Cobalt	P	Phosphorus	I	Iodine
Non existent	Cu	Copper	K	Potassium	Cl-	Chloride
Does not meet requirements of all groups	Fe	Iron	Se	Selenium	N/A	Not Available

The environmental data and the hair tissue results do show strong correlations. Horses on the moor are not generally provided with supplementary food so they have to survive on the forage available on-site. High levels of iron are present both in the forage and all water samples contained levels of iron above the recommended maximum limit with sample 1 of the drinking water containing the highest concentration. High levels of manganese were present in the forage, and some samples of drinking water had levels of manganese above recommended livestock limits. Levels of copper and cobalt were good or high depending on location/weight of pony. High levels of copper are known to be present onsite as this is what is claimed to be beneficial to the extremely rare species of moss and lichen that live there.

The site and the ponies were deficient in calcium, phosphorus, sodium and sulphur. Levels of potassium varied between sites. Levels of magnesium were low in the forage samples and it should be noted that pony 11's magnesium level was just on the borderline good/low. There were good levels of selenium levels on site and zinc levels for the most part at higher than requirements. The issue here is that the uptake of selenium and zinc is effected by the presence and excess of elements such as arsenic, iron, and manganese and more about this will be explained below.

Harman considers that ""Mineral balance is perhaps even more critical than vitamin balance in the equine diet. A complex interaction occurs among many minerals; even a slight excess of one mineral in a diet may disrupt metabolism of other minerals (see the diagram on the next page). Many of the trace minerals act as catalysts to help transform the major minerals into a form that can be used. Plants are good sources of trace minerals, and horses may seek out certain plants for their trace mineral content. Chemically fertilized soils that are farmed repeatedly (as most of our farms are) become depleted of trace minerals, so the grains grown on these soils and fed to horses are also depleted (Walters, Fenzau, 1996). Mineral nutrition then becomes extremely important. (Harman, J.: Holistic Approach to Equine Practice" published in Complementary and Alternative Veterinary Medicine: Principles and Practice (ISBN: 9780815179948), "Unit 8: Integration into Veterinary Practice," Chapter 33, pg. 601, extract available http://www.abcplus.biz/Categories.aspx?Id=CEO_Corner_2-7-2012_Holistic_Approach_Equine). The diagram on the following page helps to demonstrate the inter-relationship between minerals and their uptake.



Mineral interaction wheel (from (Harman, J.: Holistic Approach to Equine Practice" published in Complementary and Alternative Veterinary Medicine: Principles and Practice (ISBN: 9780815179948), "Unit 8: Integration into Veterinary Practice," Chapter 33, pg. 601, extract available http://www.abcplus.biz/Categories.aspx?Id=CEO_Corner_2-7-2012_Holistic_Approach_Equine)
"Arrows pointing together mean that minerals interact; both are required for either to be available. Arrow pointing toward the other one means that the second mineral requires the first one."

Arsenic is considered to have antagonistic effects on iodine, selenium, copper, mercury and lead. High dietary arsenic can exacerbate copper deficiency. "Arsenic increases excretion of selenium which may lead to selenium deficiency. Because of the possibility of continued depletion of body selenium, caused by biliary excretion of arsenic-selenium complexes, there is an increased risk of selenium deficiency in livestock that are chronically exposed to even low levels of arsenic. Such adverse effects of arsenic would be of particular concern when dietary levels of selenium are only marginally sufficient. Close monitoring of selenium status should be considered in areas where low level, long term, exposure of livestock to arsenic is widespread". https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf

"Because arsenic is classified in Group I (carcinogenic to humans), the importance of arsenic as a water quality parameter may be an issue for meat quality, due to the potential for accumulation in some edible tissues". https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf

Excess iron was found in both water and forage results. "Excess iron may affect many metabolic processes via a wide range of metabolic interactions. Among the physiologically significant effects are interactions with essential nutrients such as cobalt, copper, manganese, selenium, and zinc, where deficiency of these elements can be induced by high dietary iron. Antagonisms between copper and iron may have metabolic consequences (https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINAL web.pdf)".

"The predominant chemical form of iron in drinking water is the ferrous (Fe^{+2}) form. The ferrous form is very soluble in water compared with the highly insoluble ferric (Fe^{+3}) form present in feed sources. Highly soluble iron can interfere with the absorption of copper and zinc. The Ferritin System in cells in the intestinal wall normally helps control the risk of iron toxicity in animals by controlling iron absorption. However, highly soluble ferrous iron can be readily absorbed by sneaking between cells; thus escaping the normal cellular regulation.

Excess iron (greater than 0.3 ppm) in drinking water is much more absorbable and available than iron from feedstuffs, and thus presents a greater risk for causing iron toxicity. If high-iron drinking water is present, an alternative water source should be found, or a method to remove the iron from water before consumption by cattle and humans should be employed" (David K. Beede, 2006: "Evaluation of Water Quality and Nutrition for Dairy Cattle" Michigan State University, Page 8).

Iron uptake into plants is higher in water saturated soils and soils with higher acidity. Excess iron has been described by ForagePlus as a "ticking time bomb, building in the body, storing in the liver and spleen and has been reported in many other species, from several types of bird, black rhinoceros, tapir, lemur and dolphin. Iron can be a dangerous mineral in excess because it's high affinity for oxygen and high reactivity make it easily absorbed. It is absorbed by binding to specific metal transporters in the small intestine and also passively via junctions between the cells. Research in other species show that volatile fatty acids (VFAs) which are produced from hind gut fibre fermentation enhance iron absorption in the colon. As the horse is a hind gut fermenter this leads to the possibility of a significant source of iron. High amounts of iron stored in the liver turn the insides of this organ black and worryingly, veterinary pathologists actually consider this to be a 'normal" finding in horses. The colour is from iron deposits called hemosiderin.

A recent study evaluated the potential link between insulin resistance (IR) and iron overload, and linked iron status to IR in horses". (https://forageplus.co.uk/ultra-low-iron-equine-balancers/)

It should also be noted that "Elevated iron concentrations in the drinking water may be a significant risk factor promoting intestinal proliferation of Clostridium botulinum and subsequent botulism (Pecelunas et al., 1999)". Ascorbic acid (vitamin C) may enhance iron absorption whereas vitamin E can prevent adverse effects. (https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_QualityFINALweb.pdf)

Iron and manganese toxicity will further reduce the uptake of the already deficient supply of minerals. ForagePlus states that manganese in excess works to make the over absorption of iron even worse due to this minerals affinity for attaching to ferritin. Ferritin is one of the body's ways of regulating the uptake of iron but if excess manganese attaches to the available ferritin then this fail safe ceases to operate. (https://forageplus.co.uk/ultra-low-iron-equine-balancers/)

"Manganese may adversely affect metabolism and homeostasis of several divalent metals including calcium, cadmium, cobalt, iron, phosphorus and zinc". (https://www.ag.ndsu.edu/waterquality/livestock/Livestock_Water_Quality FINALweb.pdf)

Beryllium displaces magnesium in enzymes and causes them to malfunction.

Lithium is known to displace sodium and potassium from their intracellular compartments and substitutes for them. (Leonard, E. Fundamentals of Psychopharmacology) (https://books.google.co.uk/books?id=oMNG4AiZlrQC&pg=PA202&lpg=PA202&dq=lithium+displaces+sodium&source=bl&ots=7ckEMhsJOH&sig=dWXn6I5DKymI_doOsVffyV8tOaY&hl=en&sa=X&ved=0ahUKEwjKp57y7orPAhUsBcAKHWs9A2QQ6AEIMDAD#v=onepage&q=lithium%20displaces%20sodium&f=false)

There are many mining locations within the Caradon/Minions area and so it is possible that there is variation in amounts of toxicity across the site. The horses tested may well have roamed over different territories and grazed in areas different to each other on the available land. Whilst it is usually claimed that animals in poor condition have been dumped or abandoned in this condition on this site, the results suggest that the deficiencies and toxicities have been gained whilst inhabiting this environment. It would be beneficial for a greater number of animals to be Hair Tissue Tested to build up a larger profile of livestock toxicity on site, including sampling cows and sheep. Bone samples from goats and sheep have been tested in bioaccumulation studies on mining sites in Jordan (see below). On Bodmin Moor, horses tend to remain out on moorland areas all year round, whereas cattle and sheep tend to be removed for certain periods of the year. This means that cattle and sheep may not be subjected to such prolonged periods of exposure.

The arsenic level recorded from water Sample 1 is of great concern. Financial restrictions meant this research project was unable to test all water sources on site and there have been strong variations in the safety of the water tested. As water is drunk by livestock from former mining pits and from pools where the land is now known to contain heavy metals there may well be other concentrations and toxicities across the area. It would be beneficial for a study to look further into the bioacculmulation of heavy metals in the vegetation, as was conducted on mining sites in Jordan (see below). In the Bodmin results, all horses tested were young but all had iron, lithium, and aluminium toxicity, and arsenic present in their systems. Whilst some toxicities may have transferred from their mother whilst a foetus, it is possible that these have been accumulated on site. Lithium was not able to be tested for on site but some water pools do appear to contain a film of oil like substance on their surface.

Interpretation

Mines abandoned before 1999 carry no legal decontamination obligation. Cornwall County Council have a contaminated land register which it holds and maintains under the Environmental Protection Act 1990. No sites on Bodmin Moor are listed on the register. http://www.cornwall.gov.uk/media/12173704/cornwall-council-contaminated-land-register270415.pdf In order for a site to be listed on the register a source, a pathway, and a receptor need to be identified. The Cornwall County Council website states that "Contaminated land in the UK has largely arisen as a result of historic industrial activities and past waste disposal practices. Unfortunately in the past, legal controls and standards within industry were not as high as they are today. In a lot of cases, this has resulted in the ground being polluted by the wastes and materials from the industrial activity. There are some pollutants which are naturally occurring and these are also considered under this legislation.

Contaminating substances may include:

- Metals/metallic compounds, e.g. cadmium, arsenic, lead, nickel
- Organic compounds, e.g. oils, petrol, solvents, fats
- Gases, e.g. methane, carbon dioxide, hydrogen sulphide

For a site to be contaminated, a 'significant pollutant linkage' must always exist. The three components listed below must always be present to create a pollutant linkage:-

- Source - the contamination in, on or under the land
- Pathway - route by which contamination reaches the receptor
- Receptor - broadly defined as living organisms, ecological systems or property.

If there is a break in this pollutant linkage (i.e. there is a source and a receptor, but no pathway) the site cannot be defined as 'contaminated land'."

It is already known that the Minions/Caradon sites are SSSI's because of the presence of heavy metals but we have not found any previous research into whether the previous mining activity is having an effect on animals or livestock so a pathway or receptor may not have been proven. Through the course of this research we have generally found a lack of knowledge and awareness within the veterinary community in the UK regarding the testing, presence, and effect of heavy metals.

A research study published in May 2016 conducted by a PhD student from The University of Manchester discovered toxic exposure to arsenic in Cornish private water supplies. 5% of the Cornish private supplies tested had concentrations of toxic arsenic exceeding 10 micrograms per litre - exceeding World Health Organisation guidelines. People living in homes with high arsenic in their supplies had urine tests which generally revealed high arsenic concentrations, which the study concluded provided strong evidence that they are being exposed at concentrations potentially detrimental to their health. The researchers suggested that installing suitable water treatment or using alternative supplies for drinking water or drinks could reduce their exposure, and any consequent health risks. The research stated that "Cornwall was one of the most important mining areas in Europe until the early 20th century, as it has a geology rich in high metal (tin, tungsten) and high arsenic rocks and sediments, which has contributed to the high arsenic concentrations found in these supplies". http://www.bgs.ac.uk/news/docs/as_sw_final.pdf

Kerry Marsh's experience states the most common culprit of toxicity in horses is water. "Bore water should be tested for toxic metals. Spring water, spring fed dams and river water also may carry toxic metals and need to be tested. Heavy metals are called this because they have a high atomic weight and displace the lighter metals such as selenium, magnesium and zinc etc. This is why they are also called toxic metals as they cannot be metabolised by the body and therefore accumulate in the body. There has been very little research conducted on heavy metal toxicity in horses but from my extensive experience, the results are debilitating and serious".

Kerry Marsh's article: Toxic Heavy Metals - Equine Health Implications helps to explain heavy metals and their impact on equines:

Heavy metals are known as such due to their high atomic weight. Small (trace) amounts of some heavy metals are beneficial to horse health, but when they are not metabolized they accumulate in the tissues causing significant health problems. This article is not about poisoning due to heavy metals but about how continued low-level exposure affects mineral balance and ultimately causes symptoms.

Toxic heavy metals come from industrial exposure such as coal smoke, metal smelting, exhaust fumes, land fill, chemicals, chemical fertilizers used in agriculture, pesticides, herbicides, fungicides, old lead or metal water pipes, old metal water tanks, mining and most commonly from water supplies particularly bore water.

Many horse owners do not consider the health of their soil in relation to the health of their horse. Increasingly, horse owners fail to conduct regular soil tests and therefore fail to apply regular applications of lime. The lower pH soils have difficulty coping with heavy metals particularly aluminium.

Horse feeds and hay grown on such soils or soils that are constantly treated with chemical fertilizers, pesticides, fungicides etc., contain varying levels of toxic metals such as cadmium, lead, aluminium, mercury, arsenic, and nickel. Heavy metals prevent the absorption of nutritional elements such as calcium, magnesium, potassium, cobalt, sulphur and trace minerals making the soil sick and the feed grown on them nutritionally deficient.

Based on the analyses of hair tissue samples from hundreds of horses, we find many of the metals listed below are usually present in differing levels. Symptoms of heavy metal toxicity in horses may take years to develop. Once exposure to a significant amount of a toxic metal has occurred, it stays in the system until an antagonist removes it and the minerals it displaced are replaced. Most heavy metals cross the placental barrier and affect the foetus (fetus).

Aluminium

This element is abundant everywhere. The most common metal toxicity found in horses. This metal has no known function in the horse. Mostly horses come into contact with aluminium through pre packed feeds where it is used as an anti caking agent to prevent feeds setting hard. Also found in some horse wormers. It is in acidic soils and horses ingest it via the grasses grown on such soil. A lot of water supplies also contain large amounts of aluminium especially dam water and bore water. Aluminium is an insidious health problem for horses as it prevents phosphorus from being absorbed and affects the calcium/phosphorus ratio. High aluminium in the horse may cause colics, ulcers, lack of bone density, stiffness, periodic lameness, fractures, weight loss and condition.

Arsenic

Small amounts of arsenic are beneficial to the horse but once it accumulates it has serious health repercussions. Most of the horses that showed an elevated level of arsenic were living in gold mining areas. The soil and water were contaminated with arsenic which the horses ingested. Other common sources of arsenic are in treated pine posts which horses often chew. Symptoms of arsenic toxicity may be liver pain and or dysfunction, hoof problems, rough dry coat, hair loss, muscle weakness, stiff gait, skin conditions."

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Dr David L. Watts Phd states that "Until recent years there has been no suitable test for minerals. Testing mineral levels in the blood has not been adequate, due to its homeostatic regulation. Minerals are usually maintained in the blood at the expense of tissue concentrations. For example a tissue deficiency of an element can develop without noticeable deviations occurring in the blood levels. Bone loss of calcium can become advanced leading to increased fragility and fractures, while blood calcium levels remain within normal limits. Symptoms of iron deficiency anemia can develop long before low iron levels can be detected in the blood. It is becoming more evident that what minerals are being retained or lost in the animal is just as important as what nutrients are contained in the feed. (http://nutritionalbalancing.org/center/animal/articles/equine-htma.php)

Research by Pyatt, Pyatt, Walker, Sheen and Grattan published in 2004 revealed the results of bioaccumulation of heavy metals on a mining site in Southern Jordan. (*https://www.researchgate.net/profile/John_Grattan/publication/8138038_ Environmental_toxicology_heavy_metal_content_of_skeletons_from_an_ancient_metalliferous_polluted_area_of_Southern_Jordan_with_ particular_reference_to_bioaccumulation_and_human_health_Ecotoxicology_and/links/565f067408ae1ef92984690a.pdf*). Copper mining here was an important and large scale activity, starting in the Bronze Age and continuing until the 7th century AD. As a result of mining and smelting, the environment was heavily polluted by copper, lead, and other cations and the effects of this continue today. Cations including copper, lead, and manganese are present in high concentrations in both the spoil tips and the associated sediments. Sheep and goat skeletons from past periods as well as modern times were analysed as well as human skeletons from different time periods. Samples of teeth, lower jaws, and skeletons of goats, sheep, and ancient humans indicate that these organisms have bioaccumulated significant concentrations of both copper and lead from the environment. The values for both copper and lead are generally lower in the goat than in the sheep samples examined. As these organisms occupy the same habitat, researchers thought this was because the sheep graze and "thence can be more readily exposed to heavy metals in the substrate, while goats also browse and hence may avoid some of the more heavily contaminated substrata". Both the modern and ancient mammal samples exhibited massively enhanced copper and lead values derived from this copper- and lead-polluted area. https://www.researchgate.net/profile/John_Grattan/publication/8138038_Environmental_toxicology_heavy_metal_content_of_skeletons_from_an_ancient_metalliferous_polluted_area_of_Southern_Jordan_with_particular_reference_to_bioaccumulation_and_human_health_Ecotoxicology_and/links/565f067408ae1ef92984690a.pdf

Further research by Pyatt, Gilmore, Grattan, Hunt and McLaren looked at how the profound metalliferous pollution has persisted and has continued to influence the desert environment in southern Jordan for at least two millennia. (http://cadair.aber.ac.uk/dspace/bitstream/handle/2160/232/An%20Imperial%20Legacy.pdf?sequence=1&isAllowed=y) "Pollution deposited in ancient times will remain in the environment until removed, broken down or transported by natural processes. Where metalliferous industrial waste products are found, weathering processes may produce high concentrations of potentially toxic metals in the environment. Such toxic concentrations may persist in the environment for considerable periods of time; waste rock, tailings and slag are suspected to slowly release metals into the surrounding environment through a variety of erosional processes, both chemical and physical, and continue to pollute the surrounding environment, for long, if often imprecisely known periods of time until dissipated by natural processes". "Inevitably metals absorbed by vegetation may pass up the trophic levels into livestock and ultimately into people with potentially serious consequences for health". The environmental data showed all soil, vegetation and animal samples contain enhanced concentrations of lead and copper.

The results from the research into plants showed the "Absorption of copper and lead by plants in the study area is considerable and that this problem is not confined solely to the vegetation growing on the spoil tips. The highest values detected in the plants were found in the root samples, but the concentration of lead and copper in those parts of the plants most likely to be grazed—the stems and leaves—was also high. Of particular note are the high concentrations of metals in the leaves of Plantago coronopus and the composite Gymnarrhena micrantha. Both these plants are common in the study area and appear to be preferentially grazed when available, and both appear to have an enhanced ability to bioaccumulate metals."

Research looked at goat herds living on the area. The goats "Are not always grazed on the spoil tip sites; indeed the goat herds may travel several kilometres each day in search of grazing, which must dilute their exposure to metal pollution. Nevertheless, herds of goats and occasionally sheep were frequently observed grazing in obviously contaminated sites. Very high concentrations of both lead and copper were detected. The lead levels found in the ''live'' goat hair (326 mg/kg_1) are high and comparable to those recorded in the hair of humans living near an operating Canadian lead smelter and within the ranges noted in the hair of lead workers in direct contact with the metal working process (Chattopadhay et al., 1977; Fergusson et al., 1981). In terms of the animals it is interesting to note that "The highest value obtained was in the case of the faeces (590 mg/kg_1) and it is hence apparent that lead and to a lesser extent copper continue to be recycled."

The snail, Theba pisana, also showed evidence of bioaccumulation of metals. It was found particularly associated with the leaves "of the composite Gymnarrhena micrantha";

The researchers determined the results clearly indicated "Trophic level accumulation of metals from the soil, through the vegetation and into herbivores...these data and the degree of toxicity indicated have implications for both the consumers of the vegetation and agricultural produce". "Seed producing plants are particularly sensitive to copper pollution as well as lead, and in the concentrations reported here could be toxic to most plants ...The concentrations found in the leaves here are sufficiently high to be considered phytotoxic. The continued survival of these plants suggests that the vegetation sampled may have evolved a notable tolerance to these levels of pollution" "In the case of leaves of Plantago coronopus, which are often positively selected for consumption by grazing livestock, the lead content of the leaves at the polluted site was 16 times greater than that of leaves collected from the control site, whilst the copper content was 5·5 times greater. The high values in the roots are likely to reflect the fact that the roots penetrate deeply into the more toxic parts of the spoil and that natural filtering mechanisms are in place to reduce transport of these cations to other tissues. Plant species with bulbs had an "enhanced ability to bioaccumulate lead, which will also serve to render them even more toxic to herbivores". Plants with a prolonged life span have the ability to bioaccumulate toxins over time. Accumulation of these metals from the soil through the plants and into the consumers is indicated. There is a clearly defined ability for the vegetation to exhibit bioaccumulation of both copper and lead. Thus there is enhanced bioaccumulation of both copper and lead at the polluted site and the zone of influence of these cations apparently extends well away from the ancient source of production".

In terms of addressing the situation on Minions/Caradon, the welfare of horses and ponies on Bodmin Moor is covered under the jurisdiction of the UK Animal Welfare Act 2006. It outlines the legal responsibility an owner has to their animals and the authorities can take action if requirements are not met. The two most relevant parts of the Act which relate to the issues we have highlighted are part 9 and part 7. Part 7 relates to the administration of poisons or injurious drugs or substances. Section 9 and 7 are outlined below. The full document can be viewed here: (http://www.legislation.gov.uk/ukpga/2006/45):

"Promotion of welfare

9 Duty of person responsible for animal to ensure welfare

(1) A person commits an offence if he does not take such steps as are reasonable in all the circumstances to ensure that the needs of an animal for which he is responsible are met to the extent required by good practice.

(2) For the purposes of this Act, an animal's needs shall be taken to include—

(a) its need for a suitable environment,

(b) its need for a suitable diet,

(c) its need to be able to exhibit normal behaviour patterns,

(d) any need it has to be housed with, or apart from, other animals, and

(**e) its need to be protected from pain, suffering, injury and disease.**

(3) The circumstances to which it is relevant to have regard when applying subsection (1) include, in particular—

(a) any lawful purpose for which the animal is kept, and

(b) any lawful activity undertaken in relation to the animal.

7 Administration of poisons etc.

(1) A person commits an offence if, without lawful authority or reasonable excuse, he—

(a) administers any poisonous or injurious drug or substance to a protected animal, knowing it to be poisonous or injurious, or

(b) causes any poisonous or injurious drug or substance to be taken by a protected animal, knowing it to be poisonous or injurious.

(**2) A person commits an offence if—**

(a) he is responsible for an animal,

(b) without lawful authority or reasonable excuse, another person administers a poisonous or injurious drug or substance to the animal or causes the animal to take such a drug or substance, and

(c) he permitted that to happen or, knowing the drug or substance to be poisonous or injurious, he failed to take such steps (whether by way of supervising the other person or otherwise) as were reasonable in all the circumstances to prevent that happening.

(3) In this section, references to a poisonous or injurious drug or substance include a drug or substance which, by virtue of the quantity or manner in which it is administered or taken, has the effect of a poisonous or injurious drug or substance."

This research sheds new light on the issues surrounding equine welfare problems at Minions/Caradon Hill. In order to address the problems and bring about long term change, the results will need to be acted upon by the owners of the animals, the Bodmin Commoners' Council, the landowner, and the authorities to address the problems which have been highlighted. It may be public pressure which ultimately brings about any change.

The safety and quality of water sources should be addressed as a priority.

For those with ponies rescued, purchased, or born to mares from this area of moorland, it is possible to address toxicity issues through specific feeding plans. Advice can be sought on this.

For animals living in a semi-feral environment, Marsh recommends the provision of loose minerals on the moor, which are considered more effective than mineral blocks at helping to address deficiency issues. If supplementary hay is sourced from areas with better mineral values this would also help to combat the deficiencies present on site. Selenium (which can help to remove arsenic) can be supplemented in a domestic setting but it is not recommended in a semi-feral setting because high levels of selenium are toxic.

Conclusions

- Minions and Caradon Hill are areas of intense historic mining activity and have been designated SSSI status because of the heavy metal content present on site. The impact of the heavy metals on livestock does not appear to have been taken into account. Mining sites can have toxicities of minerals and heavy metals which have an effect on livestock.
- The testing conducted onsite for this report shows that the Minions/Caradon site:

- Has deficiencies in essential major minerals. There were huge deficiencies in calcium, phosphorus, magnesium, sodium, chloride and sulphur. The levels of these minerals onsite do not meet the daily minimum requirements of breeding or non breeding animals. The mineral requirements for pregnant and lactating mares are greater than those for working stallions, non breeding animals, and growing youngsters.

- Has environmental toxicity present, particularly in the elements arsenic, iron, and manganese. Arsenic in water sample 1 returned a level 182 times higher than the maximum acceptable human level and well above acceptable livestock limits. Hair samples also suggest toxicities of lithium (which may be from the oily substance witnessed in some pools) and aluminium. Toxicities can further accentuate the deficiencies already present on site. Levels of uranium and beryllium were also present in hair testing results.

- Has young ponies with already high levels of bioaccumulation of certain heavy/toxic elements.

- Is in contrast to East Moor where toxic elements such as arsenic, beryllium, uranium, and lithium were either non existent or at very low/trace levels. Aluminium was not present at East Moor at toxic levels. Both sites have ongoing equine welfare problems. Both sites have manganese toxicity.

- The Minions results show that the ponies do reflect the environment through their test results—through deficiencies and bioaccumulation. Minions/Caradon had high levels of toxicity and this was present in the animals. Toxicity of certain elements on-site can cause deficiencies in uptake of particular minerals, such as zinc. The results show that the issues are beyond simply claiming the animals have been dumped or abandoned in poor condition. Whilst some abandonment of animals may take place, the environments are impacting on the animals.

- The impact of toxicities on site has so far been underestimated in assessing and understanding the animal welfare problems on Minions and Bodmin Moor. The impact of toxicities further accentuating deficiencies onsite has also not been appreciated.
- Without supplementation and addressing the toxicity issues, particularly in the drinking water, the welfare problems will continue.
- Toxic elements are stored in the pony and can only be removed whilst an animal is still living. This can be done through special feeding programmes—toxicity is not removed by changing pasture.
- Toxic elements are passed onto the foetus during pregnancy. They are also passed onto a consumer once the animal is eaten—this can include scavenging wildlife, hunting dogs at kennels, zoo animals, and/or humans where animals are being passed into the human food chain.
- Knowledge about heavy metals and their impact is lacking in the UK scientific and veterinary communities—there needs to be better awareness of research that has been taking place outside of the UK.

Recommendations

- Further testing should be conducted on other Bodmin sites with previous mining activity, particularly those Commons with ongoing animal welfare problems.
- Further water testing for heavy metals and other toxic elements should be conducted on other drinking water sources across the Minions and Caradon sites. Those presenting results above maximum livestock safety limits should be fenced off or decontaminated. Pools can currently be accessed by people, animals, and wildlife.

- Further forage, soil, and hair testing would reveal further information about toxicities across the site and bioaccumulation levels within horses, sheep, and cows.
- Supplementation of minerals and hay should be provided onsite. If hay is sourced from areas with better mineral values this would help to combat the deficiencies present on site. Whilst members of the public may like to donate feed, it should be distributed by owners or individuals agreed by the Commoners' Council. This is so that the appropriate forage is provided and it is distributed in an acceptable manner. The public should not be encouraged to feed animals. If supplementation cannot be provided because of SSSI status then animals should be removed for periods of the year. Supplementation could then take place on the farm.
- Those with ponies rescued from this area may like to take advice on feeding programmes to safely release toxicity, particularly for animals that are experiencing health problems.
- Those feeding horses from the Minions/Caradon area to other animals need to be aware of the toxicity they are passing on through the food chain. Where horses are being passed into the human food chain, there needs to be awareness that any toxicity accumulated will be passed on to the consumer.
- These areas are "Right to Roam" areas and impacts on insurance cover may need to be considered.
- Knowledge of heavy metals and their effects need to be better understood by scientific and veterinary professionals working in the UK.
- Other UK sites with animal welfare problems may also need to consider whether historic mining is impacting on animals.

People4ponies is an equine charity dedicated to helping wild and traumatised ponies

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