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A Retrospective Review of 130 Years of Equine Disease in Sudan

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Review Article

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ABSTRACT

Sudan's equines are important in pastoralism and agriculture as riding, work and transport animals and in urban areas for transport. In 2010 Sudan had 7.5 million donkeys and 0.8 million horses. All donkeys and most horses are local types. Rudimentary health services were provided to British and Egyptian military units from 1884, followed by officers of the Army Veterinary Service from the mid-1890s. National veterinary services were staffed at low levels for transport and food producing animals by military personnel until 1924. Limited disease diagnosis and treatment was then assured by the civilian Sudan Veterinary Service and a research arm was established in the 1920s. Disease diagnosis, treatment and control are now assured by public and private services acting within laws governing diseases and welfare. Sudan is a Member State of the Office International des Epizooties (OIE) and contributes–not always fully–to the international reporting system. Not all Notifiable OIE diseases are Notifiable in Sudan. Most major equine diseases or ausative organisms have been found in the country, often in isolated investigations and in subclinical form. Internal parasites cause major economic loss and external parasites are vectors of many diseases. Clinical services are essentially limited to urban transport animals: field services are understaffed and have limited equipment and funding. Equines continue to contribute to national and household economies but do not and will probably not in the future receive services commensurate with their inputs. This paper reviews equine diseases via a bibliography of 105 references.

INTRODUCTION

Sudan has a large and species-diverse array of domestic animals. Estimates by the Food and Agriculture Organization (FAO) puts the Republic of Sudan–since its partition with the Republic of South Sudan in 2011–as having the third largest total livestock population of all African countries. The country ranks first to third in Africa in cattle, sheep, goat and camel numbers, third in poultry and fifth in donkeys [1]. Official Sudanese data for 2009 for the then northern states of the country indicate national livestock populations as 41.65 million cattle, 51.55 million sheep, 43.27 million goats, 4.52 million camels, 7.51 million donkeys and 784 thousand horses [2,3]. Equines have a significant presence in agricultural and transport operations and for some time in the late nineteenth and early twentieth centuries were extremely important in military operations: in the last role mules–of which there are now very few–served as riding and pack animals and provided tractive power for artillery. Almost all donkeys are the local nondescript type owned by traditional pastoralists, small-scale farmers or by small transport operators in urban areas. Most horses are owned by the same categories of enterprise and perform the same functions but there are a very small number of elite horses used for racing and other equine sports.

This paper provides details of the occurrence and status of diseases of equines in Sudan from the mid-1880s to the present day.

DISEASE SITUATION

Notifiable Diseases

The main ingredient is Sisik naga leaves which is derived from Payakumbuh West Sumatra Province, Indonesia. Other materials are distilled water, analgesic drugs (tramadol) 50 mg, CMC 1% and ethanol 70%. While the equipment used is the analytical balance, oven, blender, fabric filter, Whatman filter paper no.1, stopwatch, test tubes, glass beaker, a petri dish, measuring cup, micropipette, syringe injection 1 ml, and water bath **(Table 1)**.

Table 1. OIE Notifiable equine diseases and status in Sudan.

OIE notifiable disease	Notifiable in Sudan	Status in Sudan	Notes
Contagious equine metritis	No	Never reported	-
Dourine	No	Never reported	*Trypanosoma equiperdum* reported in donkey mare in Nyala [4]
Equine encephalomyelitis (Western)	No	Never reported	-
Equine infectious anaemia	No	Never reported	Antibodies to virus found in several parts of country in horses and donkeys [5,6]
Equine influenza	No	Never reported	Antibodies found by ELISA in very small percentage of horse and donkey sera in South Darfur [7]
Equine piroplasmosis	Yes	Last reported 1922	First reported as biliary fever in 1907 [8]; both *Babesia caballi* and *Theileria equi* identified in recent years [9-16]
Glanders	Yes	Last reported 1989	*Burkholderia mallei* isolated from donkeys in Khartoum area in 2003/2004 [17]
Infection with African horse sickness virus	Yes	Last reported 1993	Several virus serotypes identified in recent years [18,19]
Infection with equid herpesvirus-1 (EHV-1)	No	Never reported	EHV-1 and EHV-4 antibodies detected in several areas [20]
Infection with equine arteritis virus	No	Never reported	-
Venezuelan equine encephalomyelitis	No	Never reported	-

Fungi

Epizootic lymphangitis

Epizootic or contagious lymphangitis caused by the fungus *Histoplasma farciminosum* is a disease mainly of horses and mules. Formerly an OIE List B disease it is not on the new consolidated list of Notifiable diseases. The disease was first reported in Sudan in a group of mules imported from Ethiopia [21,22]. There is little other mention in early literature but it was known to and feared in Western Darfur where cases were destroyed by order of the 'nazir' (tribal leader) and it was later remarked as less prevalent than previously because of this policy[1] [23]. A record in 1927 was followed by 51 cases in 1928 [24]. In the early 1930s a researcher described a hitherto unrecorded type of primary pneumonia infection possibly due to *Cryptococcus farciminosum* [25]. In the late 1960s/early 1970s in two cases of cryptococcal pneumonia in horses, *Histoplasma farciminosum* was isolated from both, the diagnosis being based on histopathological changes in the lungs and fungal culture [26,27].

There is a single report of infection with *H. farciminosum* in a donkey at Sennar [28]. *Histoplasma farciminosum* was demonstrated in Lieshman stain smears of purulent materials from 17 horses and 9 donkeys from Gezira State in 1997-2000. Treatment intravenously with sodium iodide resulted in some success as the disease was fatal to horses but not to donkeys although lesions in the latter tended to persist for a long time [29]. Epizootic lymphangitis had not previously been reported from Gezira but the results show the disease is a challenge in the area and could have negative effects on the local economy.

Rhinosporidiosis

Infection by *Rhinosporidium seeberi* has been reported once in a horse presented at a Khartoum clinic, the horse later died from nasal obstruction and secondary bacterial infection [30]. The organism had previously been isolated from two horse attendants but the source of infection was not traced [31].

Ringworm

Ringworm in horses caused by *Trichophyton equinum* was reported in the early 1970s [32]. Cases due to T. mentagrophytes were later recorded [33]. Inflammable swellings that oozed pus were noted in a male horse at Omdurman Veterinary Clinic. Microscopic examination showed the organism was *Trichophyton verrucosum* with diagnosis

Wilson [23] is a secondary source based on original documents in the Sudan Government Archives with information obtained from three sources in particular: Sudan Intelligence Reports (a digest of information from a wide spectrum of official and unofficial sources on various topics which may have seemed being confirmed by the Mycological Laboratory of the London School of Tropical Medicine and Hygiene [34]. *T. verrucosum* was first identified in ringworm lesions from two donkeys in North Kordofan [35].

[1]Wilson [23] is a secondary source based on original documents in the Sudan Government Archives with information obtained from three sources in particular: Sudan Intelligence Reports (a digest of information from a wide spectrum of official and unofficial sources on various topics which may have seemed of concern to the conduct, initially from 1881 to 1898 of a military invasion, and subsequently from 1898 to 1924 of an occupying power); the annual reports of the Veterinary Authorities (under whatever name they were constituted) from 1900 to 1956; and, the monthly reports from 1944 to 1956 of the Provincial Commissioner for Darfur to the Governor General of the Anglo-Egyptian Sudan, known as the Darfur Monthly Diary.

Protozoa

Trypanosomes

Trypanosomosis is widespread in Sudanese domestic stock. In cattle it results from infection contracted through tsetse flies acting as parasite vectors. In camels it is known as 'surra' (a word of Sudanese origin)–Notifiable in Sudan–and results from mechanical transmission, mainly by Tabanidae, the parasite itself being *Trypanosoma evansi*. Transmission in equines, equally known as 'surra', is analogous to camels. Trypanosome species infecting Sudanese equines have been identified as *T. brucei* subgroup*, T. vivax, T. simiae, T. congolense* [36] and *T.* equiperdum [4].

An early study of equine trypanosomosis was, not surprisingly, related to their use as transport animals: "Trypanosomiasis causes heavy mortality among the transport animals of the Sudan. Every year a large number of donkeys and a lesser number of mules examined at the Chief Veterinary Hospital, Khartoum, are found to be suffering from trypanosomiasis; the animals had contracted the infection when on transport work in the Bahr-el-Ghazal province. When seen at the hospital the beasts were almost invariably in an advanced state of the disease; the mortality amongst them has been, so far as can be ascertained, 100%. Besides these many other animals die in the provinces so that it is impossible to estimate the total losses. In mules and donkeys the onset of the disease is insidious and in many cases its course is very chronic. The parasite is polymorphic and the author is of opinion that it must be regarded as identical with *Trypanosoma brucei*" [37].

Based on previous work that found that arsenic in suitable doses cured at least 70% of horses suffering from 'surra', even when contracted spontaneously and in the last stage of the disease, 19 donkeys and 3 mules were subjected to extended trials with severe doses of arsenic which were well tolerated [37]. Most animals were in very poor condition when first seen with several in extremis. Of the 22 animals, 12 died and 10 (45%) were cured: although this was not as good an outcome as in the previous trial the results were not unsatisfactory. The conclusions were that: Arsenic appeared to have specific action in a large percentage of cases and cleared the blood of trypanosomes. Taken with the earlier experiments there seemed no reason to doubt that a permanent cure may be effected in many cases and the results justified a more extensive trial, especially as no other drug had then been proved to be of greater value [37].

During the 1920s "over 600 [government, mostly transport] camels, cattle and equines were destroyed in six years". Trypanosomosis due to *Trypanosoma evansi* was first diagnosed in horses in the Gezira in 1952 and there were more cases in Nyala in 1956/1957. Treatment with Antrycide caused the parasite to disappear but animals became re-infected and further treatment failed to prevent deaths of horses [38].

In the 1930s, infection with *Trypanosoma congolense* was diagnosed, based on the presence of trypanosomes in the blood and by small-animal inoculation, in 14 horses from tsetse-infested areas. Treatment with Surfen C (Bayer) which at that time had not been released for general use and had never been used in equines. Results in terms of cures were variable [39].

Serum samples from 393 horses and 116 donkeys from various areas were examined to estimate the endemicity of trypanosomosis using the generic ITS1-PCR diagnostic method. Both species were infected by trypanosomes. *Trypanosoma brucei* subgroup, *Trypanosoma vivax*, *Trypanosoma simiae* and *Trypanosoma congolense* showed a prevalence of 12.7% in horses. Only T. vivax was found in donkeys at a prevalence of 3.4%. Prevalence was highest in South Darfur (19.3%), followed by Kassala (15.1%), Gedaref (3.7%) and Khartoum (2.6%). No trypanosomes were detected in North Kordofan samples. It was claimed this was the first time *T. simiae* and *T. congolense* had been found in horses in Sudan [36] but this was manifestly untrue in the case of *T. congolense*.

The donkey seems to be the equid with the greatest resistance to tsetse-transmitted trypanosomosis and the disease apparently becomes a clinical problem through a precipitating factor, such as the stress of work.

Dourine, a sexually transmitted disease caused by *Trypanosoma equiperdum*, is an OIE Notifiable disease but is not Notifiable in Sudan. OIE data [3] indicate that it has never been recorded in Sudan. Dourine was, however, identified in a donkey mare from the Nyala area of Southern Darfur in 1961 [4]. It has not been reported since–which does not mean it is not present–because nobody has been looking for it [40].

Piroplasma

Piroplasmosis, often difficult to diagnose clinically, affects horses, donkeys, mules and zebras. The disease is transmitted via ticks or through mechanical transmission by improperly sanitized surgical, dental or tattoo instruments or through reuse of needles and syringes. *Babesia caballi* and *Theileria equi* are the causal agents. Microscopic examination of blood samples often fails to indicate the presence of either *B. caballi* or *T. equi*. Serological tests, including the Polymerase Chain Reaction (PCR), are thus the preferred method of diagnosis.

Piroplasmosis was first reported as biliary fever in Sudan in 1907 [8]. *Hyalomma anatolicum anatolicum*, the most abundant tick in northern Sudan, is the most likely vector of piroplasmosis [9,10]. In Khartoum District, 13 of 80 randomly selected horses exhibited typical symptoms. Blood smears revealed an infection rate of 20% by microscopic examination but the Complement Fixation Test of all horses gave a positive result for 70.5% of sera with one or other or mixed infections [11]. Further studies in

Khartoum District established an infection rate of 8.3% for *Babesia caballi* and 6.2% for *T. equi* with no mixed infections in one area and 0.0% for *B. caballi* and 25.0% for T. equi and 1.2% mixed infections in another area [12]. *Babesia equi* was found in equines in South Kordofan in 16.0% of donkeys (n = 42) and 7.1% of horses (n = 12) [14].

Blood smears from 187 horses and 294 donkeys and 36 horse and 55 donkey blood samples from several South Darfur State localities were examined for the presence of equine piroplasmosis. Blood smear examination showed very few infected animals with *B. caballi* being less than *Theileria equi* **(Table 2)**. The PCR results showed *B. caballi* DNA in 33.3% of horses but none in donkeys whereas 13.9% of horses and 23.6% of donkeys exhibited DNA of *T. equi*. It was concluded that piroplasmosis is an important disease and is transmitted to equines through tick vectors that include *Rhipicephalus decoloratus*, *Rhipicephalus annulatus, Rhipicephalus evertsi, Hyalomma detritum, Hyalomma truncatum* and *Hyalomma excavatum* [16].

Table 2. Prevalence (%) of equine piroplasmosis in horses and donkeys in South Darfur identified from blood smears and by PCR [16].

Species	Blood smears			Polymerase Chain Reaction		
	Number	*Babesia caballi*	*Theileria equi*	Number	*Babesia caballi*	*Theileria equi*
Horse	187	0	2.14	36	33.3	13.9
Donkey	294	0.34	2.04	55	0	23.6
Overall total	481	0.2	2.08	91	13.2	19.8

A first Sudan study on serological and molecular diagnosis of equine piroplasmosis aimed to demonstrate *B. caballi* and *T. equi* antibodies by ELISA in 158 serum samples from horses from different locations. *B. caballi* 48-kDa and *T. equi* EMA-2 purified recombinant proteins were used as antigens. Positive results were obtained from 7 horses (4.4%) for *B. caballi* and 80 (63.5%) for *T. equi*. PCR assays using primers targeting the *B. caballi* 48-kDa merozoite antigen, *T. equi* SSUrRNA and *T. equi* EMA-1 genes on 131 blood spots in filter paper showed none positive for *B. caballi* but 33 (25.2%) positive for *T. equi*. Higher antibody prevalence of *T. equi* than of *B. caballi* could possibly be attributed to vector distribution as *Hyalomma anatolicum* might be more important in transmission of *T. equi* than of *B. caballi*. Another possible reason for the low prevalence of *B. caballi* could be earlier elimination of the parasite after a short period of infection. The study concluded that equine piroplasmosis is endemic in Sudan [13].

In a molecular epidemiological investigation on *T. equi*, the small subunit of rRNA gene (18S; ~1,600 bp) was amplified from 20 positive of 127 field samples from horses from different locations. Subsequent direct sequencing and analysis revealed 11 distinct *T. equi* sequences within 18S rRNA of which three genotypes lay within the three previously identified groups. Alignments demonstrated extensive sequence variation in the hyper variable region of the 18S rRNA gene and many SNPs within the Sudanese isolates [41]. Another cross-sectional study involved 499 samples from horses and donkeys from different areas in eastern, central and western Sudan. PCR amplification of the 18S rRNA gene showed horses from all areas positive to *T. equi* DNA but no *B. caballi* was detected. Overall prevalence was 35.95% ranging from 81.3% in eastern Kassala to 5.6% in South Darfur. In another experiment capillary electrophoresis was powerful in detecting mixed infections in artificially mixed control samples. A conclusion was that the results could contribute to the development of a national control strategy for equine piroplasmosis [15].

Leishmaniasis

Human leishmaniasis caused by Leishmania major and transmitted by a phlebotomine sand-fly has been recognized as a major problem in Sudan since early in the twentieth century and continues so at present [42]. The first (and, as far as can be ascertained, the only) recorded case of equine cutaneous leishmaniasis was made in 1935 in a native bred pony stallion aged about 8 years [43].

Globidium

Provisionally reported in 1927 to be a peculiar case of sarcosporidiosis in a horse [44] it was later shown by inspection of mounted material to be *Globidium leuckarti*. The indefatigable author of the first report described two more horse cases in 1933[2] [45].

Toxoplasma

Toxoplasma gondii is a worldwide zoonose but is not on the OIE list of Notifiable diseases. The only definitive host of the organism is the Felidae [46]. Interest has been shown in Sudan in Toxoplasma in food animals since the early 1980s [47-50]. A recent serological survey (the first for Sudan) used the Latex Agglutination Test (LAT) on 205 sera from working horses (100) and donkeys (105) in Khartoum State. Overall sero-prevalence was 32.7% being 38.0% in horses and 27.6% in donkeys with titres ranging from 1:2 (4 animals) through 1:4 (11), 1:8 (13), 1:16 (17), 1:32 (5), 1:64 (10) to 1:128 (7). Area within the State and animal species showed no significant difference in infection rates but age was significant with young animals having higher rates. One case of abortion showed Toxoplasma present with *Brucella abortus* [51]. A second survey of horses only carried out by the same group found seropositivity to *T. gondii* using LAT on 223 sera was significantly higher in the dry (107 horses, 37.4%) than in the wet season (116 horses, 23.3%). There were no differences in rates in horses from racing stables, police stables or working as cart animals, nor were there differences due to location, sex or age. Antibody titres raged from 1: to 1:64 [52].

[2]Now reassigned as Besnoitia bennetti (Bennett, 1927) Babudieri.

In another study, sera from 381 clinically healthy horses from the Greater Khartoum area were tested with ELISA for *T. gondii* antibodies. IgG antibodies were detected in 24 animals (6.3%) whereas IgM antibodies were detected in 2 horses (0.5%). Antibody titres were in the range 1:20 to 1:160 dilution with no significant differences in infection rates due to area or sex [53].

Bacteria

Glanders

Glanders, caused by *Burkholderia mallei*, is Notifiable in Sudan but is of sporadic and low incidence, occurring mainly in the cold rainy season. The disease was first reported in 1915 [54] and then in 1933 when military horses at Shendi, on the Nile 150 km north of Khartoum, were affected [55]. One case of glanders was reported to OIE in 1989 [56]. *Burkholderia mallei* was isolated from donkeys in the Khartoum area in 2003/2004 [17] but does not seem to have been recorded as a Notifiable disease.

Strangles

Strangles, caused by *Streptococcus equi*, is widespread and the cause of much production loss because of its severe and chronic effects. It "occasionally caused problems" in the 1930s [23]. The author of the present paper saw a horse with classic symptoms in Southern Darfur in 1973, exhibiting nasal discharge, inflammation of the respiratory tract and enlarged and hardened lymph nodes in the upper neck (personal observation). A horse at the Veterinary Clinic in Sennar, 300 km south of Khartoum on the Blue Nile, in 1988 presented the classic symptoms; on microscopic examination of pus an organism identified as *S. equi* was observed [57]. A few donkeys among 808 animals in the Khartoum area were found to be infected in 2003/2004 [17].

Corynebacterium (Rhodococcus)

Broncho-pneumonia in a mature horse in 1960 was considered due to a bacterium resembling *Corynebacterium equi* (now *Rhodococcus equi*): treatment with penicillin suspension for 12 days did not result in improved condition and the horse died 20 days after admission to the hospital [58]. In the late 1970s a new species of *Corynebacterium* was isolated at Omdurman Veterinary Clinic from a horse suffering from a cough and with nodules and ulcers on the face and legs [59]. *Rhodococcus* is a zoonose and although it rarely affects healthy humans it is a problem in immunocompromised people.

Brucella

Serum samples from 346 horses and 28 donkeys throughout Darfur were collected for diagnosis of *Brucella* by the Rose Bengal Plate Test (RBPT), Serum Agglutination Test (SAT) and Complement Fixation Test. Positive results were obtained from 17 (4.9%) horse sera and 1 (3.6%) donkey serum. Clinical signs (muscular stiffness, fistulous withers, difficulty of movement in hindquarters, lethargy) were observed in four horses and one serologically positive mare had aborted at four months pregnant. SAT antibody titres in positive animals were in the range 41-264 i.u./ml. All horses and donkeys were herded with cattle, the region's main reservoir of *B. abortus*. It was concluded that equines acquired infection from cattle but did not transmit to cattle and there was no equine-to-equine transmission [60]. *B. abortus* was found in 2 of 249 isolates from donkeys from Khartoum State in 2003/2004 [17] but was apparently not reported as a Notifiable disease.

Mixed bacteria

Swabs from 131 donkeys and 27 horses in North Kordofan with various wound sites but mainly saddle sores were cultured for aerobic bacteria on Blood and MacConkey Agars. Purification was done on to Nutrient Agar and identification performed by cultural, biochemical and morphological characteristics. In total 21 species of bacteria were identified **(Table 3)**. *Staphylococcus aureus, S. epidermidis, Enterococcus faecalis, E. faecium* and *Bacillus licheniformis* were commonest. *Bacillus firmus* and *Listeria* sp. were isolated only from donkeys and *Kurthia* sp., *Micrococcus roseus* and *Bacillus cereus* only from horses. There were seasonal differences in species occurrence [61].

Bacteria isolated from wounds of 808 donkeys–45.9% being under 8 years old–in Khartoum State were studied for their sensitivity to bacterial drugs. Some 249 (30.8%) animals had wounds. Most wounds (71.55%) were on the back, followed by the abdominal region (14.22%) and then the legs (11.5%): 59.44% of infected animals had primary skin diseases, 35.09% had subcutaneous abscesses and 20.48% suffered from secondary skin diseases of which 14.60% had fistulous withers. There was a direct relation between wound site and type of work. In total, 25 species of bacteria were isolated: *Rhodococcus equi* (31.68%); *Staphylococcus equorum*, *S. aureus* and *S. hyicus* (31.06%); *Micrococcus* varians and *M. roseus* (12.11%); *Corynebacterium pseudotuberculosis* (5.59%), *Actinomyces pyogenes*, *A. bovis* and *A. viscosus* (5.59%); *Bacillus mycoides* (4.96%); *Streptococcus equi, S. zooepidemicus* and *S. equisimilis* (2.8%); *Pasteurella multocida* (1.86%); *Burkholderia mallei* (1.24%); *Neisseria lactamica* (1.24%); *Acinetobacter anitratus* (0.93%); *Fusobacterium nerophorum* (0.93%), Listeria monocytogenes (0.62%); *Brucella abortus* (0.62%); *Actinobacills equuli* (0.62%); *Yersinia pseudotuberculosis* (0.62%); *Flavobacterium indologenes* (0.31%); and, *Mannheimia haemolytica* (0.31%). Most wounds were treated by owners either by traditional methods or with proprietary drugs. Of 15 bacteria tested for resistance to six antibiotics *B. abortus* was resistant to all whereas *R. equi* was resistant to ampicillin and moderately sensitive to tetracycline [17]. The authors noted the presence of *B. abortus, B. mallei* and *S. equi* but failed to mention that the first two are Notifiable diseases and the last a major problem in equines.

Table 3. Bacterial isolates from donkeys and horses and by season of year in North Kordofan [61].

Bacterial species	Equine species (number of isolates)		Season (number of isolates)			Total number of isolates	Percentage of isolates
	Donkey	Horse	Cold dry	Hot dry	Rainy		
Staphylococcus aureus	22	9	12	10	9	31	19.62
Staphylococcus epidermidis	15	3	0	9	9	18	11.39
Enterococcus faecalis	29	2	6	9	16	31	19.62
Enterococcus faecium	17	11	8	7	3	18	11.39
Bacillus licheniformis	15	1	7	9	0	16	10.13
Bacillus firmus	5	0	3	1	1	5	3.16
Bacillus cereus	0	2	0	2	0	2	1.26
Streptococcus salivarius	1	0	0	0	1	1	0.63
Streptococcus pyogenes	5	3	4	2	2	8	5.06
Streptococcus bovis	1	0	0	1	0	1	0.63
Streptococcus equinus	1	0	0	1	0	1	0.63
Gemella haemolysans	2	1	1	2	0	3	1.93
Aerococcus viridans	5	1	0	1	5	6	3.79
Actinomyces pyogenes	5	0	1	3	1	5	3.16.
Arcanobacterium haemolyticum	1	1	1	1	0	2	1.26
Corynebacterium ulcerans	1	0	0	1	0	1	0.63
Listeria sp.	4	0	2	2	0	4	2.53
Kurthia sp.	0	2	0	2	0	2	1.26
Micrococcus roseus	0	1	1	0	0	1	0.63
Micrococcus Varian	1	0	0	0	1	1	0.63
Pediococcus sp.	1	0	0	0	1	1	0.63

Uterine washes of 200 Thoroughbred and local mares aged 3-12 years with a history of genital discharge and/or abortion or which failed to conceive after repeated services were examined for bacteria in May 1977-May 1978. No bacteria were isolated from 23% of mares but at least 19 species were isolated from infected ones. In order of frequency these were *Bacillus* sp., *Staphylococcus aureus, Alcaligenes faecalis, Micrococcus* sp., *Pseudomonas aeruginosa, Haemolytic streptococci, Staphylococcus epidermidis, Escherichia coli, Klebsiella aerogenes, K. edwardsii var edwardsii, K. pneunioniae, Alcaligenes viscolactis Acinetobacter anitratus, A. lwoflii, A. mallei, Citrobacter sp., Hafnia alvei, Branhamella catarrhalis* and *Kurthia* sp.[3]antibiotic sensitivity tests were performed on isolated bacteria. Treatment was applied usually for 4 days but was extended to 8 days for severe infections. Antibiotics and dosages were: (I) Trimethoprim and sulphadoxine solution (Borgal, Hoechst) 30 ml intravenously; (ii) Sulphamethoxazole and trimethoprim (Septrin, Wellcome) 8 tablets dissolved in 70 ml distilled water for intra-uterine infusion; (iii) Penicillin, 4 mega units intramuscularly and 8 mega units in 70 ml distilled water for intra-uterine infusion; (iv) Streptomycin (Specia France) 4 g intramuscularly and 8 g in 70 ml distilled water for intra-uterine infusion; and (v) Trimethoprim and sulphamethoxazole (Bactrim, Roche) 8 tablets in 70 ml distilled water. After appropriate treatment, 17 mares conceived and carried foetuses to term, 4 conceived but showed early embryonic death and 9 failed to conceive. Other than frank cases of metritis little difference was seen between sterile specimens and those that yielded bacterial growth, suggesting that isolated bacteria were either commensals or contaminants and had little to no effect on fertility. Mares harbouring *Pseudomonas aeruginosa* were served several times but failed to conceive over 2 years and in two oestrus was accompanied by a purulent discharge [62]. It is worthy of note that although metritis was present in many cases, *Taylorella equigenitalis* the bacterium causing the Notifiable Contagious Equine Metritis was not identified. The glanders bacterium *Burkholderia mallei* (here described as *Acinetobacter mallei*) was isolated but the disease itself was apparently not seen.

Viruses

African Horse Sickness

African Horse Sickness (AHS) is Notifiable in Sudan. It was first reported in 1903 from the eastern provinces of Kassala, Senna and Singa [63] and from El Obeid in South Kordofan [23]. It is known in Sudan as 'nigma' (star) because it was originally thought to infect animals which drank at night–possibly establishing early indigenous knowledge of its transmission by nocturnal insects. It is probable that the vector of the virus in Sudan is the midge *Culicoides imicola* [64] although one early author, in a supposed absence of other haematophagous insects during an outbreak of AHS, considered the Horn Fly *Lyperosia minuta* (*Haematobia minuta*) a likely vector [65]. AHS is endemic to certain areas and associated with the rainy season but is also subject to periodic outbreaks. One such occurred in 1927 but losses had returned to a low level by 1930 and were exceptionally light in 1934 and again in 1938 in spite of heavy rains in the latter year. It is probable these observations relate only to government and military

[3]There have been several name changes since the paper was written and Klebsiella aerogenes and K. pneunioniae are not now regarded as separate species.

horses as, with one exception, no further mention in the official archives of the incidence of AHS is made after the introduction of a vaccine in 1939. Most horses belonged to nomads, however, and were not available for veterinary treatment during the critical rainy season. AHS undoubtedly continued to be a problem in native horses and the authorities were surely aware of this as shown by the vaccine offered as an inducement for mares (and their foals) bred to government stallions in order to produce stock that would meet the standard required as remounts [23, 66].

AHS was not confirmed serologically (as type 3), however, until 1957 [67]. In recent years type 9 has always been the predominant serotype isolated [68,69] although types 3 and 6 have also appeared [18]. All early reports of AHS were from horses. Later there are reports from mules [70] and donkeys [69].

Symptoms and post-mortem lesions of AHS were observed in mules at El Obeid in Kordofan Province in 1915. Land to the north, east and west was desert with vegetation to the south. Rains began about mid-July and continued until late October. The disease appeared in September and continued until the end of November. Many cases occurred among mules going to a place with no vegetation and only one well 20 miles (32 km) north of El Obeid but it seemed this place was the source of infection. Recovery could take place but animals were then useless as they remained in poor condition in spite of good feeding and they almost always lagged on the march. Many mosquitoes were not necessarily seen or heard in years when the disease was rife, suggesting that another agent may have been the vector [68].

Overt AHS has never been seen in donkeys nor are donkeys vaccinated against AHS in Sudan. In spite of close proximity during AHS outbreaks in horses, donkeys are never affected. In a study of 215 sera samples from Khartoum Province 98% possessed AHS antibodies. This suggests that donkeys are resistant to AHS or undergo some form of subclinical infection. It is not known whether donkeys act as a reservoir from which horses are affected [69].

Agar Gel Precipitin Test (AGPT), Counter Immunoelectrophorsis (CIEP), Passive Haemaglutination Test (PHA) and Serum Neutralization Test (SNT) were carried out on 455 serum samples from Southern Darfur and Khartoum States to detect antibodies against AHSV. AGPT and CIEP were negative in all samples whereas PHA showed 42.64% positives and SNT 27.75% positives. Serotypes 3, 6 and 9 infected horses on the basis of SNT. Type 3 was 6.5% positive in Southern Darfur but was 0.0% in Khartoum, type 6 was 48.3% positive in Southern Darfur and 39.5% in Khartoum with type 9 being 45.2% positive in Southern Darfur and 60.5% in Khartoum [18]. In another study in Khartoum Province antibodies to AHSV were detected in horses (78.9% of 95 sera) and donkeys (76.9% of 30), in cattle (20.0% of 20) and goats (15.0% of 20) and in Dorcas gazelle (11.0% of 9). No antibodies were detected in greater kudu (1), roan antelope (1), lion (3), vevet monkey (10) nor patas monkey (10). Antibodies to all of serotypes 1-9 except 8 were identified, although type 9 was predominant and type 8 was not identified because the relevant test was not available. AHS is frequently reported in imported race and breeding horses and it is suggested that local horses with a history of exposure but clinically normal could act as carriers of the virus [19].

A live attenuated vaccine against AHS is produced locally. Vaccination campaigns are undertaken annually in September but the extent of cover is very low, especially in the more remote and unsafe parts of the country. In the 1950s and 1960s between 550 and 2400 horses were vaccinated annually [71].

Equine Infectious Anaemia

Equine Infectious Anaemia (EIA) has never been officially reported in Sudan. Recently, however, antibodies to the virus have been found in the Khartoum area [5] and in other parts of the country. Prevalence of antibodies to EIA was investigated in 358 serum samples collected randomly in seven regions from apparently healthy horses (189) and donkeys (169) during 2008-2013. Prevalence of EIA virus antibodies using Indirect ELISA was 5.58% (3.17% horses, 8.28% donkeys). Highest regional prevalence (15.3%) was in donkeys in Nyala followed by donkeys (11.1%) in Halfa. In horses, highest prevalences were in Fasher (5.0%) and Nyala (4.8%). All horses and donkeys in Atbara were sero-negative [6].

Equine Herpes Virus

Equid herpesvirus-1 (EHV-1) (Infection with) is a Notifiable OIE disease but is not Notifiable in Sudan. Other EHV types are not notifiable to OIE. EHV-1 causes respiratory disease in young horses, abortion in pregnant mares and paralysis in horses of all ages. EHV-4 usually only causes low-grade respiratory problems but occasionally causes abortion. EHV-1 and EHV-4 were first detected in Sudan when sera of 126 horses and 82 donkeys were examined by indirect ELISA. Animals were from four different areas, mainly local types and apparently healthy. EHV-1 was detected in 1.6% of horse and 7.3% of donkey samples. EHV-4 was detected in 58.7% of horses and 58.5% of donkeys. Mixed infection with both types was recorded in both equine species. Rates of infection differed by locality **(Table 4)** [20].

Equine Influenza

According to OIE [3], which includes Equine Influenza on its list of Notifiable diseases, this disease has never been reported in Sudan. In Sudan, however, the disease is not Notifiable. A small percentage of sera of cattle, sheep, goat and camel from Kassala showed type A influenza virus antibodies when examined by Agar Gel Diffusion test. There were no positive results in sera of 113 donkeys [72]. Equine Influenza Virus antibodies were found in 5 of 213 (2.34%) horse sera and 2 of 155 (1.29%) donkey sera from various parts of South Darfur State when tested by ELISA with Optical Densities less than or equal to 45% being considered positive [7].

Table 4. Antibodies to Equine Herpes Virus Types 1 and 4 in horse and donkey sera from various areas of Sudan as measured by ELISA [20].

Location	Horse					Donkey				
	N	EHV 1% +ve	EHV 4% +ve	Mixed% +ve	Total % -ve	N	EHV 1% +ve	EHV 4% +ve	Mixed% +ve	Total % -ve
Khartoum	52	0	61.5	7.7	30.8	22	0	90.9	0	9.1
Atbara	20	0	10	0	90	20	0	30	0	70
Wad Medani	12	16.7	33.3	0	50	20	30	35	10	25
Nyala	42	0	85.8	7.1	7.1	20	0	75	5	20
Total	126	1.6	58.7	5.6	34.1	82	7.3	58.5	3.7	30.5

Rabies

Rabies is Notifiable in all domestic species in Sudan. The disease is reported in equines in most years. The brain of a donkey taken to the Khartoum University Veterinary Clinic in July 1961 that had been biting its prepuce and other parts of its body was later diagnosed as positive for rabies [73]. In 2015 rabies was identified in a group of 538 equines, there being 12 clinical cases of which 5 died and 10 were slaughtered; 25 animals were vaccinated in a partial stamping out exercise [74].

Internal and External Parasites

Internal parasites

Internal parasites are a major problem in Sudan in equines. In the military campaign of 1885, horses suffered from the climate, hunger and thirst. In addition they were pestered by insects such as *Stomoxys calcitrans* which as well as the irritation caused could be vectors of diseases. The first report of internal parasites is from this period as horses suffered from cutaneous habronemiasis, a severe hypersensitive skin problem caused by heavy infestations of the larvae of the nematode genera *Habronema* and *Draschia* [75]. The Veterinary Department Annual Report for 1914 noted infestation by *Microfiliaria* spp. Subsequent reports have listed at least 16 species of roundworms, one of tapeworm (*Anoplocephala magna*) and two of flukes (*Gastrodiscus aegyptiacus*, *Schistosoma bovis*) [76,77]. One “most peculiar thing” was isolation of *Moraxella osloensis* similar to that of humans from an infected horse’s eye [78].

Some 15 horses aged 11-20 years due for culling from the Malakal (Upper Nile Province) police unit were examined for internal parasites. Species found were *Oxyuris equi* (pinworm), *Strongylus vulgaris*, *S. edentatus*, *Trichonema* spp., *Triodontophorus* sp., *Habronema megastoma*, *H. muscae*, *Gasterophilus intestinalis*, *G. nasalis*, *Gastrodiscus aegyptiacus* and *Schistosoma* sp. Treatment with “Neguvon” (Bayer L13/59) achieved various levels of reduction in both worm and egg counts [79].

Cutaneous habronemiasis in 15 horses and 5 donkeys was diagnosed on the basis of typical symptoms and from material digested in potassium hydroxide that revealed fragments of larvae suggestive of Draschia or Habronema. Curetting and excision of lesions were effective and produced complete healing of the wound by scar tissue formation [80].

Faecal samples from 215 donkeys and 175 horses in Nyala showed 56.2% helminth egg infection in the former and 60.6% in the latter. Samples from 120 donkeys and 65 horses in the nomadic Bahr el Arab area had lower rates of 24.0% in donkeys and 18.5% in horses. *Strongylus* sp. was predominant, infection rates for the combined areas being 43.6% in donkeys and 29.0% in horses. *Oxyurus* sp. infected 10.5% of donkeys and 19.5% of horses, *Parascaris* sp. 4.4% of donkeys and 4.6% of horses, *Strongyloides* sp. 3.9% of donkeys and 4.9% of horses and *Trichuris* sp. 0.9% of donkeys and 7.3% of horses. Animals were infected by a single nematode species in 74.9% of cases, by two species in 19.8% and by three species in 4.8% of cases. Higher infection rates in urban animals were considered due to their being confined at night and allowed to graze in a limited area by day whereas nomad-owned animals roamed freely over a wider area both night and day. It was further considered that site competition within the animal resulted in the higher percentage of single species infections and also for lower egg output in 2-and 3-species infections [81].

High mortality in donkeys in three areas of Southern Darfur was attributed to heavy internal parasite burdens with faecal egg counts in sick donkeys as high as 3000 EPG and Packed Cell Volumes of less than 26%. In one village in September 1995, mortality in 250 donkeys was 22% and morbidity 18%. In an area northwest of Nyala 24% of 150 donkeys died and 7% were sick in November 1995. Elsewhere in January 2005 just over 7% of 2500 donkeys died and 32% were sick. Standard methods of faecal examination and postmortem results showed the presence of *Strongylus vulgaris*, *S. edentatus*, *S. equinus* and *Gasterophilus intestinalis*. *Gasterophilus* sp. was also shown to be a problem in another study in South Darfur. Treatment with Ivermectin injectable at 1ml/50 kg live weight repeated at 21 days resulted in improved body condition and general health [82].

The cranial mesenteric arteries and their branches in 92 donkeys at Nyala were examined for *Strongylus vulgaris* larvae during May 2005-April 2006. Overall prevalence was 64.1% with an overall mean count of 46 ± 7.3. Larval numbers started to rise from the beginning of the rainy season to reach a peak in the early cool season before declining rapidly as the hot season advanced. Numbers of larvae were correlated with monthly temperature but neither with rainfall nor relative humidity [83]. Almost all internal parasite studies in the far west of Sudan have been carried out in South Darfur [84, 85] but one adventurous one was undertaken in North Darfur [86].

Internal parasites are the most frequent cause of donkeys taken to the Khartoum University Veterinary Clinic [87, 88]. Internal parasites were the causes of 59.5% of diseases of horses and donkeys presented at Khartoum Veterinary Hospital in 2010-2012 [89]. Studies of donkeys at clinics in various parts of Sudan confirm the importance of internal parasites as a health and welfare problem [83,90,91]. Parasites identified from 90 of 92 donkeys in Nyala were *Habronema* spp. (40.2%), *Trichostrongylus* axei (30.4%), *Parascaris equorum* (18.5%), *Anoplocephala perfoliata* (4.3%), *Gastrodiscus aegyptiacus* (8.7%), large strongyles (84.0%), small *strongyles* (72.0%) and *Oxyuris equi* (1.1%) [91]. The intermediate host for flukes in Sudan is mainly *Bulinus forskalii* [92]. Slightly more than 70% of 1200 donkeys in Khartoum State had nematode parasites including *Dictyocaulus arnfieldi* (70.5%, first report in Sudan donkeys), *Strongylus* sp. (35.8%), *Cyathostome*s sp. (36.7%), *Parascaris equorum* (10.7%), Trichostrongylus axei (12%) and *Strongyloides westeri* (3.4%); single species infections (53.2%) slightly exceeded mixed infections (46.7%) and infection rates and EPG counts were higher in the hot season than at other times of year [93, 94]. Trichinellosis is Notifiable in Sudan and a case in equines was communicated to the OIE in March 1993 [3].

Several small trials on anthelmintic efficacy have been undertaken in donkeys. Some drugs had not previously been administered to equines or were not registered for use with them. When administered at the correct or recommended dose rate most anthelmintics successfully reduced faecal egg counts to zero after one or two treatments with intramuscular injections performing slightly better than subcutaneous ones. Some adult worms and late stage larvae survived treatment and treatments were only moderately effective (33-63%) against larvae in the cranial mesenteric artery [84,93-96]. Moxidectin administered subcutaneously or intramuscularly and Ivermectin subcutaneously at 0.2 mg/kg live weight to three groups each of six donkeys reduced initial EPG of faeces from a mean of 550 to 90 by Moxidectin administered subcutaneously, from 700 to 150 by Moxidectin intramuscularly and from 600 to zero by Ivermectin subcutaneously. Both products were highly effective against immature and adult nematodes. No Gasterophilus larvae were found in donkeys from treated groups whereas all donkeys in a control group were infected. Ivermectin had an efficacy of 99.8% against Strongylus vulgaris larvae in the mesenteric artery aneurisms compared to 74.4% for Moxidectin [96].

External parasites (ectoparasites)

There has apparently been less interest in external parasites of Sudanese equines than in internal ones. External parasites were responsible for only 13.8% of equine cases at the Khartoum Veterinary Hospital in 2010-2012 [88]. They are important not only for the direct debilitating effects of their blood sucking, physical damage and the irritation they cause but, and perhaps more importantly, as vectors of disease organisms [97].

Hyalomma anatolicum anatolicum, main vector of *B. caballi* and *T. equi* [13], is widely distributed in Sudan. Around Khartoum 97.4% of 1344 ticks from 62 horses were H. a. anatolicum, the other 2.6% being *H. dromedari*, *H. rufipes* and *Rhipicephalus evertsi*. Mean infestation by *H. anatolicum* was 41.1 ticks per horse. Some 35.5% of eggs were positive for motile stages of *Babesia* spp. and *Piroplasma* spp. Only 3.7% of female ticks had such agents in their haemolyph, none being found in male haemolyph [10]. In wooded savannah near the River Atbara, the cultivated Gash Delta and River Gash Acacia seyal savannah in Kassala, *Rhipicephalus sanguineus* was found on sheep, goats, cattle, camels and donkeys [98]. *R. evertsi evertsi* and *R. sanguineus* were found on horses and donkeys as were *Hyalomma excavatum* and *H. rufipes* [99].

Psoroptic mange is said to be very rare on equines in Sudan [100]. The rabbit ear mite *Psoroptes cuniculi* was found to be the cause of typical mange lesions on the body of a donkey in the early 1970s [101]. An apparent first report of psoroptic mange due to *Psoroptes equi* in five donkeys (the disease had previously been described for horses) was published in 1987: treatment with injectable Ivermectin at 0.2 mg/kg live weight was successful with hair growth on the affected areas beginning at 32-35 days after initiation of treatment [102]. Ivermectin had previously been used successfully against *Sarcoptes scabiei* in donkeys [103]. Mange was diagnosed as the reason for 6.6% of visits to Khartoum Veterinary Clinics in 2010-2012 [88]. Local remedies such as ‘gutran’, a kind of tar made from *Colocynthis vulgaris* (‘hanzal’) and water melon seeds and ‘damerga’, an infusion of millet seeds are moderately to very effective in controlling mange on donkeys [14, 104].

Members of the dipterous family *Muscidae* usually affect livestock physically by irritation and lapping of fluid membranes. Stomoxys calcitrans is unusual, however, as it sucks blood and as such is a mechanical carrier of ‘surra’ and bacterial diseases and is an intermediate host for *Hymenolepis carioca*, *Habronema microstoma* and *Setaria cervi*. Another haematophagous dipteran, the Horn Fly Lyperosia minuta (= *Haematobia minuta*) was once considered to be a likely vector of AHS [65] and may continue to cause harm to equines through irritation and its blood feeding.

Other dipterous families that cause direct and indirect harm to equines are the *Glossinidae, Hippoboscidae, Tabanidae* and *Oestridae*. The Horse Bot Fly Gasterophilus intestinalis is a major equine pest in Sudan [105]. It causes indirect damage through attempts at egg laying and its flying about causes annoyance and possibly fright among horses: injuries can be caused through evasive action and loss of weight may result. The fly is also, however, an internal parasite. After eggs hatch on the hair coat, first instar larvae burrow into the mouth causing severe irritation and development of pus pockets and loosened teeth. Second and third instar larvae inhabit the gastrointestinal tract attached to the stomach and intestines. Large numbers of larvae can cause blockages, lead to colic and damage to stomach and gut lining in addition to diverting nutrients for their own use.

DISCUSSION AND CONCLUSIONS

Horses and donkeys in Sudan are smitten by and suffer from a plethora of diseases. Equines (including mules) received most veterinary attention in the last 15 years of the 19th and the early years of the 20th centuries. Equines were important in the Anglo-Egyptian armies in the cavalry and artillery campaigns against the Mahdist State and later for communications and transport which ensured the effective administration and supply of goods to the newly reconquered country. Emphasis soon shifted, however, to food-producing animals as their economic and social value became apparent. Equine health care then declined except for provision by a few remaining military and ex-military veterinarians. Development of a research arm principally resulted in identification of obscure diseases rather than in seeking to improve equine health and welfare. This last thrust has continued to the present day whereby researchers in both government and universities pursue the isolation of diseases not previously recorded in Sudan. In this context, also, the use of various serological tests in identification of infections has proved their superiority over microscopic techniques.

From the early 1990s the single veterinary faculty has expanded to become five with a concomitant explosion in the number of veterinary surgeons. Expansion in human resources has not been accompanied by an expansion in other resources such that the veterinary services are now chronically short of finance, of field equipment and vehicles and of laboratory equipment. Equine numbers have continued to increase but the health services with which they are provided have been greatly depleted. A very small minority of equines–the “lucky” few in urban areas–now benefit from any kind of medical or surgical input (although these have a price to pay for the privilege in poor nutrition, poor welfare and overwork). In the rural areas it is indeed a lucky horse or donkey that receives any medical attention other than that supplied through traditional remedies.

Many zoonoses do not manifest themselves clinically in Sudan’s equines. The limited positive microscopic and serological results indicate, however, that the horse and donkey are potential reservoirs of these diseases. They probably constitute an underlying threat to other animals and to the possible contamination of humans directly (brucellosis, listeriosis) or indirectly (toxoplasmosis). Determination of anti *T. gondii* antibodies in horses does not imply a direct risk for human health because horse meat is not eaten in Sudan but occurrence could favour more widespread infection via the dead horses and donkeys left outside in villages that are prey to stray dogs and cats living in intimate contact with people. Listeria is a major zoonose but in Sudan has been found only by accident and there do not appear to be measures in place to prevent its spread to people. Similarly hydatid disease/echinococcosis is widespread in Sudan’s food-producing livestock but has not been studied in equines which may be a reservoir and could be important in the transmission cycles of the parasite and as a possible source of infection for definitive hosts. Bacterial and viral infections can affect fertility and identification and treatment is important to reduce embryonic death and improve fertility. Internal and external parasites are a common and major problem but very few horses and donkeys have access to prophylactic or curative treatments.

It is a moot point as to whether the existing legislation is adequate with respect to equine disease identification and control. Whatever the case it is clear that it is not effectively implemented. Sudan is a Member State of the OIE and as such is required to submit regular 6-monthly and annual reports to the Office. It seems that the regulatory authorities generally respect this requirement but it also appears that reports are sometimes incomplete. In addition some OIE Notifiable diseases are not Notifiable in Sudan. An active research community continues to work on the identification, presence and location of disease organisms even when no clinical signs are present. Examples from references in this paper are African Horse Sickness, Glanders, Equine Infectious Anaemia and Equine Influenza where disease causing organism have been isolated but apparently not reported through the appropriate channels. The “Not Reported” status of Notifiable diseases in OIE lists are effectively meaningless and serve only to emphasise the deficiencies of the system.

Sudan’s approximately 8 million equines are, indeed, a minor component of national livestock wealth. They do not contribute directly to food production nor to foreign currency exports. They do, however, contribute directly to human welfare in both rural and urban areas. As sentient beings in the care of people they deserve more consideration than they receive or are likely to receive in the near future.

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