

SOME OBSERVATIONS ON THE THEORY AND PRACTICE OF DIPPING.

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(With Plate XII and 2 Text-figures.)

Introduction.

THAT ticks are a very serious trouble in countries where stock forms the basis of the wealth of the country is too well known to require elaborate demonstration, for the fact that they are the agents of transmission of some of the most fatal and devastating diseases is now generally recognised by the stock-farmer.

As the cure of these diseases, once established, is generally impracticable, or even, in many cases, impossible, reliance must be placed mainly on preventive measures directed to the destruction and eradication of the vector—the tick.

It is true that preventive inoculation has been given extensive trials, and with some measure of success. In East Coast Fever, for instance, *inoculation* may save some 40 per cent. of infected stock, but as inoculation does nothing to reduce the numbers of ticks, young stock are as susceptible as ever to infection, and the disease is not stamped out.

Dipping, on the other hand, strikes directly at the prime cause of the trouble by destroying the tick, and, provided the operation is systematically and properly carried out, affords the most certain means of combating tick-transmitted disease of stock.

It is our experience that many of the essential points in the process of dipping are not understood or realised by those in authority, and, in consequence, dipping measures which have been impelled by the weight of official recognition have frequently failed to achieve their object. We think, therefore, that a *résumé* of the work done in the past, with deductions made from the available data, may serve a useful purpose.

We may fairly claim to have had a greater experience of the scientific aspect of the problem than many, who have had neither time nor facilities to devote to the matter. Our views on the subject have been confirmed both by experimental investigations and a large experience of practical results.

If this paper does nothing more than to invoke discussion, or to lead others to put our deductions to the test by further investigation, we shall consider that its purpose has been achieved.

In 1908, we were engaged by a commercial firm to make a study of the dipping problem at Gonubie Park, East London, S. Africa. A farm of 3000 acres, with 300 head of cattle, a swim bath and sufficient funds were placed at our disposal. A large amount of work was done, but the results obtained, being the property of the firm, were not immediately available for publication. Since then, further work has been carried out, detailed experiments have been continued, and, as permission has now been obtained to make use of such results as may be deemed to be of scientific interest, it is our intention to publish an account in the near future.

The theoretical considerations which led up to the experiments carried out at Elliotdale, British East Africa, and also our dipping experiments in connection with the Tsetse Fly and Trypanosomiasis, referred to later, were based on this investigation.

A large amount of analytical work was carried out by us at Gonubie Park, but unfortunately, the very limited quarters at our disposal soon became so thoroughly contaminated with the arsenic used in the preparation of large quantities of dipping materials that, though sufficiently good for our purpose at the time, our analytical results are not sufficiently reliable for the purpose of publication. Since then, Lieut.-Col. Watkins-Pitchford (1909, 1910 and 1911), who was working concurrently, though quite independently, on the same subject, has published results of his analyses, and as these results are readily available to the reader in reprint form (1911a), we have not thought it necessary to repeat this portion of the work, but shall make frequent references to this reprint.

The Process of Dipping.

For the benefit of English readers, to many of whom the method of dipping of large numbers of cattle is unfamiliar, we give the following brief account, omitting certain practical details which are, for the present purpose, unimportant.

The dipping bath (Fig. 1) is a concrete tank built in the ground into which it is sunk to such a depth that the rim of the tank is flush with the ground level. The bath measures some fifty feet in length and the side walls are inclined outwards in such a manner that while the width at the bottom is about two feet, the width at the rim is some four to five feet. The end wall at the entrance of the bath is vertical, at the exit it is sloped at an angle of about 20° to the horizontal to enable the animals to walk out of the tank. Near the entrance of the bath is an enclosure in which the stock to be dipped are collected, and from this a short entrance race leads directly to the vertical end of the tank. The exit slope leads to a draining pen. The bath is filled with the dipping-fluid to such a depth as to allow of complete submersion.

The cattle are driven through the entrance race and jump into the bath where for a moment they are completely immersed; they then swim down the bath to the exit slope, up which they walk to the draining pen where they stand while the superfluous dip drips off and drains back into the tank.

At first there may be some difficulty in persuading the cattle to enter the bath, but as they become used to the operation, the difficulty lies in checking their eagerness. The process is very rapid and economical—400–600 head of stock can be dipped in an hour at a cost of $\frac{1}{8}$ – $\frac{1}{4}$ of a penny per head.

The concentration of the dipping-fluid should vary according to the interval between each successive dipping, and also the species of tick to be killed. The South African ticks may be divided into three classes in this respect, of which the Blue Tick (*Boophilus decoloratus*) forms one; the Bont Tick (*Amblyomma hebraeum*), with which may be associated the Bont-legged Tick (*Hyalomma aegyptium*), a second; and the Brown Tick (*Rhipicephalus appendiculatus*) together with all the species of *Rhipicephalus* which transmit East Coast Fever, the third.

The ticks of the first class are easily killed and are not now considered to be of serious importance.

The Bont Tick, which is important as the transmitter of Heartwater, is most difficult to kill, and the dipping-fluid must be moderately strong and an interval of a fortnight between the dippings is sufficient.

In the case of the Brown Tick (*R. appendiculatus*) the life cycle is so short that the dipping must be repeated at frequent intervals. For this reason, an interval of three days between dippings was adopted, since, as Lounsbury (1904) has shown that the minimum period of attachment of the adult tick was three days, all ticks attached to an animal must

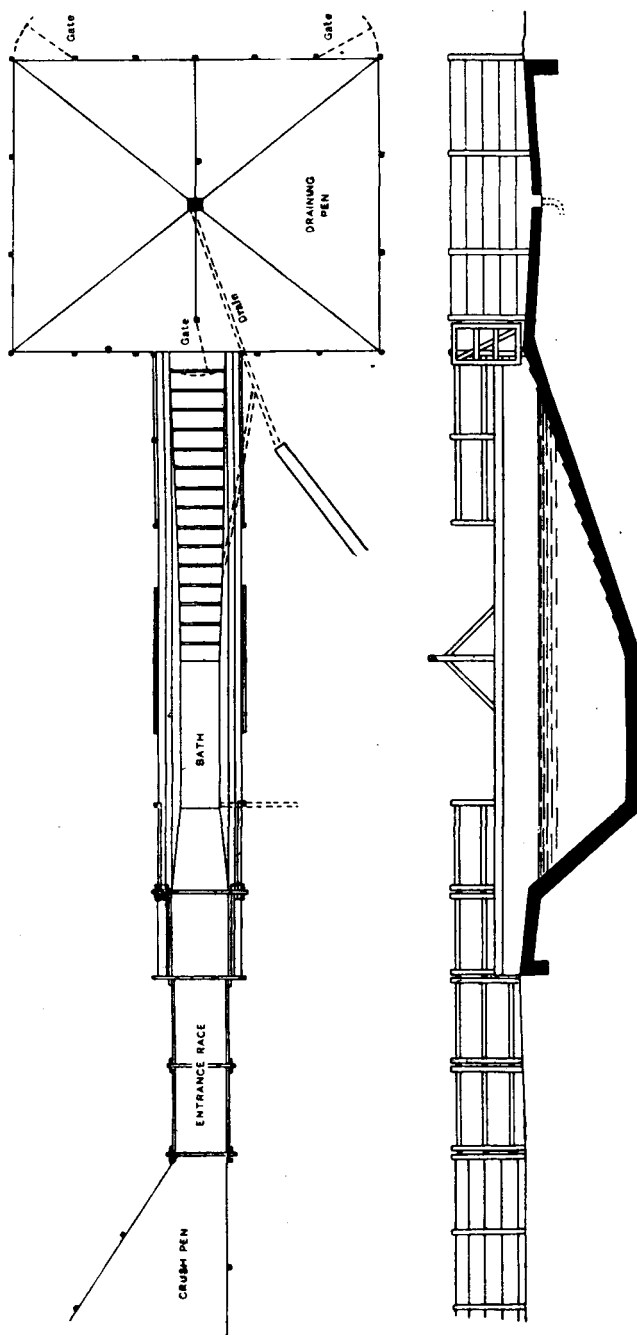


Fig. 1. Plan and elevation of Cattle Dipping Bath.

pass through the dipping-fluid and be killed. It was found later that, after dipping, the stock remain distasteful to ticks for at least two days, and, in consequence, the interval was lengthened to five days, and it would appear that an interval of seven days may suffice, though this has not yet been satisfactorily proved.

While a solution of sodium arsenite alone causes some inconvenience, owing to the fact that stock cannot be used for ploughing and transport for one or two days after dipping, the addition of an emulsion to the fluid allows the concentration of the sodium arsenite to be considerably reduced without decreasing the effectiveness of the dipping-fluid; consequently, with the use of such a dipping-wash, the stock suffer no inconvenience and the work of the farm is not unduly interfered with. At Gonubie Park, some of the oxen have been dipped regularly over a period of several years and used continually for trek work and ploughing.

Horses, mules, etc., also may be dipped regularly, but in the case of sheep, it is desirable to retain a separate bath for their use, as the loose hairs of previously dipped stock get into the wool and cause much trouble and inconvenience in the manufacture of the wool into goods.

Instead of making the cattle swim through a bath, they may be driven through a tunnel into which the dipping-fluid is sprayed by means of suitably arranged jets, the general principle being that of the ordinary 'needle' bath. The method is not so rapid as the swim bath and there is a wide-spread opinion that it is not so thorough in its effects. Nevertheless, the spray bath (Plate XII, figs. 1 and 2) is effective, in spite of the objections raised by some authorities. Practically all of Watkins-Pitchford's work was done with this apparatus and we used the method in our investigations at Elliotdale. Of those who condemn the spray bath, it is generally found that few have had any real experience in its use.

Scalding. By the use of a too concentrated dipping-fluid a more or less severe inflammation of the skin is set up, which condition is generally referred to as 'scalding.' It is not necessarily due to an excessive proportion of arsenic in the dipping-fluid; for it may be caused by the use of a faulty formula, in which the percentage of arsenic is not necessarily excessive, in the preparation of the dip, or by negligence in observing certain general principles in the actual operation of dipping. These principles are related chiefly to meteorological conditions and to the physical condition of the stock at the time of dipping, and as they are generally recognised by those who practise dipping and are not of

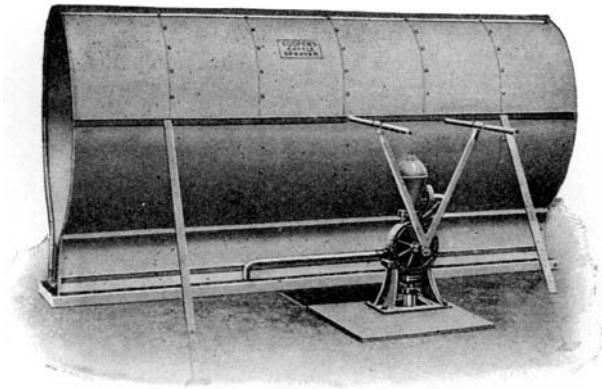


Fig. 1. Side Elevation of Cattle Spraying Machine



Fig. 2. End view showing Spraying Machine in operation

direct importance for our present purpose, we do not consider it necessary to dwell upon them.

The symptoms of *scalding* manifest themselves as follows: the skin becomes hot and tender and as the inflammation progresses, more or less induration, which in bad cases is followed by wrinkling and cracking, with oozing of blood and serum from the fissures, makes its appearance. A constitutional symptom which is almost invariably present is diarrhoea, and this tendency to 'scour,' which is often the first and only sign of scalding, is of great importance and should not escape attention. The maximum degree of soreness is naturally found in those parts where the skin is most subject to flexion, particularly the knee and the hock, and in consequence the animal walks stiffly and shows a great disinclination to movement.

As the inflammation subsides, the cuticular layers of the skin peel off and as the hair follicles are not affected a new growth of hair ultimately appears.

The Effect of Dipping on the Tick.

Concerning the precise mode of operation of the dip in killing the tick, various views have been formulated which may be summarised as follows:

(a) That the tick absorbs the poison through its own skin, either in the dipping bath or subsequent to the dipping.

(b) That the tick imbibes the poison with the blood which it sucks from the host.

In order to ascertain whether it is possible for a tick to absorb a lethal dose of the poison through its skin, various investigators have submitted ticks *removed from an undipped host* to the action of a dipping-fluid. The authors made the observation some years ago that mere immersion of free ticks in a dipping-fluid does not kill them. Ransom and Graybill (1912) found that engorged female ticks generally survived this treatment, but many failed to lay eggs, and in those cases where oviposition took place, the eggs failed to hatch. In two experiments only, did hatching occur and then only to the extent of 1 to 2 per cent. respectively of the eggs laid. In practically all cases, the untreated ticks, used as controls, oviposited normally, and from 60 to 99 per cent. of the eggs hatched, while in the few cases in which the percentage of successful hatching was low, this result was directly attributable to the unfavourable conditions of humidity and temperature which

obtained in the laboratory. Attention was first called to this infertility of the eggs of dipped females by Lounsbury (1905).

Brünnich and Smith (1914) concluded from experimental observations that the poison is in part absorbed through the skin of the tick subsequent to the time of dipping and is also imbibed with the fluid extracted from the skin of the host.

According to our own experiments with dipped animals, an effective dip kills the ticks before they can lay eggs, and this even applies to ticks removed from a host which has been subjected to periodical dipping. This is an important point when considered in relation to the results obtained by Ransom and Graybill, which showed that simple immersion of free adult ticks taken from an undipped host failed to kill.

Watkins-Pitchford (1911*a*), in his observations on the effect of the dip on adult female ticks attached to the host, writes (p. 69) as follows:

‘How rarely after one dipping such female forms remain on their host uninjured, and go on to full distension, may be judged from the fact that out of over 10,000 adult ticks actually counted throughout these observations on cattle being subjected to the new process, only sixty-nine partially distended females have been found.

‘Careful detachment of these distended ticks and observations under favourable conditions show that—in the majority of cases—the dipping arrests the process of egg-laying, while of those eggs which are laid only a small percentage are capable of subsequently hatching out.’

Again (p. 50):

‘It can be shown that the poisonous effect, though strictly local, is not due to a simple deposition on the surface of the skin, resulting from one or more dippings. If, in an habituated animal, a patch of skin is shaved closely and then thoroughly washed so as to remove all deposited arsenic with the hair and surface epithelium before attaching the ticks, the lethal result will follow in the same degree as in the case of an habituated animal in which such precautions have not been taken.’

Watkins-Pitchford also found that ticks were killed when placed on an animal *after* dipping; and, further, that this effect persisted for several days (see Appendix I). Similar experiments carried out by us have given the same result.

Experimental inquiry therefore tends to prove that the poison is imbibed by the tick while feeding on the host.

The fact that engorged females are rendered infertile by mere immersion in the dipping-fluid can have little effect in actual practice, inasmuch as real success is only attained by killing the ticks before they can lay; if the ticks do not die, it indicates a deficiency on the part of the dipping-fluid.

The Effect of an Emulsion in a Dipping-Fluid.

It was found in the course of our investigations that, to obtain the same killing effect, a plain solution of sodium arsenite must be more concentrated than a solution to which an emulsion of soap and oil, or even soap alone, has been added.

The method followed was to record by means of diagrams the numbers and situations of the ticks on several head of cattle. The animals were then dipped in the various solutions which it was decided to test and the effect on the ticks noted. Bont (*Amblyomma hebraeum*), Blue (*Boophilus decoloratus*) and Red ticks (*Rhipicephalus evertsi*) were present.

It was found that a solution of sodium arsenite containing only 0.153 per cent. of As_2O_3 , but to which sufficient emulsion had been added, was as efficient as a plain solution, i.e. a solution containing no emulsion—containing 0.225 per cent. of As_2O_3 .

Watkins-Pitchford (1911a, p. 31) showed that sodium arsenite alone, at a strength sufficient to kill the ticks, scalded the cattle. On reducing the amount of arsenic, the dip failed to kill the ticks, but by adding a paraffin and soap emulsion to the more dilute solution, the ticks were destroyed without injury to the cattle (see Appendix II).

It may be pointed out that the Department of Agriculture of the Queensland Government attribute great importance to the presence of an emulsion in a dipping-fluid, in that they give official recognition only to such dips as contain an emulsion.

It might be supposed that the increased killing effect of emulsion dips is due solely to the presence of soap in the emulsion, but we have found that a similar increased effect is obtained by the addition of an emulsion of glue and oil. Preparations containing emulsified oil in a state of fine division are all characterised by their high wetting power, whether the emulsifying agent is soap, glue or some other compound. It is probable, therefore, that the increased killing power in both cases

is to be referred, in a very great degree, to the increased wetting power resulting from the addition of an emulsion. It was proved that by the addition to the sodium arsenite solution of a certain quantity of alcohol, which would also facilitate wetting, an increased killing power was obtained. Nevertheless, the increased killing power of an emulsion dip probably cannot be completely attributed to increased wetting power alone, it is probable that certain physical properties of the emulsion come into play.

The Action of the Emulsion.

Under the supposition that the tick is destroyed by the arsenic which it absorbs through its own cuticle, the enhanced action of a dip containing an emulsion is readily explained by the greater wetting

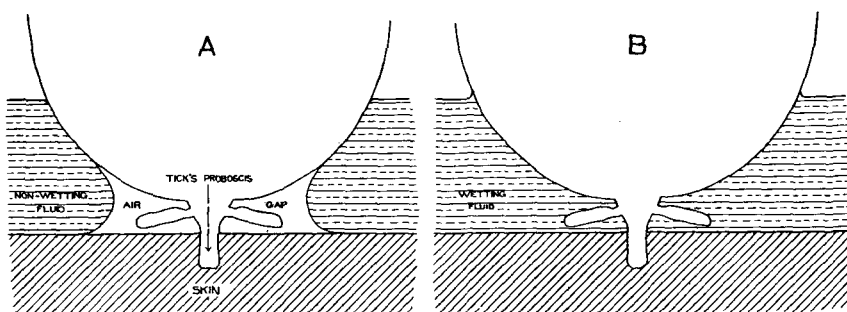


Fig. 2. Diagrammatic representation of the different results obtained by the use of *non-wetting* and *wetting* fluids respectively.

power of such a dip. With the more perfect wetting, the absorption of arsenic would be considerably facilitated. But it has been shown that the tick obtains most, if not all, of the lethal dose of poison from the skin of the host; and we explain the enhanced action of the emulsion-dip in the following manner:

A tick attached to the skin of an ox is a more or less spherical body, difficult to wet, applied to a flat surface—the skin of the ox—likewise, on account of its greasy nature, not easily wetted. It is obvious that under such conditions, a plain aqueous solution would tend to form an 'air gap' or bridge surrounding the point of contact between tick and host (Fig. 2, A).

If however the surface tension of the dipping-fluid is sufficiently small no such 'gap' would form, for the capillary attraction would

cause the solution to run between the spherical and flat surfaces so as to wet the skin of the host thoroughly (Fig. 2, B). This is precisely the object of adding an emulsion to the aqueous solution of sodium arsenite; the surface tension¹ is materially reduced thereby, and the arsenic is brought into intimate contact with the tick's proboscis and the skin of the host immediately adjacent and is thus enabled to exert its greatest effect, for as the tick then sucks up its food from the host, it is almost certain to imbibe a lethal dose of arsenic. If, on the other hand, an air-gap is formed round about the tick's proboscis, the arsenic is some distance removed from the point of insertion and the amount sucked up would be comparatively small.

Though Watkins-Pitchford showed the great value of an emulsion, he does not appear to have made any observation on the physical phenomena involved, though an examination of his results absolutely confirms the foregoing explanation.

*Does the Tick take up Arsenic from the Blood or from the
Skin of the Dipped Host?*

For the furtherance of our inquiry, it seemed to us that the question as to whether the arsenic, imbibed by a tick while feeding on a dipped host, was derived from the blood or the skin, must be settled definitely. With this object in view, we carried out a series of experiments in which arsenic was administered, *per os*, up to the maximum possible dose, yet no ticks were killed (see Appendix III).

It may be argued that with internal dosing, no great amount of arsenic reaches the circulating blood owing to the rapid excretion from the bowel, due to purgation, arrest in the liver, etc. In order to overcome this difficulty and to ensure the presence of an active quantity of arsenic in the circulating blood we then administered the doses in the form of subcutaneous injections, again without positive result (see Appendix IV).

Finally, experiments were carried out, in which a solution of arsenic, much stronger than could be used for general application in the form of a dip or spray, was distributed over a limited area of the skin. In these experiments the ticks on the treated areas were killed, but the

¹ The term 'Surface Tension' is used here in a general sense only. It is now realised that the wetting power of a solution is dependent upon other factors in addition to the surface tension of the wetting fluid. A paper, by one of the present authors (W. F. C.) in collaboration with another, dealing with the Theory of Wetting and the Determination of Wetting Power, is in course of preparation.

action of the arsenic did not range beyond a margin of six inches surrounding these areas (see Appendix V).

The general conclusion to be drawn from all these experiments is that the tick does not obtain a lethal dose from arsenic present in the circulating blood.

Cumulative Action of Arsenic in Dipping.

Although all the ticks present on an animal at the time of dipping may be killed by a single immersion, yet this does not prevent reinfestation by ticks subsequently picked up in the grazing area. To prevent reinfestation it is necessary to repeat the dipping at short intervals and in order to do this without injury to the stock, the concentration of the dipping bath must be reduced accordingly. It is then found that, at the reduced strength, although a single dipping fails to kill all the attached ticks, repeated dippings render the host poisonous to all ticks, both those attached to the host at the time of dipping and also those ticks which may be picked up later. Now, a single immersion is ineffective, therefore, the only conclusion to be drawn is that the arsenic is cumulative in its action and that the quantity absorbed by the tissues of the skin is augmented by each subsequent dipping until, as will be shown later, a certain maximum is reached.

From Watkins-Pitchford's statements, it is obvious that he holds similar views to ourselves with regard to this cumulative effect of short interval dipping, and the affinity of the skin of an habituated animal for arsenic. Concerning this he writes (1911*a*, pp. 47-48) as follows:

'In fact, as will be seen from the succeeding observations, the deeper layers of the skin appear to be capable of becoming so tolerant of the presence of arsenic that the latter becomes tolerated to a considerable extent. That this accumulation is not a mere mechanical deposition or passive soaking is indicated in Schedule E, items 5 and 5*a*. This indication of the vital action of the skin is further borne out by the fact that any arsenic in excess of the maximum content is eliminated from the skin, the elimination taking place through absorption by the blood-vessels which are contained in its deeper layers, such excess of arsenic appearing shortly afterwards in the urine. When we further consider it is into this deep layer of the skin that the tick thrusts its mouth parts and obtains its nourishment, we shall partly see the significance of being able to establish and maintain a supply of arsenic at such a point of attack.'

That the arsenic accumulates by repeated applications is proved by analysis of the skin of animals dipped at short intervals. Watkins-Pitchford carried out numerous analyses, the results of which we briefly tabulate (see Appendix VI), and our own analyses absolutely confirm his findings. He goes on to state (pp. 49-50):

'that the value of frequent dipping lies in the sustained effect produced rather than in the mechanical destruction of ticks which follows immersion in the dip tank, and...this maximum killing efficiency of a beast is only to be maintained by the repetition of the dip or spray process with such frequency as will compensate the skin for the loss of arsenic which is continuously absorbed from it and excreted in the urine by a natural process of elimination.... The power of an habituated animal to destroy ticks placed upon it (or gaining access in the natural manner after dipping) is rapidly lost, five or six days' lapse sufficing to reduce such an animal to nearly the same condition as that which exists in the case of an unhabituated animal or beast which is dipped at the long interval of, say, ten days or a fortnight.'

Although Watkins-Pitchford expresses the opinion that a five or six days' lapse is sufficient to reduce the resistant powers to that of an unhabituated animal, we found, in our work at Elliotdale (see Appendix VIII), that, in actual practice, a five-day interval is sufficient to keep stock free from East Coast Fever.

In short, although the fact is not admitted by several eminent veterinary authorities, exclusive of those who have carried out investigations on the lines of Watkins-Pitchford and ourselves, we do not consider that this cumulative effect of arsenic applied to the skin is open to any reasonable doubt¹.

Arsenical solutions applied to the skin penetrate the actual cellular tissues by osmosis, and it is reasonable to presume, from what has already been said of the cumulative effect in the cutaneous tissues, that the arsenic enters into an actual combination with some organic constituent of the cells.

The work of Ehrlich, Nierenstein, Breinl, Levaditi² and others, on

¹ In order not to obscure the main points of our paper, we have collected, in the form of an appendix, some of the more cogent objections to our theories, together with our criticisms (see Appendix IX).

² Ehrlich (1908), *Verhandl. d. Deutschen dermatolog. Gesellsch.* x, Kongress, Juni, 1908. Nierenstein (1908), *Ann. Trop. Med. and Parasitol.* ii, 249-255. Breinl and Nierenstein (1909), *Zeitschr. f. Immunitätsforsch. u. exper. Therap.* i, 620-632. Levaditi and Yamanouchi (1908), *C. R. Soc. Biol.* LXV, 23.

the mode of action of certain organic compounds of arsenic as trypanocides in the animal body, is very interesting in connection with the above mentioned subject, but a discussion of the matter would lead us away from the subject matter of this paper; it is being dealt with by one of us (W. F. C.) in collaboration with others, in another paper now in course of preparation, on the application of arsenical dipping to the prophylaxis and treatment of trypanosomiasis in stock.

In view of the success which has resulted from the detailed study of the mode of action of arsenic and other substances, the cumulative effect in the cutaneous tissues would appear to be an important and interesting problem to follow up. We may say that we hold the view that something of this sort does take place as a result of short interval dipping, and as soon as the large amount of field work in hand is completed, we intend to undertake a systematic investigation of the problem.

For the moment, it is sufficient to know that the arsenic is taken into the body and we have evidence, derived from the work on trypanosomiasis in dipped animals referred to above, that although the quantity of arsenic thus absorbed into the circulating blood is insufficient to poison ticks, yet it may be present in sufficient quantity to exert a toxic action on such pathogenic protozoa as trypanosomes.

The Quantity of Arsenic applied in Dipping.

The amount of arsenic left on the animal after dipping may be roughly estimated as follows: an average animal, after allowing the superfluous dip to drain off, retains about 0.75 gallon. In the case of the 'Laboratory' dip, 50 gallons of the dip contains 1 lb. of sodium arsenite (80 per cent.), giving a concentration of 0.16 per cent. of arsenious acid. Three-quarters of a gallon would contain, therefore, 5.4 gms. (84 grains) of arsenious acid. Thus, some 5.4 gms. are applied to the skin of the animal at each dipping, and at the rate of five-day intervals, the amount applied per month would be 32 gms., and under proper conditions, this process can be continued for years without causing any inconvenience or injury to the stock. The lethal dose of arsenic for cattle, according to Kaufmann¹ (see Appendix III), varies from about 15 gms. to 30 gms.: it follows, therefore, that quantities of arsenic which would almost certainly prove fatal to the animal if administered internally may be safely applied to the skin by dipping.

¹ Cited by Finlay Dun (1910), *Veterinary Medicines—their Actions and Uses*, 12th ed., Edinburgh, David Douglas, p. 275.

*The Effect on Pathogenic Organisms of Arsenic in the Blood
of Dipped Animals.*

It has been shown that the epidermal cells possess a special affinity for arsenic (see pp. 200–202 and Appendix VI), and once this arsenophile proclivity is satisfied, the excess of arsenic is available for absorption by the blood.

It is obvious that the *total* amount of arsenic in the general blood system cannot be very great, since the general health of the animal is not interfered with in any way. But a consideration of the amount of arsenic applied every week, or even at shorter intervals, and especially the appearance exhibited by the inner surface of the skin of an animal which has been dipped in a solution only slightly too strong, would lead us to suppose that the amount of arsenic present in the blood circulating in the *most peripheral vessels of the skin* would be very considerable. It is quite conceivable that the blood circulating in the capillaries which are in close relation to the external surface of the skin to which the very strong dose of arsenic has been applied, might contain a very large amount, far greater in fact, than the amount that would be possible in the general blood system; for this peripheral blood containing a large quantity of arsenic would be immediately diluted by the general mass of the blood from the internal parts of the animal, so that the total amount in general circulation would not be excessive.

This is what we consider actually takes place, and the results attained at Elliotdale (see Appendix VIII) are sufficiently good evidence that this deduction is correct; and upon this deduction we base our anticipation of success in our experiments at present in hand.

In the case of such diseases as are transmitted by external parasites—East Coast Fever for example—the infective organisms can only be injected into the most peripheral cutaneous capillaries, where the concentration of arsenic is sufficiently great to kill them. Such being the case, regularly dipped animals running on infected pastures would remain free from the disease.

Watkins-Pitchford (1911a, p. 56) has given figures to show that the incubation period of East Coast Fever is prolonged in dipped animals; we give an abstract of these in Appendix VII. In connection with these results, it should be observed that the cattle were only dipped a few times before exposure to infection and that after exposure they were not dipped at all.

Had these cattle been dipped as soon as a rise in temperature was observed, we think it probable that they would have recovered. This however is a different matter to the killing of the pathogenic organisms before they can propagate. The point was tested by us at Elliotdale, on a large practical scale, and found to be correct. The details of this experiment are given in Appendix VIII, from which it is seen that 500 head of cattle remained free from disease for a period of eighteen months during which they were able to produce young and increase to 620 head.

Subsequently the Government Veterinary Department adopted a system of inoculation against East Coast Fever, in place of dipping, but in consideration of the expense and trouble involved in the system of inoculation, together with the losses occasioned thereby, we venture to express our opinion that the practice of dipping would have proved to be superior.

We hoped to be able to continue our experiments in British East Africa, but the Government officials refused to grant facilities to enable us to carry out systematic work. However, we purchased a farm in an area reported to be badly infected with East Coast Fever and placed 100 head of stock upon it. Three died in the first month after which no further deaths from East Coast Fever occurred.

These experiences, especially those at Elliotdale, showed that cattle could be kept alive and increase by dipping; but it remains to be ascertained for how long, after ceasing to dip, cattle remain immune to East Coast Fever when running on infected pasture. It is possible that they will not act as carriers of East Coast Fever for a period of several days after dipping. If this point could be proved, it would be possible to relax the present system of quarantine set up in some of the infected areas so as to allow some movement of stock. Under present conditions, if East Coast Fever breaks out, the affected farm and the surrounding area are placed in quarantine for fifteen months and all movement of stock is prohibited—a great inconvenience and the cause of considerable pecuniary loss. In a country where oxen form the chief means of transport, the prohibition of movement of stock is a very serious matter, but, until it can be definitely proved that dipping does confer such immunity, at least for a certain period, the quarantine system is absolutely necessary. We believe, however, that sufficient evidence has been obtained to indicate that in systematic dipping there lies a means of bringing about such a relaxation of these irksome regulations as would enable farmers to make a turnover on their stock.

Dipping in Relation to Trypanosomiasis.

If by dipping, the amount of arsenic which can be introduced into the peripheral cutaneous vessels is sufficient to kill ticks, then it is reasonable to imagine that it might also kill other blood-sucking pests, such as Tsetse flies; also the natural infection of stock by Tsetse flies should be preventible by the same means.

Regarding the effect of dipping on biting flies, the fact that the latter feed so rapidly, in comparison with the very slow rate of feeding of the tick, introduces a possible difficulty, but experiments are now being carried out by one of us (W. F. C.) in the Congo, to test this point.

With regard to *trypanosomiasis* it is highly probable that dipping would exert a pronounced effect. In the experimental treatment of trypanosomiasis, it has been shown repeatedly that arsenious acid, administered *per os*, is very effective, but the effect is not permanent because it is impossible to prolong the treatment without producing symptoms of arsenical poisoning and the ultimate death of the host.

But dipping furnishes a method of applying arsenic in comparatively large doses at frequent intervals without deleterious effects on the treated animal, and there is reason to believe that its use in this manner would exert a remedial as well as a prophylactic effect.

The whole point has been considered in connection with some preliminary investigations on Nagana-infected dogs carried out by one of the authors (W. F. C.) in collaboration with Dr E. Hindle and Mr L. E. Robinson, at Cambridge, which form the subject of a paper now in course of preparation for the press.

APPENDIX I.

A tabulation of the results of Watkins-Pitchford's experiments, to show that the killing effect of the dip on the ticks persists for some days after dipping.

No. of days since attachment of ticks	Days since dipping						Controls (not dipped)
	1st day	2nd day	3rd day	5th day	7th day	10th day	
No. of ticks attached	No. of ticks attached	No. of ticks attached	No. of ticks attached	No. of ticks attached	No. of ticks attached	No. of ticks attached	No. of ticks attached
$\frac{1}{2}$ day	12	19	22	28	21	26	8
1 "	10	18	21	22	20	21	8
1 "	3	9	8	15	14	15	8
$1\frac{1}{2}$ days	0	5	8	13	12	14	8
2 "	0	2	3	12	12	14	8
3 "	0	1	0	8	9	13	8

This table is modified and abridged from the table given by Watkins-Pitchford (1911a, p. 54). Two beasts were used for each experiment.

APPENDIX II.

The effect of the addition of various substances to solutions of sodium arsenite in averting 'scalding.'

Watkins-Pitchford (1911a) gives the results of his experiments with plain solutions of sodium arsenite (p. 31) and with sodium arsenite solutions to which other substances have been added (pp. 34-37). In order to facilitate a comparison of these results, the following table has been compiled from his published results.

Composition of Dip		No. of sprayings before scalding occurred	Remarks
Sodium arsenite		4	
"	+ soap	4	
"	+ glycerine + soap	4	
"	+ " + " and paraffin emulsion	0	In 3 separate trials, no 'scalding' occurred after 23, 19 and 10 sprayings respectively
"	+ soap and paraffin emulsion	11	

It will be observed that in these comparative tests, the fluid was applied as a *spray*; our own experience leads us to believe that a *dip* is less apt to scald than a *spray* and can, therefore, be used a little stronger, but, for all practical purposes, these results apply equally to either method of application.

Watkins-Pitchford tried the addition of glycerine, with the hope that it would exert an emollient action tending to reduce the irritating

effects on the skin of both arsenic and paraffin. With the same view the authors tried glycerine but, as it seemed to have little effect, and the cost prohibited its use on an extensive scale, they dropped it. It will be observed that Watkins-Pitchford omits glycerine in his final formula (1911a, p. 37).

APPENDIX III.

The Effect on Ticks of Arsenic administered per os.

The object of this experiment was to ascertain whether it was possible to destroy attached ticks by dosing the host with arsenic. By internal dosing, it was surmised that some of the arsenic would be taken up by the blood and thus conveyed to the skin. The lethal dose of arsenic for cattle is stated by Kaufmann (see footnote on p. 202) to be 4–8 drachms (= 15.5–31 gms.).

Beast No. 1200. ♂, aged $2\frac{1}{2}$ years.

Date 1909	Temperature °F.	Effect on ticks	Remarks
March 9th			0.75 gm. ($11\frac{1}{4}$ grains) of As_2O_3 administered <i>per os</i>
„ 10th	104.0	None killed	
„ 11th	103.0	„	
„ 12th	105.7	„	Diarrhoea
„ 13th	104.2	„	
„ 14th	103.4	„	
„ 15th	105.8	„	
„ 16th	106.6	„	

Up to March 16th, no ticks were killed. The animal was not showing any signs of arsenical poisoning. This beast had been continuously dipped prior to the commencement of this experiment and as it had not shown any untoward symptoms after the initial dose of 0.75 gm. we assumed that it had acquired some degree of tolerance, and it was then decided to reduce the dose and administer it at frequent intervals:

Date 1909	Temperature °F.	Effect on ticks	Remarks
March 31st	103.2	None killed	0.3 gm (5 grains) of As_2O_3 administered
April 1st	104.4	„	„ „
„ 2nd	104.2	„	„ „
„ 3rd	103.4	„	„ „
„ 4th	104.6	„	„ „
„ 5th	103.8	„	Beast emaciated
„ 6th	102.8	„	Beast breathing hard, bowels very loose
„ 7th	—	„	Beast found dead

At no time could any effect on the ticks (*Boophilus decoloratus*) be observed. The post-mortem examination showed the usual symptoms of acute arsenical poisoning.

It is evident therefore that the internal administration of arsenic is useless, whether in large or small quantities.

APPENDIX IV.

The Effect on Ticks of Arsenic administered subcutaneously.

The object of these experiments was to determine the effect of local subcutaneous injections of arsenical solutions on ticks attached to the host. It was anticipated that by such means it might be possible to ensure the presence of a sufficient quantity of arsenic in the circulating blood to destroy the ticks which fed upon the treated animal. The subjoined protocols show that such injections are purely local in their action, and that with the exception of those ticks which are attached immediately round the site of the needle-puncture no effect is to be observed. Unfortunately the general symptoms produced in the host made it impossible to continue these experiments, and, for the same reason, no certain conclusion can be drawn from the results obtained.

<i>Beast No. 0102. ♂.</i>			
Date 1909	Temperature	Effect on ticks	Remarks
March 9th			0.25 gm. of As_2O_3 , as sodium arsenite, dissolved in 3 c.c. of water injected subcutaneously on right shoulder; a similar dose injected on the escutcheon
" 14th	105.8° F.	All ticks dead over an area of some 6 ins. × 3 ins., surrounding the site of the needle-puncture. Some adults had gorged. Elsewhere, ticks unaffected	Parts round sites of injection swollen and inflamed
" 17th	104.0 "	Ticks on body generally, still unaffected	Skin over swollen areas cracked and raw surfaces infested with maggots. Wounds cleaned and disinfected with carbolic acid
" 26th	105.2 "		All living ticks killed by application of oil; beast cleaned and disinfected
April 7th			Wounds healed and beast quite well

Beast No. 2010. ♂.

Date 1909	Temperature	Effect on ticks	Remarks
March 9th			0.5 gm. of As_2O_3 , as sodium arsenite, dissolved in 15 c.c. of water injected on escutcheon
„ 15th	104.4° F.		Skin badly swollen between hind-legs, from anus to sheath
„ 19th	101.8 „	Ticks within few inches of needle-puncture all dead. Elsewhere ticks unaffected	Swelling incised and dressed with carbolic acid and subsequently attended to daily
„ 23rd	103.4 „	Ticks on body generally, unaffected	Beast almost unable to walk
„ 31st	103.6 „		All living ticks destroyed by application of oil
April 7th			Beast recovered.

APPENDIX V.

The Effect on Ticks of Arsenic in strong solution applied to a limited area of the skin.

The following experiment was carried out with the object of determining whether arsenic, applied in strong solution to a *limited* area of the skin, would be absorbed in sufficient quantity to destroy ticks distributed generally over the skin, or, in other words, whether such a solution is only effective in the area to which it is applied.

A beast was taken and the skin of one side of the body was divided into two approximately equal halves by a vertical red paint line situated midway between the fore and hind legs. The fore quarter of the ox having been covered to prevent contamination, the hind quarter posterior to the paint line was carefully sprayed with a 2 per cent. solution of arsenious oxide as sodium arsenite. Such a solution is, of course, far too strong for an application to the entire skin surface and would cause the death of an animal so treated in a very short time¹. Four days later, the skin of the sprayed area showed a marked glossiness and the ticks attached thereto were dead. Later, symptoms of scalding developed, and in about three weeks the epidermis, with the hair attached, peeled off in sheets the size of a piece of note-paper. New hair ultimately appeared and recovery was apparently complete. The experiment was repeated twice, using less concentrated solutions, with identical results.

¹ The strongest solution ever advised is 0.25 per cent.; the strongest advocated by any Government is one containing 0.20 per cent. of As_2O_3 .

The animal was infested with Blue ticks (*Boophilus decoloratus*) which are easy to kill, and whereas all the ticks on the sprayed area and within a margin of six inches surrounding this area, were killed, none of the ticks distributed over the unsprayed part of the animal's skin was in the least affected.

In other cases, in which we had the misfortune to cause the death of the animal, the autopsies showed that the cutaneous vessels in the scalded areas were much congested and there was some considerable extravasation of blood. This, together with the fact that the animals exhibited symptoms of acute arsenical poisoning prior to death, indicates that arsenic was absorbed, but in quantities insufficient to affect ticks attached at a distance of six inches or more from the sprayed area.

APPENDIX VI.

The Quantity of Arsenic retained in the Skin of Oxen after Dipping.

Watkins-Pitchford has given data (1911a, Schedule "E," pp. 58-61) relative to the amounts of arsenic retained by the skin (hair and hide) of dipped animals; these figures are tabulated below and some further calculations, based on these, have been added in the last three columns.

The animals under investigation were dipped for varying periods; some every five days for many months, others once only (see Column 4 of table). After the lapse of different intervals (Col. 5) the animals were killed, and from each one square foot of skin was taken. The hair was removed and the arsenic contents of both hair and hide were separately determined (Cols. 6 and 7).

It appeared to us, however, that the results would be more comprehensive if the amount of arsenic in the entire skin of the animal was estimated. Several measurements made on three animals of normal size established the fact that the mean area of the skin, inclusive of the head and legs, was about fifty square feet, and the figures given in the last three columns of the table represent Watkins-Pitchford's data multiplied fifty times.

The Quantity of Arsenic retained by the Skin of the Oxen for Various Periods after Dipping.

No.	Nature of Hair	Integument Hide	Frequency of dipping	Period elapsing since last dipping	Amount of arsenious oxide per square foot of skin			Amount of arsenious oxide in entire skin (based on average superficies of beast of 50 sq. ft.)		
					Hair gm.	Hide gm.	Total gm.	Hair gm.	Hide gm.	Total gm.
1	Long, fine and thick	Very thin	Every 5 days, then 6 sprayings in 24 hours	1 day	0.302	0.228	0.530	15.100	11.400	26.500
2	Strong, medium length, not thick	Medium thickness	Every 5 days, then daily for 10 days	1 „	0.201	0.196	0.397	10.050	9.800	19.850
3	Fine, long and very thick	Medium thickness	Every 5 days for months; last sprayings every 3rd day	1 „	0.527	0.224	0.751	26.350	11.200	37.550
4	Strong, medium length, fairly thick	Very thick	Every 5 days for several months	5 days	0.352	0.251	0.603	17.600	12.550	30.150
5	Moderately long	Fairly thick	Dipped regularly for several months	10 „	0.260	0.137	0.397	13.000	6.850	19.850
Mean					0.328	0.207	0.535	16.420	10.380	26.780
6	Fairly long, fine, medium thickness	—	1 spraying 5 days before death, not sprayed for previous eight weeks.	5 days	0.116	—	—	5.800	—	—
			Carcass sprayed immediately after death	Analysis made as soon as skin was dry	0.470	0.008	0.478	23.500	0.040	23.540
7	Fairly long, medium thickness	—	—	8 weeks	0.159	—	—	—	—	—
8	—	—	—	6 months	0.388	—	—	—	—	—
9	—	—	—	7 „	0.019	—	—	—	—	—

In such an investigation as this, it would be desirable to make a very large number of analyses before drawing conclusions from small variations in the figures, but the amount of labour and the cost of stock would be excessive.

By taking the mean values of Watkins-Pitchford's figures, however, the results should be sufficiently accurate for practical purposes, and

we have therefore added these values for the first five experiments (see Col. 6 *et seq.*). From these it will be seen that some 26 gms. of arsenious oxide are retained by the skin of a regularly dipped animal, of which 16 gms. are present in the hair and 10 gms. in the hide. From the figures it would appear that the quantity of arsenic remaining in the hide of a regularly dipped animal is much the same up to five days after dipping, but after a lapse of ten days the amount has been reduced by nearly one-half. From this it follows that between the fifth and the tenth day after dipping, some 3.5 gms. of arsenious acid have been removed from the skin, and as this removal must have been effected by the blood circulating in the cutaneous capillaries, the animal has received a continuous internal dose of arsenic at the rate of about 0.70 gm. per diem, extending over five days. If, then, this amount of arsenic is absorbed by the blood from the fifth to the tenth day, what happens during the five days immediately following the dipping? We believe that the absorption of arsenic from the skin proceeds continuously from the time of dipping, but that for the first five days or so, the amount thus removed from the skin is constantly replaced by further quantities absorbed by the skin from the very considerable amount which dries on the surface.

APPENDIX VII.

The Augmentation of the Incubation Period of East Coast Fever by Dipping.

In our own work, a direct practical test of the correctness of our deductions was carried out at Elliotdale (see Appendix VIII), but permission could not be obtained to carry on the work sufficiently to determine the details.

Watkins-Pitchford, however, has since published his data of observations, showing that the incubation period of East Coast Fever is prolonged by dipping. He took three lots of five animals each, which were exposed on infected pastures for periods ranging from half an hour to nine hours. Lot *A* was *undipped* and served as a control to Lot *B*, dipped *after* exposure, and to Lot *C*, dipped *before* and after exposure. An abridged form of his schedule of results is given below.

Lot	Treatment	Mean incubation period
<i>A</i>	Not dipped	9 days
<i>B</i>	Dipped directly <i>after</i> exposure	11 "
<i>C</i>	Dipped 24 hours <i>before</i> and immediately <i>after</i> exposure	17 "

It would have been interesting to see the results, had these tests been extended. For instance, it is exceedingly probable that in Lot C, two animals of which, out of a total of five, failed to exhibit any febrile symptoms within the period of the experiment (eighteen days), the incubation could have been prevented entirely by continuing the dipping at five-day intervals. In Lot C again, the earliest appearance of fever was on the fifteenth day after dipping and it is quite within the bounds of probability that, up to as much as fourteen days, the animal was non-infective and could have been used for transport purposes within that period with perfect safety. It is very desirable to establish this point in order that some system of allowing transport, under licence, to and from infected areas might be devised. Such a system would prove a great boon to farmers and graziers in certain parts of South Africa and particularly in British East Africa.

APPENDIX VIII.

Dipping Experiments at Elliotdale.

East Coast Fever broke out at Elliotdale (Lat. 32° S., Long. 29° E.), in the Transkeian Native Territories, South Africa, in February, 1910, as diagnosed by Veterinary Surgeon J. Spreull.

By that time, the chief deductions expounded in the body of this paper had been made and this outbreak appeared to offer an excellent opportunity of putting them to an extensive practical test. As it was necessary to get the work under way without delay, it was impossible to make elaborate preparations, and, after all, our object was to ascertain whether, by means of dipping, animals could be rendered immune to the disease.

On May 18th, 1910, one of us (H. E. L.) commenced operations with 500 head of Kaffir stock (bullocks, cows and calves—mixed) collected in the district. A dip, prepared by us at Gonubie Park, consisting of sodium arsenite with an emulsion, was used. At that time there were no cattle swim baths in the area and we had to rely on the spraying method, using the Seabury machine¹. The spraying operations were started at the end of May and were repeated at intervals of five days.

Between the first and second sprayings one animal died, and after the second dipping another animal died, but from that time no further deaths occurred amongst the sprayed stock.

¹ The construction and mode of operation of the Seabury machine is dealt with in Lounsbury, C. P. (1908) and Cooper, W. F. and Laws, H. E. (1908).

At the end of June, the experiment was left in the charge of our agent until it could be taken over by a stock inspector at the end of July.

In April, 1911, eleven months after the commencement of the experiment, Mr A. H. Stanford, the Chief Magistrate, reported that all the stock in the district had succumbed, except those which had been sprayed. Among the latter, with the exception of the two cases mentioned above, not a single death occurred and the herd had increased to some 600 head.

The experiment was continued for a further six months, by which time the results were becoming generally known among the natives throughout this part of the Transkei. Consequently they introduced other stock, at first surreptitiously, many of which were heavily infested with ticks. It was impossible, owing to the absence of fences of any kind, to prevent the promiscuous mixing of these newly-introduced animals with the domiciled stock, and eventually such large numbers were brought into the area that it became impossible to deal with them and the work had to be abandoned.

This experiment cannot be regarded as a strictly scientific investigation, but it proves in a very conclusive manner that dipped cattle remain immune for indefinite periods although they are allowed to run on heavily infected pastures and to mix freely with undipped stock which were dying from East Coast Fever.

As a matter of fact, in such a case as this, where the 'controls' were so numerous, there was no necessity to make a definite proof that the deaths in the undipped stock were due to a *Theileria parva* infection. The disease had been diagnosed at its outbreak as East Coast Fever by a competent authority, and the subsequent deaths were clearly attributable to the same cause.

APPENDIX IX.

In most of the published work on the effects of dipping very little consideration has been given to the essential importance of the addition of an emulsion. The objection generally raised, *e.g.* Dixon (1911, p. 16), is that when hard or brackish water is used in the preparation of the dip, the soap used in the preparation of the emulsion is precipitated and rendered useless.

We claim that, by this precipitation, calcium and magnesium salts, which otherwise would form ineffective arsenates, are removed. The amount of soap thus rendered inert is at the most relatively small in

quantity, and the presence of the precipitate does not inhibit the action of the dip in any way.

It has been shown (pp. 197-198) that the presence of an emulsion in the dip facilitates wetting, the importance of which latter factor is demonstrated in Appendix V. Both Watkins-Pitchford and Brünnich and Smith have called attention to the ease with which certain parts of the body (as under the tail) escape wetting. Hence it is a matter of vital importance that the solution should have the maximum possible wetting power, and any addition which increases this factor is more than justified.

A point which is generally disregarded in matters concerning the theory of dipping is the cumulative effect (pp. 200-202). For instance, Theiler (1911, p. 505), writing on the subject of the eradication of East Coast Fever, states: 'When the disease has taken a firm hold on a farm, that is to say, a number of cattle sickened and died and disseminated ticks in large numbers, then no dipping will help to stop the disease.' Further, on p. 508, he warns farmers 'not to trust to it (dipping) as a panacea for the prevention or eradication of East Coast Fever.... No dip has yet been found which prevents ticks from biting, and as long as infected ticks are present, so long East Coast Fever will be found.'

We claim that on account of the cumulative effect the fact that the ticks bite does not matter. Watkins-Pitchford (1911a) showed most conclusively that the 'Laboratory dip' kept stock clean after a few dippings at five-day intervals. On p. 18 he says: 'Such ticks as have attached themselves to the cattle have been regularly destroyed.' In Schedule "B" (p. 54) he shows that ticks placed on a recently-dipped beast may attach, but, if they do, they are killed within a period of 2-3 days after dipping. Schedule No. 21 (p. 38) shows that after ten dippings, the animals remain free from ticks, provided the dipping is repeated at five-day intervals.

On the basis of these observations of Watkins-Pitchford we are at a loss to see how such statements as those cited from Theiler's paper can be reconciled with actual experimental data.

Further, these remarks have been shown to be invalid in actual practice, in a paper published by Manning and During (1912). They give details of a case (p. 451) in which East Coast Fever broke out in a herd of 805 cattle in April, 1911. By the end of September, up to which time very desultory dipping had been practised, 221 head had died of the disease. Five-day dipping was then established and in the following

two months ninety-six deaths occurred. From December to the end of June, 1912, only ten deaths occurred! The authors do not state whether an emulsion-dip or a plain solution of sodium arsenite was used—a very important point in a case where it was necessary to be so very particular about wetting the whole surface of the animal. It may be pointed out that the stock was native-owned, a fact that would considerably reduce the chances of efficient control. Manning and During estimate the cost of dipping as $\frac{1}{2}d.$ per head, and on this basis the cost of dipping, in the case cited above, would be approximately £52. If, by inoculation, the mortality was 30 per cent., the total loss on a valuation of £5 per head would have been £750. Moreover, if inoculation had been practised, the stock would still have remained infective, whereas with continued dipping, the disease would have been stamped out. As a matter of fact, instructions for inoculation were issued, and to obtain a supply of the necessary virus twenty head were placed on the most heavily infected ground, but as they were regularly dipped, 'none of them became infected.' In their concluding remarks, the authors state 'practically no more cases of East Coast Fever have since occurred on these combined farms.'

Surely this is proof enough!

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The papers cited below form a small part only of the numerous papers dealing with the subject of dipping, but they are the most important from our point of view and are those to which reference has been made in our paper.

Since 1905 practically the only detailed scientific work on the subject published in South Africa, is that of Lieut.-Col. H. Watkins-Pitchford (1909, 1910 and 1911). These separate papers have since been published collectively in the form of a pamphlet (1911a), and it is from this reprint that our references are cited.

An 'Inquiry into Dips and Dipping in Natal' was made by Sir Arnold Theiler and Mr C. E. Gray, the results of which were published in the *Cape Agricultural Journal*. The data obtained, although of the greatest interest as giving the opinions of farmers, are not, of course, of much value from a purely scientific aspect.

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