THE GLOBAL FOOT-AND-MOUTH DISEASE SITUATION DURING 1998 AND ITS RELEVANCE TO CONTROL AND ERADICATION EFFORTS IN SOUTHEAST ASIA

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Abstract

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This paper reviews the recent successes in the control of FMD in Europe, South America and southern Africa and highlights the lessons to be learnt from those experiences, which could be applied to Southeast Asia to promote the control and eradication of the disease in that region.

1. THE GLOBAL SITUATION OF FOOT-AND-MOUTH DISEASE (FMD) DURING 1998

1.1. Europe

The former USSR republics of Georgia, Armenia and Azerbaijan were the only countries in Europe to report FMD during 1998. The outbreaks in Georgia and Azerbaijan were caused by type O virus, those in Armenia by a type A virus, shown by the All Russian Research Institute for Animal Health, Vladimir, to belong to same genotype as the type A Iran/96 strain, which has been circulating in Iran and Asiatic Turkey.

1.2. South America

The Hemispheric Eradication Programme in South America proceeded successfully during 1998 pushing FMD further northwards on the sub-continent. Chile, Uruguay, Surinam, French Guyana and Guyana retained their status as FMD-free, non-vaccinating countries. Argentina, Paraguay and the States of Santa Catarina and Rio Grange do Sol in the south of Brazil were also free (with vaccination). The veterinary authorities in Argentina intend to cease the annual vaccination of cattle by the end of March 1999. The countries in South America in which FMD was reported in 1998 included Ecuador, Colombia, Venezuela, Brazil and Bolivia.

1.3. Africa

No reports of FMD were received this year from Morocco, Algeria or Tunisia. Outbreaks of type O did, however, occur in Egypt. Further to the south, type O outbreaks took place in Uganda, Tanzania and Malawi. Sero-type A strains received by the WRL from Gambia and Senegal in West Africa, and from Eritrea in East Africa (Table I), were found to be antigenically different from existing vaccine strains. Eritrea and Uganda suffered type SAT 2 outbreaks also.

1.4. West Asia

The A Iran/96 variant of type A virus continued to spread in Iran and Asiatic Turkey. Homologous vaccines have been developed by private laboratories in Europe and Asiatic Turkey and by State laboratories in Iran and Turkey. Type O virus was isolated by the WRL from samples from Asiatic Turkey, Lebanon, Kuwait, Bahrain and Saudi Arabia (Table I) and reported by Qatar, Kazakhstan and Kyrghystan.

1.5. Central and East Asia

Type O virus was identified by the WRL in samples from Taiwan Province of China, Pakistan, Nepal, Bhutan, the Philippines, Hong Kong and Myanmar. Type O continues to cause sporadic outbreaks on Luzon and Leyte islands in the Philippines. Type A virus was found in samples from Thailand and Nepal and Asia I in samples from Pakistan and Myanmar (Table II). The People's Republic of China reported outbreaks in Yunnan Province but samples were not sent to the WRL. Malaysia did not report any outbreaks of type A during the year. No type C viruses were identified in

samples submitted from the region to the WRL. Indonesia, Singapore, Japan and South Korea remained free of the disease.

2. CONTROL AND ERADICATION OF FMD IN EUROPE

This century has seen dramatic improvement in the FMD situation in Europe. For centuries the disease ebbed and flowed according to the rise and fall of the naturally acquired immunity of the livestock populations. Century after century most countries in Europe suffered tens, even hundreds of thousands of outbreaks per year. This century there were particularly serious epidemics in the 1920's and 1930's. After the Second World War the incidence declined but then it surged again in the early 1950's [1].

The first major impact of control measures occurred in the mid-60's when the Netherlands introduced mass annual vaccination of its national cattle herd. France and Germany followed soon afterwards then the majority of other countries. Although methods for the large-scale production vaccines had been developed and used with success earlier [2], they had been administered haphazardly; this was the first time that vaccine was applied in a systematic manner.

TABLE I. OIE/FAO WORLD REFERENCE LABORATORY FOR FMD*
CUMULATIVE REPORT FOR JANUARY TO DECEMBER 1998

	No. of	FMD Virus Sero-type							No virus
Country	Samples	O	A	C	SAT1	SAT2	SAT3	ASIA I	isolated
Bahrain	8	8	–	–	–	–	–	–	–
Bhutan	2	2	–	–	–	–	–	–	–
Burkina Faso	9	–	–	–	–	–	–	–	9
Cambodia	10	10	–	–	–	–	–	–	–
Eritrea	12	–	2	–	–	7	–	–	3
Gambia	52	–	10	–	–	–	–	–	42
Greece	10	–	–	–	–	–	–	–	10
Hong Kong	5	1	–	–	–	–	–	–	4
Iran	28	15	12	–	–	–	–	–	1
Italy	18	–	–	–	–	–	–	–	–
Kuwait	3	2	–	–	–	–	–	–	1
Lebanon	17	14	–	–	–	–	–	–	3
Malawi	2	2	–	–	–	–	–	–	–
Myanmar	2	1	–	–	–	–	–	–	1
Nepal	8	6	–	–	–	–	–	–	2
New Zealand	11	–	–	–	–	–	–	–	11
Pakistan	12	1	–	–	–	–	–	3	8
Philippines	18	16	–	–	–	–	–	–	2
Rwanda	6	3	–	–	–	–	–	–	3
Saudi Arabia	43	12	–	–	–	–	–	–	31
Taiwan (China)	13	2	–	–	–	–	–	–	6
Tanzania	10	9	–	–	–	–	–	–	1
Turkey	44	9	29	–	–	–	–	–	6
Uganda	21	4	–	–	–	2	–	–	15
Yemen	15	12	1	–	–	–	–	–	2
TOTAL	379	129	54	–	–	9	–	3	161

* Institute for Animal Health, Pirbright Laboratory, Woking, Surrey, UK.

TABLE II. OIE/FAO WORLD REFERENCE LABORATORY FOR FMD. REPORT FOR JANUARY 1999

Country	WRL reference	Animal species	Date of Collection	FMD sub-type
Bhutan	BHU 3/98	Bovine	NK	O
	BHU 4/98	Bovine	NK	O
	BHU 5/98	Bovine	NK	O
	BHU 6/98	Bovine	NK	O
Hong Kong	HKN 6/98	Porcine	07.12.98	NVD
	HKN 7/98	Porcine	10.12.98	O
	HKN 8/98	Porcine	10.12.98	O
	HKN 9/98	Porcine	16.12.98	O
	HKN 10/98	Porcine	18.12.98	O
	HKN 11/98	Porcine	18.12.98	O
	HKN 12/98	Porcine	30.12.98	O
	HKN 1/99	Porcine	05.01.99	O
LAO PDR	LOA 1/98	Bovine	00.11.98	O
Mauritania	MAU 1/99	Bovine	19.01.99	NVD
	MAU 2/99	Bovine	19.01.99	NVD
	MAU 3/99	Bovine	19.01.99	NVD
	MAU 4/99	Bovine	19.01.99	NVD
	MAU 5/99	Bovine	19.01.99	NVD
	MAU 6/99	Bovine	19.01.99	NVD
Philippines	PHI 19/98	Porcine	NK	O
	PHI 20/98	Porcine	NK	O
	PHI 21/98	Porcine	NK	O
	PHI 22/98	Porcine	NK	O
	PHI 23/98	Porcine	NK	O
	PHI 24/98	Porcine	NK	NVD
	PHI 25/98	Porcine	NK	O
	PHI 26/98	Porcine	NK	NVD
	PHI 27/98	Porcine	NK	NVD
	PHI 28/98	Porcine	NK	NVD
	PHI 29/98	Porcine	NK	NVD
	PHI 30/98	Porcine	NK	O
	PHI 31/98	Buffalo	NK	NVD
	PHI 32/98	Buffalo	NK	NVD
	PHI 33/98	Porcine	NK	NVD
	PHI 34/98	Porcine	NK	NVD
	PHI 01/99	Porcine	NK	O
Saudi Arabia	SAU 44/98	Ovine	00.12.98	NVD
	SAU 45/98	Ovine	00.12.98	NVD
	SAU 46/98	Ovine	00.12.98	NVD
	SAU 47/98	Ovine	00.12.98	NVD
	SAU 48/98	Ovine	00.12.98	NVD
	SAU 49/98	Ovine	00.12.98	NVD
	SAU 50/98	Ovine	00.12.98	NVD
	SAU 51/98	Ovine	00.12.98	NVD
Tanzania	TAN 1/99	Bovine	13.01.99	SAT2
	TAN 2/99	Bovine	13.01.99	NVD
	TAN 3/99	Bovine	13.01.99	NVD
	TAN 4/99	Bovine	13.01.99	NVD
	TOTAL 48			

NK – not known NPF – 3rd. February 1999.

The success of the policy quickly became apparent as the prevalence of outbreaks began to decline. Within a decade the number of outbreaks in Western Europe fell from more than 20 000 to less than 4000 per year. The decline continued and by the 1980's the number was below 400 most years [3].

Success did not result from vaccination alone, other control measures had been brought into operation. These included booster vaccination around foci; the prevention of the movement of animal and products around infected premises and the heat treatment of waste food to prevent the circulation of virus through the feeding of swill. A range of safeguards were introduced at harbours and airports to reduce the risk of virus entry from other countries in livestock and animal products. As the prevalence of disease was reduced it became economically viable for an increasing number of countries to apply stamping out.

Control policies were not uniform, however, and while the majority of the countries on the continent vaccinated their cattle populations prophylactically and, in the event of an outbreak, applied ring vaccination and total or partial stamping out, in the others routine vaccination was not routinely undertaken and stamping out and movement restricts were the main actions taken against the disease.

The next major change in European policy was instigated in 1986 when the Commission of the European Community (CEC) decided that the methods for controlling FMD would have to be harmonized throughout the Community, well in advance of 1 January 1993, the date set for the commencement of free movement of livestock and animal products across the borders of the Community, and the creation thereby of the Single Market. The CEC, having consulted expert groups who examined over a two year study period the two options of non-vaccination and pan-vaccination, and the risks and cost–benefits for each, decided in 1989 that the preferred option was one of non-vaccination. Consequently, the Member States that had applied routine vaccination were instructed to abandon the policy so that a period of at least 12 months could lapse before the commencement of the Single Market on 1 January 1993. Some countries stopped vaccination during 1990, the remainder had complied by 31 December 1991.

In deciding in favour of the non-vaccination policy the CEC took into account the cost–benefit calculations of an expert group who, on the basis of an 11– year retrospective analysis, proposed three scenarios during the 10 years following the cessation of vaccination (i) the best case of 13 primary outbreaks without secondary outbreaks; (ii) the central case of 13 outbreaks and 273 secondary outbreaks; and (iii) the worst case of 13 primary outbreaks and 1963 secondary outbreaks [4].

Strong points against the continued use of vaccine was the evidence that around 38% of the outbreaks in the Community during 1977–1987 study period were 'home grown', i.e. had originated from within the Community. These were attributed either to faulty (incompletely inactivated) vaccine or escapes from vaccine production laboratories [4]. Nucleotide sequence analysis and comparison of vaccine and outbreak strains of virus provided the evidence for those conclusions [5].

During the first five years after the cessation of vaccination the Community suffered two primary outbreaks. The first in Italy in 1993 caused 56 secondary outbreaks and the second in 1994 in Greece resulted in 94 secondary outbreaks. Stamping out and movement control were the main control methods used. The total cost of the two episodes was approximately ECU 10 million [6].

An economic evaluation of the non-vaccination policy concluded that since 1991 it had saved the agricultural industry about ECU 135 million in vaccination costs per annum at 1987 prices and that the total savings to the Community agriculture converted to 1996 prices was around ECU 800 million. The value of the additional exports and freedom of trade in the Single Market was probably many times higher [6].

The Eastern Bloc countries of the former USSR, being anxious to preserve their export trade to Western Europe, decided that they too would have to cease vaccination, which they did around the same time as the Community. In the years immediately after adoption of that policy, the former Eastern Bloc suffered a number of outbreaks. Bulgaria had single outbreaks during 1991 and 1993, which were both controlled by stamping out, movement restrictions and ring vaccination.

The eastward extension of the non-vaccination policy during 1990–1991 ended at the Russian Federation, which held to its policy of strategic vaccination. Under that system vaccine is routinely

applied around the Moscow region and along its borders with the Transcaucasian Republics in the south to Mongolia and China in the east. The Russian Federation had its last outbreak in 1995, on a pig farm near Moscow, which was linked to pig meat imported from China contaminated with a strain of virus closely related to isolates from Hong Kong, considered to represent those circulating in China [7]. Stamping out and ring vaccination were used to eradicate the disease.

The only other outbreak of FMD reported in a European country during 1995 was in European Turkey where an outbreak of type O was confirmed close to the border with Greece and Bulgaria. By nucleotide sequence analysis it was shown that the type O virus was very similar to those isolated previously in Greece in 1994 and in Bulgaria in 1991 and 1993.

During May and June 1996 two more type O outbreaks were reported in European Turkey, one in the south and another in the north of Edirne province. One month later a series of outbreaks began across the border in the neighbouring Greek Prefecture of Evros. The strains of virus were identical and transfer across the border was most probably due to the movement of infected small ruminants. The same strain of type O virus also caused an outbreak in Bulgaria a short distance north of the border with European Turkey, but how it reached this area is not known [7].

Europe was also affected by type A virus during 1996. The first outbreak was confirmed on 24 May in Albania in the District of Korcha in the southeast of the country. Ten villages were affected. The clinically affected animals were immediately destroyed. The other susceptible animals in the infected premises/villages were slaughtered later. The outbreak strain was shown to be very closely related to a strain circulating in Saudi Arabia and India. These results and the finding of buffalo meat on the bone pointed to India as the probable origin of the epidemic [7]. Ring vaccination with A22 vaccine was carried out covering a zone of approximately 50 km radius. On 25 June an outbreak was reported in the Former Yugoslav Republic of Macedonia (FYRM) and shown later to be due to the same strain of virus as that in Albania. An epidemic followed, comprised of seventeen outbreaks in the Skopje District and one in Titov Veles District. The control measures consisted of the stamping out of the cattle in the 18 villages and two rounds of vaccination. The veterinary service of the Federal Republic of Yugoslavia reported FMD in Kosovo, close to the border with the FYRM on 7 July. Later a total of 101 villages were diagnosed to be infected. The WRL was unable to identify or isolate any FMD virus from tissue samples or to demonstrate specific antibody in 131 serum samples submitted for diagnosis. Control consisted of stamping out without vaccination [8].

During 1997–1998 and in 1999 up to the time of writing (February) FMD has been restricted in Europe to the former USSR Republics of Armenia, Georgia and Azerbaijan. Type A virus, closely related to the type A Iran/96 strain circulating in Iran and Asiatic Turkey was isolated in Armenia during 1998. The outbreaks in Georgia and Azerbaijan were type O.

2.1. Lessons learnt from European experiences

The control of FMD in Europe is a success story from which a number of lessons can be learnt. These include the following:

- The greatest risk of spread of FMD is associated with movement of infected animals, next is the movement of infected animal products.
- The factor which exerts the strongest influence on animal trade movement is price. The flow of trade will be towards the region or regions where the price is highest.
- Control will be more difficult for countries which share land borders and so they should co-operate with their neighbours in a regional control programme.
- Conversely, control will be easier for countries which are isolated by geographical barriers, i.e. seaways or high mountains. Such countries can be more independent in their control policy.
- The availability of potent, safe vaccine and a high vaccination coverage are essential if the prevalence of disease is to be reduced.
- Vaccination alone will not be sufficient to achieve a high impact on disease prevalence, it must be supported by zoo-sanitary measures.

- Cost–benefit analyses are valuable in assisting decision-making about the control options to implement.

3. CONTROL AND ERADICATION OF FMD IN SOUTH AMERICA

FMD was transported to the southern part of South America from Europe around 1870, most probably by infected cattle. Within a short period the disease became widely distributed through the beef production areas of Argentina, Uruguay, southern Brazil and Paraguay. The disease reduced livestock productivity and curtailed live animal exports from most of the sub-continent until recent years when some countries, having eradicated the disease, could export live animals and fresh meat. Previously, very few live animals could be exported to FMD free countries, and generally only after extended quarantine and testing. Beef had to be deboned and other products had to be processed in such a way that FMD virus would be inactivated.

Chile was the first country in South America to complete a programme of FMD eradication. It was given its impetus in 1969 when the terms of a loan by the Interamerican Bank of Development were agreed with the Government of Chile so that it could implement a national plan for control and eradication. The objectives of the plan were: to vaccinate 94% of the bovine population older than three months every four months; to implement zoo–sanitary measures and to promote a publicity campaign for the plan beginning in the south of the country and progressing northwards in a gradual manner [9].

The number of recorded outbreaks during the decade before the start of the plan was 7009. It was reduced to 1684 in the next decade and of that total 1061 outbreaks were registered in the first year (1970) of the plan. By 1972 the number of outbreaks had fallen to fewer than 50. Most of the outbreaks from 1972 to 1974, from 1976 to 1977 and in 1978 were considered to have originated from imported animals — smuggled through the Andean mountains from Argentina. Steady progress in control was maintained and in January 1981, Chile declared freedom from FMD.

The total cost of the plan was US $35.71 million. The Chilean Government contributed 56.3% of the cost, the livestock industry 40% and the Interamerican Bank of Development 3.7% as a loan. The estimated gross benefit was US $94.88 million, i.e. a cost–benefit ratio of 1:2.66 and a net benefit of US $59.17 million (Report 1981).

In 1974, Colombia initiated a plan for the regional FMD when a co-operative programme was agreed between the Ministry of Agriculture of Colombia, the Colombian Agricultural and Livestock Institute (ICA) and the Department of Agriculture of the USA (USDA). The Colombian Ministry of Agriculture delegated to ICA the planning and implementation of the actions, which led to the creation of the ICA–USDA Programme.

The activities of the programme were focused in a region in the northern part of Colombia that borders Panama and extends for a short distance along the Caribbean Sea towards the north-east and along the Atlantic Ocean to the south-west. The region was subdivided into areas. During the next two decades the FMD situation was steadily improved so that currently there is a free non-vaccinated area, surrounded by several areas that are disease free with vaccination and then vaccinated, buffer areas. The region is protected from the surrounding endemically infected region by a network of border control posts located on the principal land and river ways. There is also a system of fixed and mobile control posts between the areas inside the protected region. The animals in the different areas carry ear-tags of different colour and the main purpose of the checkpoints is to ensure that livestock move from areas of higher to lower health status only. The personnel at checkpoints also inspect vehicles to make sure that animal products are not being moved illegally.

In the areas where cattle were routinely vaccinated the policy in the early stages of the programme was to apply vaccine three times per year. When the potency of the vaccines improved, the frequency was reduced to twice per year. More recently, with wider use of oil-adjuvant vaccines it has been reduced to just once a year. Before owners could move their cattle they had to obtain a certificate confirming that they had been appropriately vaccinated. These practices are universal throughout South America.

In April 1987, the 5th Inter-American Meeting on Animal Health at the Ministerial Level (RIMSA V) issued Resolution XIII, which entrusted the Panamerican Health Organisation (PAHO)

and the South American Commission for the Control of FMD (COSALFA) with preparing the hemispheric programme for eradicating FMD, including adequate mechanisms for its implementation. This meeting approved the creation of a Hemispheric Committee for the Eradication of FMD consisting of a representative from the Government of each of the following sub-regions: the Southern Cone, the Andean Region, the Amazon, Central America, the Caribbean and North America, also one or more representatives of the producers of each of the above sub-regions.

The main objectives of the Hemispheric Programme for the Eradication of FMD are (i) to eradicate FMD from the American Hemisphere, (ii) to prevent its introduction into free areas and (iii) to settle new livestock areas, especially the Amazonian Sub-region, thereby preventing the introduction of FMD virus and other alien pathogenic agents and at the same time respecting the ecological integrity of those areas. The programme has been very successful and the disease has been pushed progressively northwards. The last confirmed outbreaks were in June 1990 in Uruguay in April 1994 in Argentina, in September 1994 in Paraguay and in December 1993 in the States of Rio Grande do Sul and Santa Catarina in Brazil. Uruguay has been disease free without vaccination since 1996. Argentina plans to stop vaccination by the end of March 1999. As a result of the higher health status of its livestock and animal products, Uruguay has gained access to the lucrative markets of the United States and Japan. Argentina and the other countries of South America should soon be able to follow suit.

3.1. Lessons learnt from South American experiences

In a few parts of South America there is a similarity between the husbandry systems and the epidemiology of FMD and those in Europe. However, for the most part the systems differ and so different control procedures have evolved. Particular lessons, which have been learnt in South America, are:

- The need for control measures to be harmonized and implemented on a multi-national basis and for the countries in a region to co-operate at all levels.
- The need for politicians to be involved in high level review and planning meetings to maintain the support for programmes.
- Livestock producers should be given the opportunity to participate at all levels of review and planning activities as they can make important contributions to the success of programmes.
- It may be beneficial to proceed in a step-wise manner from one area to the next with the progression being from the higher towards the lower health status.
- Regions which have attained a high health status should be protected by installing safeguards to prevent the re-introduction of virus from regions of lower health status.
- It is essential to achieve a good vaccination coverage with potent, safe vaccines containing antigens appropriate to the region where they will be applied.
- Animal movement must be controlled. Colour-coded ear tags can help to identify the origin of animals.
- Publicity campaigns through schools and the media are important to obtain the compliance of farmers with control programmes.
- Specialist advice, training and diagnostic activity should be provided through a network of national laboratories linked to a regional laboratory.
- Regular cost–benefit analyses are valuable to assess the progress of a programme and to persuading sponsors and livestock producers to continue their support.

4. CONTROL OF FMD IN SOUTHERN AFRICA

The history of FMD in southern Africa, its main epidemiological features, its economic impact and the measures used for control has been comprehensively reviewed by G.R. Thomson [10]. He included ten countries in his paper viz. Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia,

South Africa, Swaziland, Zambia and Zimbabwe. With the exception of Lesotho, FMD has been reported in all of the countries since 1931, the year when the disease re-appeared in the region after an absence of several decades for a reason that has not been explained. Between 1971 and 1980 the total number of epidemics was equivalent to those during the previous twenty years. An unusually high incidence in Angola and Mozambique accounted for the major part of the 1971–1980 total, which was probably a consequence of civil unrest and disruption of the infrastructure in both countries.

Since the 1980's the incidence of disease in the region has declined considerably. In Angola and Mozambique this may have been due to the dramatic reduction of the livestock populations as a consequence of military actions in farming and wildlife areas. The more favourable disease situation elsewhere in the region has been attributed by Thomson [10] to improved disease control, in particular since the late 1970's of locally produced vaccine of good quality. Some countries of the region have not had outbreaks for many years. South Africa has not had an outbreak in its domestic livestock since 1983, whilst Botswana's last episode was in 1980.

There are some epidemiological features of FMD that are particular to southern Africa, the uniqueness of the virus types in the region (Southern African Territories SAT 1, 2 and 3) and the central role of the African buffalo in the epidemiology of the disease. Areas within the region which are prone to outbreaks caused by SAT type viruses are associated with higher densities of buffalo whereas outbreaks of type O and A, generally in the north of the region, are usually associated with established trade routes. While nucleotide sequencing has provided evidence linking several outbreaks in cattle with buffalo the technique has also demonstrated that some SAT 2 outbreaks, in Zimbabwe for example, had originated from carrier cattle. Investigations of carrier cattle in Zimbabwe have shown that they can be persistently infected for up to three years [7].

Although the details are not fully understood, it is believed that FMD infection in southern Africa is maintained within buffalo herds and that they are the source from which the virus occasionally spills over into other wildlife species and domestic livestock. Therefore, the major strategy for protecting domestic livestock is to keep buffalo away from areas of livestock production. This is done by the containment of buffalo behind game fences. For some distance beyond the fences cattle are vaccinated to create a buffer zone. The vaccines contain the strains of virus considered to be circulating in the buffalo. These are identified by capturing and probing sampling the buffalo at intervals. Beyond the buffer zone cattle are left unvaccinated and in several countries, e.g. Botswana, Namibia, Swaziland and Zimbabwe, these constitute the FMD free zones from which beef is exported to the European Union. This trade is a valuable source of hard currency for those countries.

4.1. Lessons learnt from southern African experiences

Fencing is an effective method for controlling the movement of wildlife and cattle and preventing the spread of virus from buffalo to domestic livestock. However, fences may severely impair the migration of certain wildlife species. It is important to use vaccines of good quality and they should contain antigens related to the primary threat which in southern Africa are the SAT types circulating in buffalo.

There is a need to monitor the antigenic profiles of the SAT viruses circulating in buffalo populations and it would be beneficial to develop a regional approach to define the extent of intra-typic antigenic variation of the SAT viruses in circulation and to standardize the methods for rapid strain selection for vaccines.

5. RELEVANCE OF THE EXPERIENCES OF OTHER REGIONS TO SOUTHEAST ASIA

Since FMD has been controlled and eradicated from most of Europe and a large part of South America, the focus for control and eradication has shifted to Southeast Asia. The drive for this has come from different quarters: from international organizations and from individual countries which have recognized the need to increase agricultural productivity to meet the demands for more protein to feed the rapidly expanding populations; from certain countries which want to eradicate the disease to increase their hard currency earnings through increased export, in particular of pig meat and pork products to Japan and finally pressure from vaccine producers who face a declining market elsewhere.

Southeast Asia can learn lessons from the experiences gained in the control and eradication of FMD in other regions of the world but lessons can also be learnt from campaigns within Southeast Asia itself, for example from the experiences of Indonesia which mounted a very successful programme during 1974–1981 which lead to the eradication of the disease from Bali and Madura in 1978, and from South Sulawesi and East Java in 1981. The last case of FMD was reported in Kebumen, Central Java in December 1983, while the last vaccination in Java against FMD was at the end of 1985. All of Indonesia was declared free in 1986 [11].

The successful campaigns in Europe, including the former USSR, South America, southern Africa and Indonesia have certain elements in common which should be considered when plans are being formulated to control and eradicate FMD in the Southeast Asian region. These include:

- Each of the countries of the region should formulate a national plan for the control and eradication of FMD which has the legal and financial support of the Government and the appropriate resources at all levels, i.e. personnel and technical support to effectively undertake and sustain the activities of the campaign through to the achievement of its final objectives. Guidelines for formulating national contingency plans for FMD have been provided in a document prepared jointly by the CEC, OIE and the European Commission for the Control of FMD and published by FAO [12].
- The technical requirements of the campaign, i.e. surveillance, diagnosis, implementation of control measures, vaccine availability and delivery systems etc. must be given sufficient resources, if they are to be effective. There should be a central fund which is protected against the possibility of regional economic crises.
- From the earliest possible stage, representatives of the livestock industry in each country should be invited to participate in control campaigns and be involved in decision-making at all levels.
- Countries in the region should benefit from the establishment of regional groups to develop common control strategies, especially those which share land borders with their neighbours.
- The control of the movement of livestock within and between countries will be essential if the areas which have achieved a high health status are to be protected against re-introduction of virus from areas of lower status. This will require a knowledge of livestock trade movements and probably checkpoints and barriers to reinforce the controls. Colour-coded ear-tags have been found to be useful in several parts of the world for identifying the origin of animals and in helping to deter illegal movement.
- Adequate supplies of safe, potent vaccines of appropriate antigenic specificity are essential to reduce the prevalence of disease to levels where it will be economically acceptable to cease vaccination, implement stamping out and move towards the final goal of virus eradication.
- Campaigns should have a publicity group, whose main responsibility is to ensure that farming communities and the livestock industry are aware of the campaign and its potential benefits.
- The progress of a campaign should be evaluated at regular intervals including the production of 'running' cost–benefit analyses.

6. REQUIREMENTS FOR CONTROL WHICH ARE UNIQUE TO SOUTHEAST ASIA

The domestic livestock in Southeast Asia have several special features. The domestic pig predominates throughout the region and the water buffalo population is more numerous there than in other parts of the world. Pigs, especially, play an important role in the epidemiology of the disease and so there is a requirement for safe, good quality vaccines in sufficient quantity to protect them. There is a need for the establishment of internationally accepted protocols for testing FMD vaccines for pigs and for an independent body to take responsibility for overseeing the procedures. These shortcomings were clearly illustrated during the 1997 FMD epidemic in Taiwan Province of China and highlighted during the last meeting of the OIE Sub-commission for FMD in Southeast Asia [13]. The issues have been brought to the attention of the OIE Standards Commission and the proposals of that body are awaited.

Infected pigs have been defined as amplifier hosts for FMD virus [14]. In the European context this was with reference to the role of the pig in excreting enormous quantities of airborne FMD virus, which under certain climatic and epidemiological conditions can result in an explosive spread of the disease. While the evidence suggests that airborne spread of FMD is not a common event in Southeast Asia, the pig still fits the definition of an amplifier host in that it is frequently the species that is primarily infected by virus circulating in contaminated waste food, which then leads to the initiation of outbreaks. The adoption of procedures to prevent the spread of FMD virus through waste food will be essential if the virus is to be eradicated from Southeast Asia.

Another feature of the epidemiology of FMD that appears to be currently unique to Southeast Asia is the occurrence of species-adapted strains, in particular strains which are highly adapted to pigs. This has been recognized in Taiwan Province of China, the Philippines and Viet Nam [13,15]. The capability of pig-adapted strains to cause very serious economic impact and the need for an early warning of their presence, therefore, were highlighted at the last meeting of the OIE Sub-commission for Foot-and-mouth Disease in Southeast Asia [13].

The part which the water buffalo plays in the epidemiology of FMD in Southeast Asia has not been fully investigated and is worthy of further attention, especially to know more about the maintenance and persistence of FMD virus in that species and whether there are special requirements for vaccines to be effective.

7. DIAGNOSTIC REQUIREMENTS TO ACCELERATE FMD CONTROL IN SOUTHEAST ASIA

Under the FAO/IAEA sponsored Co-ordinated Research Project entitled "Improved diagnosis and control of FMD in Southeast Asia using ELISA-based technologies" the methods required to detect FMD viral antigen and antibody were successfully introduced into the national FMD laboratories of Southeast Asia. The priority activity for the laboratories of the region should be to use their diagnostic and surveillance capabilities to support national control and eradication schemes. The veterinary authorities should ensure that their field officers make maximum use of laboratory support to investigate all suspected cases of FMD. Unfortunately, at present the number of samples collected is too few in most of the countries in the region for conclusions to be drawn about the true prevalence and incidence of disease and for assessments to be made about the appropriateness of the antigens in vaccines. When outbreaks occur, therefore, judgement of the suitability of vaccine is based on whether vaccination prevents further spread or not. This is a high-risk strategy and one that will need to be changed if control is to be more effective. Planning and accurate costing of resources for campaigns will not be possible until comprehensive and reliable surveillance data are available.

When national laboratories are routinely using their diagnostic and surveillance tests they should consider expanding their capabilities to acquire a tissue culture capability. A few laboratories have already taken this step. A tissue capability enables a laboratory to isolate viruses from field samples, to grow them and send aliquots to the regional laboratory or the WRL for antigenic and genomic analyses. Laboratories with the capability can also confirm ELISA results by using virus neutralization tests. The liquid phase blocking ELISA is highly sensitive and ideal for screening large numbers of serum samples. However, a small number of samples will inevitably give equivocal results and so further testing by virus neutralization, the definitive confirmatory test, is necessary to obtain a final result. Clearly, this requires a tissue culture capability.

The antigenic characterization of field isolates has two functions (i) to confirm the appropriateness of current antigens in vaccines and (ii) to determine if there is a requirement for a new strain to be included in the vaccines. These activities fall within the remit of a regional laboratory. However, that does not preclude the possibility of a national FMD laboratory undertaking those activities should it have the capability. The WRL remains willing to provide additional support if it were required.

Nucleotide sequencing has been shown by the WRL, some national FMD laboratories in Europe and the FMD laboratory in South Africa to be a valuable tool for identifying the origin of outbreaks. The technique is also very useful for many research activities. There would be scope to use the technique in Southeast Asia for molecular epidemiological purposes and possibly for research, for

example to investigate the duration of persistence in the water buffalo. The method requires specialist knowledge, equipment, reagents and access to sequence data banks. It is expensive and so the potential benefits would have to be balanced against the cost. In the author's opinion, Malaysia, the Philippines and Thailand are countries where there could be grounds for using the techniques —primarily for molecular epidemiological investigations of the origin of outbreaks.

Donaldson and Kihm [16] reviewed developments in diagnostic methods and other techniques, which could accelerate the control and eradication of FMD. They pointed to the need for a reliable, practical, rapid and sensitive method to differentiate infected from vaccinated animals. The applications of the test are two-fold. Firstly, when a country or zone has not reported any outbreaks of disease for some months and the veterinary authority is considering the possibility of ceasing vaccination then the test can be used to verify, that virus is no longer circulating. Secondly, when an FMD-free country or zone experiences an outbreak and uses emergency ring vaccination in the face of disease, the test can be employed to test vaccinated animals before they are allowed to leave the vaccination zone to ensure that they are not carrying virus. In the Southeast Asian context the author suggests, that there would be applications for the test in the Philippines, Malaysia and Thailand.

Several different types of test have been developed to differentiate infected from vaccinated animals. Most depend on the fact that cattle which have been infected with FMD virus can be differentiated from those which have been vaccinated on the basis of the detection of antibody to one or more of the non-structural (NS) proteins of the virus. During the period 1994–1997 the CEC sponsored a concerted action programme in which several EU laboratories collaborated to investigate the potential of using assays measuring antibody to the NS proteins of FMD virus to differentiate infected from vaccinated animals. A number of national FMD laboratories worldwide pursued similar objectives during the same period. At a meeting held at the Institute for Animal Science and Health, Lelysad, the Netherlands, on 28 and 29 April 1997, the findings were presented and discussed [17]. The most promising results have been obtained with an indirect ELISA, which uses as antigen the NS polyprotein 3ABC expressed as a fusion protein in *E. coli*. Measuring antibody to 3ABC on a herd basis is useful to detect exposure of vaccinated herds to live virus and herds so identified can then be examined for the presence of virus. However, there are serious limitations to the reliability of the use of antibody to NS proteins for the detection of carrier animals, especially at the individual animal rather than the herd level, and further work in this area is required. This will be among the topics that will be addressed during the next FAO/IAEA Co-ordinated Research Project on FMD.

REFERENCES

[1] DONALDSON A.I., Control of foot-and-mouth disease in Europe, Proc. Int. Workshop, Lampang, Thailand, 6–9 September 1993, ACIAR Proceedings No.51 (1993) 70–74.

[2] FRENKEL H.S., Research on foot-and-mouth disease. III. The cultivation of the virus on a practical scale in explanations of bovine tongue epithelium, Am. J. Vet. Res. **12** (1951) 187–190.

[3] MOWAT G.N., Foot-and-mouth disease in the Community after 1992 – the end or the beginning of a problem? 11th Int. Symp. W.A.V.M.I. Perugia and Mantova, Italy. 2–6 October 1989, 123–132.

[4] COMMISSION OF THE EUROPEAN COMMUNITY, Report from the Commission to the Council on a study carried out by the Commission on policies currently applied by Member States in the control of foot-and-mouth disease, CEC Brussels, Belgium (1989).

[5] BECK E., STROHMAIER K., Subtyping of European foot-and-mouth disease virus strains by nucleotide sequence determination, J. Virol. **61** (1987) 1621–1629.

[6] WESTERGAARD J.M., Health strategies to control swine infectious diseases: European experience, Proc. 14th IPVS Congress, Bologna, Italy 7–10 July 1996, 32–38.

[7] KITCHING R.P., A recent history of foot-and-mouth disease, J. Comp. Path. **118** (1998) 89–108.

[8] LEFORBAN Y., Foot-and-mouth disease in Europe in 1996 and 1997: control and prevention measures, Proc. of First World Conf. on Vaccines and Immunisation. Istanbul, Turkey (1998).

[9] MINISTERIO DE AGRICULTURA SERVICIO AGRICOLA Y GANADERO, CHILE, Chile free from foot-and-mouth disease. Report of the Ministerio de Agricultura Servicio Agricola y Ganadero, Santiago, Chile (1981).
[10] THOMSON G.R., Overview of foot-and-mouth disease in southern Africa, Rev. sci. tech. Off. Int. Epiz. **14** (1995) 503–520.
[11] SOEHADJI M.M., SETYANINGSIH H., The experiences of Indonesia in the control and eradication of foot-and-mouth disease. In Diagnosis and Epidemiology of Foot-and-Mouth Disease in Southeast Asia, Proceedings of an International Workshop, Lampang, Thailand, 6–9 September 1993, Editors J W Copland, L J Gleeson and Chanpen Chamnanpool. ACIAR Proceedings No.51 (1993) 64–69.
[12] EUROPEAN COMMISSION FOR THE CONTROL OF FOOT-AND-MOUTH DISEASE Report of the Thirtieth Session of the European Commission for the Control of Foot-and-Mouth Disease, Rome, 27–30 April 1993, FAO, Rome (1993) 48–62.
[13] THE OIE SUB-COMMISSION FOR FOOT-AND-MOUTH DISEASE Report of the Fourth Meeting of the OIE Sub-Commission for Foot-and-mouth Disease in South-East Asia with the Participation of FAO/IAEA. Bangkok, Thailand. 3–6 March 1998 (1998A).
[14] SELLERS R.F. AND PARKER J., Airborne excretion of foot-and-mouth disease virus. J. Hyg. Camb. **67** (1969) 671–677.
[15] DUNN C.S., DONALDSON A.I., Natural adaptation to pigs of a Taiwanese isolate of Foot-and-Mouth Disease virus, Vet. Rec. **141** (1997) 174–175.
[16] DONALDSON A.I., KIHM U., Research and technological developments required for more rapid control and eradication of foot-and-mouth disease, Rev. sci. tech. Off. Int. Epiz. **15** (1996) 863–873.
[17] REPORT (1998B) Proceedings of the Final Meeting of Concerted Action CT93 0909. The Veterinary Quarterly, **20**, Suppl 2, (1998) 1–40.