

A review of rabies elimination in Europe

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ABSTRACT: The rabies situation has changed drastically in all European countries where oral vaccination campaigns of red foxes against rabies have been implemented. All types of oral vaccines used have shown to be highly efficacious, enabling rabies elimination over large areas. Several countries are already declared rabies-free according to the internationally conditions set and other countries are in the final stage of this process. In this review, the rabies situation in a number of selected European countries is described, with special emphasis on oral vaccination.

Keywords: rabies; red fox; vaccine bait; oral vaccination

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1. Introduction

Rabies spread progressively from Poland to Central – and West-Europe at the beginning of the 1940s (Pastoret and Brochier, 1998). The front of the rabies epizootic moved about twenty to sixty kilometres annually. In 1967, the front of the rabies outbreak reached the north-western part of Switzerland and during subsequent years rabies spread over the whole country. The majority of rabies cases in Switzerland were registered in the period July 1975 to June 1976, when 1957 cases were reported (Breitenmoser et al., 1995). In the 1970s, the front of the rabies wave reached a line which can

be drawn between The Netherlands and Italy. The westernmost point reached was in France in 1982, approximately 1 400 km from the original location in Poland (Anonymous, 2002b,c). In the second half of the 1950s, most rabies cases involved red foxes (*Vulpes vulpes*). This change from urban to sylvatic rabies required a new strategy to control the disease (Muller and Schluter, 1998). In more recent years, raccoon dogs (*Nyctereutes procyonoides*) represent another animal species important in the rabies epizootology in several European countries (Schuster et al., 2001; Vos et al., 2001; Zienius et al., 2003). This animal species was translocated and released from East Asia to Russia and other countries during the

twenties of the last century (Russia, Baltic countries, Finland, Poland) (Nowak, 1993).

It was assumed that with increasing fox density, the number of contacts between foxes would also increase. Hence, rabies could spread among the fox population when a certain threshold density was reached, giving rise to epizootics. Therefore, efforts to halt the spread of this virus disease were directed to reduce the red fox population below this threshold. For this purpose, different methods were applied; e.g. hunting, gassing of fox dens, digging up the cubs, poisoning. However, it was recognised that these methods did not give good results in the long term and new methods were asked for.

First field trials involving vaccination of the red fox were performed in Switzerland and Germany. Red foxes were captured and vaccinated by the parenteral route with an inactivated vaccine and subsequently released. This method was very time consuming and labour-intensive and only a very limited number of the red foxes were immunised. The method was rapidly abandoned (Aubert et al., 1994; Aubert, 1995).

2. Rabies in Europe and rabies elimination using oral vaccination

At the beginning of 1960s, Baer et al. (1971) found, that there was a possibility to protect red foxes against rabies by means of oral vaccination with attenuated rabies viruses. The ERA (Evelyn Rokitnicki Abelseth) virus-strain was used in these trials. This did not draw any attention until the year 1970, when the author presented the results at a WHO conference in Europe (Wandeler, 2000). The paper was subsequently published and has created a scientific base for the commencement of oral vaccination due to its effectiveness in the immunization of the red foxes, whereby the attenuated rabies virus enters the body over the mucous membrane of oral cavity and pharynx. Oral vaccination campaign has led to the elimination of rabies in various regions and has pushed the front of the rabies wave back eastwards. It is in fact the first example of pathogen elimination from the wild animal population by means of vaccination and not by means of reduction of a host population (Artois et al., 2001). The first field trial with oral vaccination was performed in Switzerland in the year 1978 (Steck et al., 1982a,b). A significant part of the country was freed from rabies during the following four years till the year 1982 (Kappeler

and Wandeler, 2000). During the eighties, oral vaccination against rabies was commenced in several other western European countries (Germany – 1983, Italy – 1984, Austria, Belgium, France, Luxembourg – 1986, Finland, The Netherlands – 1988). Political changes in the central and eastern European countries at the end of nineties in the last century enabled others to join this programme of oral vaccination (Slovenia – 1988, Czech Republic – 1989, Hungary, Slovakia – 1992, Poland – 1993) (Aubert et al., 1994; Muller and Schluter, 1998; Vos et al., 2000). Clear improvement in the disease situation on the treated territory could be seen soon after the commencement of oral vaccination (Brochier et al., 1988, 1991a). However, it became clear that it was necessary to cover large areas and coordinate the whole process at the international level for maximum impact (Frisch et al., 1987; Anonymous, 1989). Information obtained and lessons learned from the first years of oral vaccination campaigns have been taken into account to modify the vaccination strategy, resulting in the elimination of rabies from large areas (Schluter and Muller, 1995). By the year 1994, oral vaccination of red foxes had commenced in 17 European countries. In the middle of 1990s about 15 million baits were distributed every year. In the year 1994, the incidence of rabies cases had shrunk to less than 20% of the level at the start (Stohr and Meslin, 1996). The clear positive effect of oral vaccination on the rabies incidence in EU member states can be seen in the following table, compared to rabies prevalence in Europe:

	Europe total	EU Member States
1980	18 605	11 214 = 60.3%
1990	21 027	11 317 = 53.8%
1995	8 127	1 242 = 15.3%
1999	6 586	102 = 1.5%

Source – Rabies Bulletin Europe (4/80, 4/90, 4/95, 4/99)
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In the year 2002, the situation improved even further. In the first half of the year, the EU member states registered only 43 rabies cases in total and from this number 19 cases were in Germany and 24 in Austria. These cases were concentrated in two areas: the federal state of Hesse in Germany and the Austrian province of Karnten, which is located at the south of the country and bordering Slovenia. Rabies was reintroduced in this part of Austria after six years. This outbreak after reinfec-

tion in Austria was very effectively brought under control by means of emergency vaccination and no case was reported in the second half of 2002 (Vogl, 2002; Anonymous, 2002f).

3. Short summary of the rabies situation and rabies control by means of oral vaccination for the individual European countries

Specific conditions in individual countries have to be taken into consideration when one tries to evaluate the whole process of rabies elimination. The situation, for instance, in Italy and Switzerland, and that in Belgium and France is quite different to that in Great Britain and Germany (in West Germany and in the former German Democratic Republic). Nevertheless it is still possible to draw on the experiences gained by these countries and learn from mistakes to find generally valid methods of rabies elimination, which can be useful for other countries considering or at the beginning of an elimination program. This enables rationalization of the whole programme.

3.1. Great Britain

In spite of the fact that Great Britain is a country free of terrestrial rabies and oral vaccination of red foxes against rabies have never been used here, it is interesting to familiarize oneself with the rabies history of the British Islands. The first documented cases concerning rabies were found in 1026 (Fleming, 1871 – cited in Pastoret and Brochier, 1998), and the disease was present throughout the Middle Ages. Increase in the prevalence of rabies was registered from 1735 onwards and by 1776, rabies had spread all over Britain. Between 1752 and 1862, rabies was confirmed in the dog population in London. It is interesting that sources spoke about mad dogs. This is fully understandable, as the cause of the disease was at that time not known. In spite of the dense population of red foxes, rabies did not spread to other species with the exception of two outbreaks in deer during the years 1856 and 1886, when only the urban form of rabies was registered (Pastoret and Brochier, 1998).

By the end of the nineteenth century – in the years 1889 to 1898 – more than 160 people became infected, which led to a new Act coming into force

in 1897. Enforcement of the Act and compliance with its requirements led to elimination in the year 1902. Unfortunately, the disease was reintroduced in 1918, but it was finally eradicated in the year 1922. 328 rabies cases were registered in total (Pastoret and Brochier, 1998).

In spite of being eliminated by 1922, rabies has caused 21 human deaths in Great Britain between 1922 and 1998. In all cases, the people got infected abroad (Pastoret and Brochier, 1998). Recently, on 24th November 2002, another human rabies case has been recorded, but this was connected with rabies found in bats (Fooks, 2002). This was the fourth confirmed human case due to bat rabies reported from Europe (Fooks et al., 2002).

Surveillance of British bats for lyssaviruses has taken place since 1985. The first positive case was registered in Newhaven during 1996. The second confirmed case of an EBL virus infection isolated from bats was found in September 2002 (Fooks et al., 2002). That is the reason why the UK lost the status of a rabies-free country according to the WHO rules since the 27th September 2002 (Muller, 2002).

Great Britain had very strict quarantine measures in place after the successful eradication of urban rabies, which required six months' of quarantine for all imported carnivores. These measures were scaled down later according to the animal health situation in the country of origin (Anonymous, 2003). From 1922 to 1970, 29 animals died in quarantine. In the following period, when vaccination with inactivated cell-cultured vaccines started, the number of rabies cases in quarantine decreased considerably; from 1971 to 1991, only two cases (ill dogs) were reported. Although 200 000 animals underwent quarantine since 1971, no case was recorded after the animals were released from quarantine (Pastoret and Brochier, 1998).

Despite the favourable disease situation in Great Britain, there have been several publications which considered the use of oral vaccination in case of sylvatic rabies introduction (Smith, 1995; Suppo et al., 2000; Smith and Cheeseman, 2002). Owing to the fact that several parts of Great Britain are extraordinarily densely populated by red foxes the fear of a rabies epizootic, in the case of rabies introduction, is understandable. Badgers represent another animal species which can influence, in the case of sylvatic rabies, the epidemic. Therefore the possible role of badgers in spreading terrestrial rabies has been studied as well (Smith, 2002).

3.2. Switzerland

The first rabies case in red foxes was confirmed in Switzerland in March 1967. The spread of the disease and progress of its elimination during the following thirty years is described in detail by Muller et al. (2000). Up until 1977, on average three people died due to rabies annually.

Switzerland was the first European country to start oral vaccination, in 1978. It proved that the method is highly effective and suitable for practical use. It was as a matter of fact already a great success that the field trial took place at all considering that a lot of problems had to be solved at this time or were not clear, for example the residual pathogenicity of the vaccine virus. Scientists admit that nowadays it would be almost impossible to obtain all the necessary approvals enabling to start a similar action (Wandeler, 2000). The development of an effective, safe and attractive vaccine bait, selection of the correct vaccination strategy (spatial and temporal pattern) were the basic elements for the successful implementation of the oral vaccination campaign (Kappeler and Wandeler, 2000).

The first vaccination campaign was performed in the canton of Valais. The valley between the Alps ranges was chosen for the trial to reduce, as it was confirmed in a following period, the migration of red foxes. It was assumed that the fox density in the landscape ≥ 1 500 metres above sea level is less than the threshold density necessary for rabies spread. The area of the canton was about 5 000 square kilometres in total, of which one quarter was ≥ 1 500 metres above sea level. (Steck et al., 1982b). By the year 1982, ten vaccination campaigns had been carried out in the canton which freed the area from rabies. The topographical conditions of alpine Switzerland are very unique. Therefore, the whole country could be divided into distinct epidemiological units, which were progressively freed from this disease. Lakes, big and rapidly flowing rivers, mountain ranges, highways with protective fences and the cities are natural/artificial barriers which can prevent the spread of rabies (Wandeler et al., 1988a). The vaccine baits were distributed by hand. This was supported by complimentary vaccination by means of helicopters in regions at higher altitude (practically inaccessible). 15.5 baits per square kilometre were distributed on average. The amount of baits varied from 11 to 20 baits per square kilometre per campaign. The campaigns took place in March and

October. Elimination was deemed to be successful in the regions where 50–80% of the red foxes had detectable levels of virus neutralizing antibodies (Steck et al., 1982a; Wandeler et al., 1988b).

In the year 1982, 1 001 positive cases were reported, of which 652 cases were red foxes. In 1990, only 25 rabies cases were diagnosed, of which 24 cases were red foxes (Zanoni et al., 2000). As France did not begin vaccination in the neighbouring regions until 1992, rabies was repeatedly reintroduced (Breitenmoser et al., 2000). Another important factor for the reintroduction of this disease was the increase of the red fox population. Oral vaccination can only protect the fox population against a re-infection effectively if the number of non-vaccinated animals remains below the threshold density required for the spread of rabies (Breitenmoser et al., 1995). In 1994, 225 cases were reported. In the following year there were only 23 cases diagnosed and in the year 1996 only 6 rabies cases were reported (one red fox). In 1996, the last rabid fox was registered (Breitenmoser et al., 2000). In 1997, one rabies case in a dog imported from Morocco was registered. In total 17 109 rabies cases were registered during thirty years. 73% of the positive cases were in red foxes. 25 000 people had to be treated (Zanoni et al., 2000). According to WHO regulations Switzerland was declared rabies free in 1999 until the third quarter of 2002, when the third case of bat rabies in Switzerland was diagnosed. According to the OIE rules the country still remains rabies-free (Anonymous, 2002e).

In the first years of oral vaccination, the conventional vaccine SAD Bern was used. The capsule containing the vaccine was placed underneath the skin of chicken heads that were used as bait. Since 1991 the French vaccine SAG1 was used and later on an improved version – SAG2 – was used (Aubert et al., 1994). 2.8 millions of vaccine baits were laid on the territory during the twenty years (Zanoni et al., 2000).

3.3. Germany

In the second half of the twentieth century, the rabies incidence continued to increase until the start of oral vaccination in 1983; the only exception was a very short period in the seventies, when the intensifying hunting pressure decreased the red fox population density (Schluter – personal communication).

In 1983, Germany joined Switzerland as the second country to carry out field trials with oral vaccination. The rabies virus selected was a variant of the original SAD Bern strain, and was called – SAD B19. From 1989, another vaccine with the virus strain SAD P5/88 has been used in certain regions. During the first two years, also in Germany the chicken head bait was used (Vos et al., 2000), but shortly after that, new industrial baits were developed. The industrial baits have been used since 1985 (Schneider and Cox, 1983).

Different federal states joined the oral vaccination program during the eighties, in the following order: 1983 Bavaria and Hesse, 1984 Lower Saxony and Baden-Württemberg, 1985 Schleswig-Holstein, North Rhine-Westphalia and Rhineland-Palatine, 1987 Saarland, 1990 Thuringia and other federal states from the former Eastern Germany joined practically at the same time i.e. they commenced a vaccination in Mecklenburg-Western Pomerania in 1989 and in the following year, the remaining three federal states Saxony-Anhalt, Brandenburg and Saxony.

In spite of the results, which were without any doubt positive in the whole country, we can show with an example using different baiting strategies that the rabies elimination was not achieved at the same time. In the old federal states, where the campaigns had started several years earlier than in the new federal states, repeated rabies reinfections occurred in already freed regions. On the other hand the new federal states, which did not start the campaign before 1990, finished the whole process within several years.

Schluter and Muller (1995) analyzed this difference and drew the following conclusion: the treated area was very often changed in the territory of the old federal states according to the rabies situation in the previous year. Furthermore, each federal state had its own strategy, the co-operation among federal states was not satisfactory, the baits were sometimes laid out by hands, sometimes by airplanes, postvaccination surveillance was insufficient or deficiencies were found. Incentives given to the hunters were sometimes considered too low, so hunters were sometimes not motivated to cooperate (Vos, personal communication). 15–18 (up to 30) baits were laid out per square kilometer, sometimes three times per year (April, June, September). In former East Germany, 18–22 baits per square kilometer were distributed by airplane twice a year (April and September). With the exception of large cities,

the whole area of the territory was treated and there was mutual co-operation among the federal states and even at the international level with the bordering states – the Czech Republic and Poland. The results of surveillance were compiled and entered onto the computer and hunters received incentives for the red foxes they handed over for investigation (Schluter and Muller, 1995).

Elimination strategy had to be adjusted according to the increasing population density of red foxes (Muller et al., 1995) by progressively increasing the number of baits per square kilometre (Schenzle, 1995). Trials with additional vaccination campaigns, placing the baits near the fox dens and emergency vaccination, were also conducted (Thulke et al., 1997). At the turn of the eighties and nineties, it was found that the average spring population density of red foxes living outside the Alps in the region Garnisch-Partenkirchen was 1.77 red foxes per square kilometre and that it was still not the maximum carrying capacity of the environment (Vos, 1995; Thulke et al., 1997).

There are a lot of red foxes in and around the big cities (Berlin) because they have access to sufficient food supplies of anthropomorphic origin. This is a complicating factor for the air distribution of the vaccine baits because it is impossible to distribute baits by plane in the surroundings of the towns and inside the larger green areas of the cities. Under these circumstances, only the Bavarian model of hand distribution is possible.

3.4. Italy

Urban rabies was eliminated in Italy in 1973. Four years later terrestrial wildlife rabies was found for first time in the northern part of Italy (Mutinelli, 2002). Rabies had been present only in the Eastern part of the Alps (northern Italy) so the elimination was easier due to the fact that the migration of foxes is limited in these mountainous regions as in Switzerland. The first vaccination campaign took place in Italy in 1984. Only 7 500 baits SAD B19 vaccine baits were distributed. In the following year the same number of baits was used. More baits were laid out in the year 1986, when slightly more than 35 000 baits were used. However, in the following year the number was decreased to less than 10 000 baits. In 1988, no vaccination was carried out. The greatest campaign was performed during the year 1989 when 39 000 baits were used. In the following

two years the vaccination was discontinued again (Anonymous, 1990). At this time only the infected areas were treated and immediately afterwards, when no rabies cases were reported in the area, the vaccination was stopped. During the nineties, the baiting strategy was improved with the result that Italy succeeded in becoming a rabies-free country. The last case was diagnosed in December 1995 (Mutinelli, 2002). According to Vos et al. (2000) 348 000 baits were used till 1998. It is clear from the above mentioned data that the treated area was relatively small (for comparison it represents an area of one district in the Czech Republic) and only the infected area along the Swiss, Austrian and Slovenian border was treated (Mutinelli, 2002).

3.5. Belgium

Belgium has the sea as one of its borders hence from the epidemiological point of view the most optimal elimination strategy is to push the front of the rabies in the other direction. The first field trial with oral rabies vaccination took place in 1986. In the first two years, SAD B19 vaccine baits were distributed, and from 1988 to 1990 the V-RG recombinant vaccine, was used as well (Pastoret *et al.*, 1988; Brochier *et al.*, 1988, 1990a, 1991a,b; Boulanger, 1996). Belgium became the first country in the European Union to use this vaccine. A field trial in France with V-RG began the following year. In the 1990 the number of recombinant V-RG (Raboral) vaccine used was for the first time more than the number of SAD B19 vaccine used. Since 1991 only recombinant vaccine has been used and a decrease of registered rabies cases was observed (Brochier *et al.*, 1990b; Aubert *et al.*, 1994; Vos *et al.*, 2000).

Before the start of oral vaccination approximately 500 rabies cases were registered in Belgium every year. In the first two years of oral vaccination the number of rabies cases decreased by about one half (342 and then 242). However, 515 cases were again found during the year 1989 and 842 in the following year. This was the highest number since the year 1983. It was recommended to create buffer zone up to a depth of 30 kilometres at this time (Coppens *et al.*, 1992). As it happened, this buffer zone was enlarged to 50–70 kilometres (Anonymous, 1998).

Only two rabies cases were registered (in a badger and a cat) along the French border but without any common link. Brochier *et al.* (1994) compared the percentage of antibody positive red

foxes in the whole treated region. The average level of virus neutralizing antibodies in the sera of foxes originating from five municipalities varied between 25–86%. Rabies spread in the following years as follows: 213 cases were found in the year 1995 in spite of three air vaccination campaigns in March, July and in the autumn. 15.7 to 17.2 baits were laid out per square kilometre. Additionally, 5 baits were placed at or near the entrances of fox dens in June. The whole treated area was less than 8 700 square kilometres. The worst affected area was always the triangle near the French and German border. This called for better international co-operation with the bordering states and a change of the vaccination strategy (Brochier *et al.*, 1995a, 1996a). At the end of the eighties, for example, only 11.3–15 baits per square kilometre were used and in the year 1993 records spoke about a better epidemio-surveillance but only 4.88 red foxes per 100 square kilometres were tested which is not enough from today point of view (Brochier *et al.*, 1995b). In 1995 an average of 15 red foxes were tested per 100 square kilometres (Brochier *et al.*, 1996b). In the year 1996 bait distribution was similar to the previous year, but the number of baits placed at the dens increased from 10 to 20 baits per den. A progressive increase in the percentage of red foxes found with tetracycline and rabies antibodies was observed (Brochier *et al.*, 1997). During the following years the strategy was identical; twice a year 17 baits per square kilometre were distributed and den vaccination continued as well. The last rabid red fox was found in the year 1998 and the last rabies case was recorded in the same region in cattle in the year 1999 (Brochier *et al.*, 1998, 1999, 2000).

During 1966 to 2000, 29 340 animals were examined in Belgium of which 6 780 animals tested rabies positive, 4 073 cases involved red foxes. The percentage of adult red foxes that tested positive for the bait marker, tetracycline, reached levels above 80% during the second half of the nineties and even the percentage of rabies antibody positive red foxes reached 70%, with the exception of the year 2000. Belgium and Luxembourg are according to OIE and WHO rabies-free since 2001 (Brochier *et al.*, 2001).

3.6. Luxembourg

Since Luxembourg represents a very small area, it was absolutely necessary to start oral vaccination simultaneously with its neighbouring countries

Belgium and France, i.e. in autumn 1986. The first campaign was organized with hunter organizations and, as in Belgium, SAD B19 vaccine was used. The number of baits was 15 baits per square kilometre. The conventional vaccine was used till the beginning of nineties. Since 1988 the recombinant vaccine V-RG was also used. Several years later the latter had completely replaced the SAD B19 vaccine bait. The development of the diseases situation resembled the situation in Belgium, with the last case recorded in 1987 (Frisch et al., 1987; Vos et al., 2000).

3.7. France

France started oral vaccination of red foxes in 1986. Initially the SAD B19 vaccine bait was used. The vaccination programme was a collaboration between Belgium, France and Luxembourg and co-financed by the European Union since 1989 (Cliquet, 2000). In 1989, the recombinant vaccine V-RG was used in one part of the treated area. At that time France was and remains the third and last European country to have used this vaccine. Since 1990, the French vaccine SAG1, (later replaced by SAG2) has also been used (Cliquet, 2000). France is the only European country to have used four (SAD B19, SAG1, SAG2 and VRG) vaccines. Evaluation of the results proved that all vaccines are effective and that it is possible to use any of them as to obtain a rabies-free status (Artois et al., 1993; Aubert et al., 1993). Other publications prefer the use of V-RG vaccine due to its better thermo-stability, so it can also be used during period with high temperatures. It is interesting to note that the bait uptake of recombinant vaccine was low by adult red foxes during the summer months. A statistically significant increase in antibody titres was only observed in fox cubs in the year 1992. Melting of the baits was suggested as the possible reason why the lower percentage of red foxes pick up the VRG vaccine bait. The results obtained with the SAG1 bait in 1992 were better, than those obtained in previous two years. This was probably due to the progress made in ensuring the stability of both the vaccine and the bait casing to higher temperatures (Masson et al., 1996, 1999). Another hypothesis could be that baits have a significant difference in appeal for foxes, but this was not proved by field trials. Similarly, any difference in the consumption of artificial baits by non-target species was not demonstrated in field

observation in Lorraine (Ruelle, 1993 – cited in Masson et al., 1996)

During the 1980s about 2 500 rabies cases were registered in France every year. This figure did not change when the first vaccination campaigns took place. In the years 1989 and 1990 even more cases were registered, i.e. 4 214 and 2 984, respectively. It has to be mentioned, that oral vaccination was only practised in a small area of the total infected area. At that time the front of the rabies wave reached the line from the north (half of southern Belgium-France border) to the southeast (Switzerland-Italian border). The breakthrough came in the year 1992 when the number of rabies cases decreased by a half (less than 1 300) and in the following year when only 261 cases were found. This trend continued and by the end of the 1990s only few cases were registered (Vos et al., 2000). Sylvatic rabies was recorded in the country since 1968 and at the time about 80% of positive cases were red foxes.

Oral vaccination of red foxes was confirmed to be the only suitable method enabling the elimination of rabies. During the 1990s the rabies situation improved considerably and resulted in a reduction of the baited areas from 133 000 square kilometres in 1990 to less than 4 000 square kilometres in 1998. This positive trend was also followed by a decrease in human post-exposure treatments (Aubert, 1999). The most critical area was the region on the common border with Belgium (Luxembourg) and Germany (Jaussaud et al., 2000). The last terrestrial wildlife rabies case was reported on 23rd December 1998 (Cliquet, 2000). This status has been retained thanks to the rapid discovery of a rabies case in a dog imported from the northern Africa in 2001 (Bruyere-Masson et al., 2001).

3.8. Austria

Austria was the fourth country to start with oral vaccination in 1986. The vaccine SAD B19 was used until 1994. Presently, the SAD P5/88 vaccine is used. During the 1980s only the part of the Austria was covered, but following the good results obtained in the previous treated regions, the vaccination area was enlarged at the beginning of the 1990s. Partially because of the rabies situation in non-vaccinated areas during 1991 and 1992 (Anonymous, 1990; Vos et al., 2000). Austria, like the Czech Republic, is completely surrounded by other countries. This creates additional problems for the successful

implementation of rabies control programmes. Austria adjoins two rabies-free countries, Italy and Switzerland. Furthermore, the federal state of Bavaria in Germany is also rabies-free, but the situation still remains very problematic on the south-eastern border with Slovenia, Hungary and Slovakia. Austria has still not succeeded in obtaining a rabies free-status, although only a very limited number of rabies cases has been reported annually since 1996. It has seen a radical decrease in the number of positive cases since large scale application of oral vaccination: 1991 – 2 465 cases, 1992 – 1 117 cases, 1993 – 675 cases, 1994 – 254 cases, 1995 – 95 cases, 1996 – 14 cases, 1997 – 8 cases, 1998 – 2 cases, 1999 – 5 cases, 2000 – 2 cases on the border with Hungary, 2001 – 1 case in a dog imported from Balkan, up until mid- 2002 – 24 cases in one outbreak in the south of the country against the Slovenian border. The outbreak was very effectively brought under control by means of emergency oral vaccination (Vogl, 2002). 3 577 animals were examined for rabies with negative result during the third quarter 2002 (Anonymous, 2002f).

3.9. Finland

Finland was a rabies-free country from 1959 until April 1988, when sylvatic rabies was reintroduced. In contrast to the majority of other European countries, raccoon dogs were the main reservoir species during this outbreak in Finland. Up until the end of February 1989, 66 positive rabies cases were registered, but during the following period up until the end of 1989 only three further cases were confirmed. Based on monoclonal antibodies the isolated virus was assigned to the arctic group of rabies virus. This virus-strain is typical for the (sub)arctic regions of the northern hemisphere. During the autumn of 1988 baits containing the SAD B19 vaccine virus were distributed using the so-called Bavarian model (hand distribution by hunters and forest rangers) over an area of about 2 400 square kilometres – at a density 15 baits per square kilometre. Post-vaccination surveillance proved that it is possible to successfully use the vaccine even for the above mentioned animal species. Even though rabies was eliminated from Finland within two years, oral vaccination has continued along the Russian border in subsequent years to prevent a reintroduction of rabies (Nyberg et al., 1992).

3.10. The Netherlands

No case of terrestrial rabies has been reported from The Netherlands since the beginning of the 1990s. Like Finland vaccination in The Netherlands started in 1988, when rabies cases were reported from a small area in the south of the country bordering Belgium and Germany. After successful elimination of rabies, the oral vaccination campaigns with the SAD B19 vaccine baits were discontinued in 1991. The number of rabies baits distributed was very small and never exceeded 8 000 baits per campaign. For the distribution of the baits, the Bavarian model was used, and 15 baits per square kilometre were distributed. The treated area was also very small and only represented about 300 square kilometres. Since 1989 all registered cases (totalling more than one hundred) have occurred in bats (Aubert et al., 1994; Vos et al., 2000).

3.11. Slovenia

Sylvatic rabies was reported for the first time here in 1973. This was in the north-eastern part of the country near the border with Hungary. The majority of cases were found in the late 1970s and early 1980s. Slovenia also commenced oral vaccination in 1988 (Curk and Carpenter, 1994). Originally they distributed 16 baits per square kilometre twice a year. Up until 1992 there was a progressive increase in the number of vaccine baits used (SAD B19). This was accompanied by a decrease in the number of positive cases, but the intended effect was not achieved. As a result the strategy was changed in 1995. This involved the whole country (20 000 square kilometres) being treated by aircraft according to all recommended principles and resulted in a significant decrease in the number of positive cases during 1997 and 1998. At the end of the 1990s (since the year 1998) the Czech vaccine Lysvulpen, based on the SAD Bern virus, was used on the western half of the territory. The number of baits was increased to 20 per square kilometre. No differences have been found between the two vaccines in respect of efficiency. The significant decrease of rabies occurrence was registered in the whole country (Kovac et al., 2000). In 1999 only 6 rabies cases were registered, 5 of them were in red foxes and 1 in a cat. Unfortunately in 2000 this had risen to 114 cases and in the following year to 135 cases. The situation seemed to stabilise during

2002 when only 5 cases were registered in the first half of the year.

The rabies situation in Slovenia is very difficult to control because the extended border with Croatia. In this country the present rabies situation is rampant. Continued vaccination is very important from the epidemiological point of view. The buffer zone must be maintained to prevent the spread of rabies north and west into the free regions. The European Union is aware of the problems and therefore provided financial subsidies to Slovenia through the approved PHARE programme at the end of 2002.

3.12. Hungary

Urban rabies has occurred in Hungary since the beginning of the last century. At the end of the 1930s (after the introduction of compulsory preventive rabies vaccination of dogs and after the implementation of a law concerning dog keeping) Hungary became the first country on the continent to successfully control urban rabies. Sylvatic rabies was reported in Hungary for the first time in 1954 and by 1971 it had spread throughout the whole country (Nagy and Kerekes, 1995; Bone, 2000).

The first oral vaccination campaign took place in 1992 using the SAD B19 vaccine bait. It is interesting, that aircrafts were already used during this first campaign covered a belt 25–50 kilometres wide along the Austrian and Slovenian borders. The flight lines were 250 metres apart and additional hand distribution of 16 baits per square kilometre was carried out (Heltay, 1995; Mocsari et al., 1994; Nagy et al., 1995). In total an area of 5 000 square kilometres was covered. In the following years the treated area was progressively enlarged and the number of baits was increased up to 25 baits per square kilometre (Mocsari et al., 1994; Nagy et al., 1995). From the onset, the situation in Hungary was very complicated. Like Austria, the country is completely surrounded by other countries. Only Austria, Slovenia and the Slovak Republic used oral vaccination in 1992, when the first campaign took place in Hungary. Other neighbouring countries, like Croatia, Serbia, Rumania and Ukraine, had not started with oral vaccination or had vaccinated only randomly and to a limited extent (Muller, 1995). Vaccination was performed only in certain regions of Hungary before 1996. In 1997, the whole western part of Hungary along the Austrian border (38 000

square kilometres) was included in the oral vaccination programme.

Some 900 to 1 400 cases were registered each year from the 1980s until 1996. Since 1997, the number of cases has decreased from 571 to 554 cases in 1998 and 398 cases in 1999. This level was last seen 25 years ago. Also in Hungary, the ecological impact of oral vaccination has been discussed, especially by the hunters. They see oral vaccination as human intervention into the nature and complain about an increase of red fox population as a result of oral vaccination. Balint (2000) explained that oral vaccination is only one of the factors responsible for the increase in red fox populations. Others also came to the same conclusion after comparing the situation in two parts of Hungary. They confirmed that the population of red foxes has doubled even in the part of Hungary east of the river Danube, where oral vaccination has never been performed (Miklos et al., 2000).

In the years 1998 and 1999 the SAD B19 and the SAG1 vaccines were used practically equally. In the year 2000 three vaccines were used with 769 000 baits of SAD-P5/88, 498 400 of baits SAD B19 and 40 400 baits of SAG1 (Bone, 2000).

In 2000, 514 cases were confirmed, 310 in the following year and 69 rabies cases were registered during the first half of 2002. It is important to mention that the rabies situation in the vaccinated areas (western-part of the country) has improved tremendously, actually only few cases have been reported from these areas.

3.13. Slovak Republic

The Slovak Republic started a field trial with oral vaccination in the border regions with Austria and the Czech Republic on the area of 2 042 km² in 1992 using its own conventional live attenuated vaccine based on the SAD-Vnukovo-32/107 virus strain (Stohr and Meslin, 1996; Ondrejka et al., 2002). In the following year a similar operation was completed with three to seven districts being vaccinated. From 1994 to 1996, for the first time the whole country was treated under a three year approved programme of oral vaccination by vaccine. In 1994 the vaccine Lysvulpen, based on SAD Bern vaccine strain, was also used during the spring campaign. The Bavarian model was used for the distribution of the baits and baits uptake were assessed on the third, eighth and fourteenth days post distribution. A high bait-uptake and sero-conversionrate were determined.

No case of post-vaccination rabies was detected using monoclonal antibodies (Durove et al., 1996; Ondrejka et al., 1997). In the following years, vaccination was only performed in 19 districts over an area of 14 517 square kilometres in 1997. As a result of this limitation, a further spread of the rabies was seen in 1997, 1998 and 1999 when 259, 414 and 503 rabies cases were reported, respectively.

During the last three years the Slovak Republic has succeeded in treating a larger area and changed the strategy. The Bavarian model was replaced by aerial baiting and rabies has started to disappear. In 2000 only 351 cases were found, in 2001 only 87 positive cases were registered and in the first half of 2002 just 49 cases were registered. As in the most of the neighbouring countries rabies is also found among the bat populations (Ondrejko et al., 2002).

The situation in the Slovak Republic is also very complicated as the country has a relatively favourable situation only on the border with the Czech Republic and on the western part of the border with Hungary. However, there is no or very limited information on the rabies situation in the Ukraine, but we can assume that rabies occurs in the border region with the Slovak Republic.

3.14. Poland

After the Second World War the majority of rabies cases reported involved dogs, which is why compulsory vaccination was ordered by law. An increased spread among the wild animals started in 1957. During the 1990s there were 20 790 rabies cases confirmed in Poland. Of this number 18.6% were registered among domestic animals and the remaining 81.4% among wild animals (67.7% from the total number were red foxes).

Poland started a field trial with oral vaccination in 1993 by distributing 1 400 000 SAD B19 vaccine baits in the border regions with Germany. The number of baits increased progressively during subsequent years. For example, 5 340 000 vaccine baits (18 baits/km²) were distributed by plane in 1998. In spite of the extended oral vaccination programme the total number of registered rabies cases remained practically the same during the nineties and was even higher than it had been during eighties. But the most of these reported cases came from untreated areas (Vos et al., 2000; Zmudzinski and Smreczak, 2000). An improvement in the situation came only in the years 1997, 1998 and 1999, when 1 495, 1 332

and 1 147 rabies cases were found, respectively, and the rabies-front was pushed back to the east. By the end of 1999, rabies was brought under control in the border regions with Germany and the Czech Republic. Unfortunately there was a deterioration in the situation in the following years and by the year 2000 there were 2 211 cases registered, by 2001 already 2 958 rabies cases and during the first half of the year 2002 in total 1 012 rabies cases. An even more alarming situation than the increase in the number of positive rabies cases is the movement of the rabies wave front in the western direction towards the German border and in the southern direction towards the Czech border.

3.15. Czech Republic

Rabies, mainly in dogs and cats, was already reported from the territory of the Czech Republic at the end of the nineteenth century (Matouch et al., 2002). This occurrence was confirmed in dogs and cats originating from bordering highland regions up to 700 meters above the sea level. No rabies cases were registered among wild animals before World War II, but the situation among the human population was alarming. Between the years 1919 and 1937 a total of 132 people died due to rabies and almost 25 000 people were given post-exposure treatment. Voluntary vaccination of dogs against rabies as from 1927 led to an improvement of the situation. True progress has been observed since the beginning of compulsory, free of charge, vaccination of dogs in 1953.

The spread of rabies among the wild animals started after World War II as also happened in neighbouring countries. The first rabid fox found originated from the district of Broumov near to the Polish border in March 1947. In the following year, a total of 106 fox rabies cases (74% of the 146 positive findings) were reported (Matouch et al., 2002). The number of rabies cases increased progressively up until the half of the eighties. Rabies among domestic animals increased simultaneously with rabies among wild animals. The most cases were confirmed in 1984, when 2 232 cases were found. Of this number, 2 052 cases were red foxes and 86 were domestic carnivores. Significant improvement was seen after the start of oral vaccination in 1989, when field trials commenced in three districts along the German border (Klatovy, Domazlice, Tachov) (Matouch and Jaros, 1999).

From 1989 to 2002 a total of 127 946 animals were tested for rabies. During the last fourteen years 6 180 rabies cases were confirmed. The highest number of cases was found in 1989 when 1 501 cases were reported and the lowest number in 2002, when only 3 rabid red foxes were found. All these foxes were shot in the district Trutnov bordering Poland (Matouch and Vitasek, 2002).

5 908 (95.6%) of all rabies cases involved wildlife and only 4.4% (272 cases) of all cases were found in domestic animals. The most commonly infected animal species was the red fox with 90.3% of positive cases.

Despite the positive trend in the disease situation among animals, especially in the second half of the nineties, the situation in the human population concerning post-exposure treatment still remains at the same level (Benes et al., 2000).

Year	Number of post-exposure treatments
1995	1 146
1996	1 078
1997	1 366
1998	1 230
1999	1 362
2000	1 276

Since the beginning of the nineties the vaccinated area has been progressively enlarged until the autumn of 1993, when the whole territory of the Czech Republic was covered, with the exception of six already rabies-free districts along the border with Germany. This treatment included 68 districts with an area of 56 250 square kilometres (the whole territory of the Czech Republic is 78 864 square kilometres) and involved 926 000 vaccine baits being distributed by hand.

Conventional SAD B19 vaccine was used from 1989 to 1992 at rates of 15 baits per square kilometre. Some 1 435 000 baits of this vaccine were laid out in total. In 1992 the Czech company, Bioveta Ivanovice na Hane, started production of the conventional vaccine Lysvulpen which is based on the SAD Bern attenuated virus strain. This vaccine has been used since 1993. During the following period the number of the baits distributed per square kilometre increased and the Bavarian model had been replaced by aerial distribution. Aerial distribution started in several districts (4–6) in 1995. By 1999 one third of territory was covered by plane, by 2002 already one half and by 2003 baits were exclusively distributed by airplane. From 1989 until 2002 a total of 19 179 000 vaccine baits were distributed.

3.16. Other countries

According to the information presented at the international seminar organized by TAIEX in Brussels in December 2000 even more countries have commenced field trials with oral vaccination. These included Croatia and Latvia in 1991, Moldavia in 1992, Lithuania in 1995, Ukraine and Russia in 1998 and Serbia in 1999. At the end of 2002 the European Union approved an oral vaccination program against rabies in Estonia under the framework of the PHARE programme.

4. Conclusion

Oral vaccination of wild animals against rabies has proved to be the most effective method to eliminate rabies. In spite of the difficulty organising campaigns and ensuring (i) the necessary laboratory diagnostic facilities, (ii) the need for considerable know-how, practical experience, enthusiasm of all interested people (hunters, veterinarians, governmental officials) and (iii) at last but not least, the financial resources, the whole European project for elimination of this most dangerous zoonosis has brought unambiguously positive results. However, we need to consider that we are still only half. There is still a possibility that the tremendous progress achieved could be interrupted if for any reason a breakdown in project occurred. This would be a worst case scenario which would bring a multiple increase in expenses.

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