A TECHNOLOGY REVIEW:
NEWCASTLE DISEASE

with special emphasis on its effect on village chickens
The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.
FOREWORD

FAO Technology Review: Newcastle Disease

Keeping poultry makes a substantial contribution to household food security throughout the developing world. They help diversify incomes as well as providing quality food, energy, fertilizer and a renewable asset in over 80 percent of rural households. Poultry keeping also helps to sustain the village economy and contributes to the prevention of urban migration. The benefits derived from keeping poultry go directly to the rural poor and, in most cases, to the women in their capacity as active caretakers.

Small-scale poultry production however suffers from number of constraints including poor animal health, especially Newcastle Disease, as well as insufficient nutrition and poor housing. Together, these factors result in high losses and corresponding low levels of productivity. Overcoming these constraints could substantially increase productivity would result in real and direct benefits of the farmers themselves.

One of the principal constraints to increasing small-scale poultry production is Newcastle Disease (ND). This acute viral disease can typically kill up to 80 percent of unprotected poultry in rural areas and is found throughout the developing world. The disease is spread by contact between birds and is exacerbated by birds being mixed together in rural markets, although many aspects of the epidemiology of the disease in the village situation is not yet fully understood.

This technical review is written by three of the foremost experts in the field of Newcastle Disease control in the developing world. It presents the latest understanding of Newcastle Disease, its characteristics, epidemiology, symptoms and control. It will be of practical value to state and private veterinarians and to all those involved with rural poultry production and wishing to control this disease.

FAO acknowledges and commends the effort that the authors have put into making this such a comprehensive and valuable reference for those involved in the control of Newcastle Disease in the developing world. The views expressed are, however, those of the authors and do not necessarily reflect those of FAO.
CONTENTS

Chapter 1  
NEWCASTLE DISEASE VIROLOGY AND EPIDEMIOLOGY  

Chapter 2  
DIAGNOSIS OF NEWCASTLE DISEASE  

Chapter 3  
VACCINATION  

Chapter 4  
NEWCASTLE DISEASE IN VILLAGE CHICKENS  

BIBLIOGRAPHY
CHAPTER 1

NEWCASTLE DISEASE VIROLOGY AND EPIDEMIOLOGY

INTRODUCTION

History

The first outbreaks to be recognized and termed Newcastle disease (ND) occurred in poultry in 1926, in Java, Indonesia (Kraneveld, 1926), and in Newcastle-upon-Tyne, England (Doyle, 1927). However, there are earlier reports of similar disease outbreaks in Central Europe before this date. (Halasz, 1912). In particular, Macpherson (1956) attributes the death of all the chickens in the Western Isles of Scotland in 1896 as being due to Newcastle disease. It is possible, therefore, that ND did occur in poultry before 1926, but its recognition as a specifically defined disease of viral aetiology dates from the outbreaks during this year in Newcastle-upon-Tyne.

The name “Newcastle disease”, (after the geographical location of the first outbreaks in Great Britain), was coined by Doyle as a temporary measure because he wished to avoid a descriptive name that might be confused with other diseases (Doyle, 1935). The name has, however, continued to be used although when referring to the ND virus (NDV), the synonym ‘avian paramyxovirus type 1’ (APMV-1) is now often employed.

Later it became clear that other less severe infections were caused by viruses almost identical to the original virus. In the United States, a relatively mild respiratory disease, often with nervous symptoms, was first reported in the 1930s and subsequently termed pneumoencephalitis (Beach, 1942). It was shown to be due to a virus indistinguishable from NDV in serological tests (Beach, 1944). Since then, numerous NDV isolations of viruses that produce an extremely mild disease or no evidence of disease in chickens, have been made around the world and it is now accepted that pools of such viruses are perpetuated in waterfowl and other wild birds.

The pattern of outbreaks which are due to virulent NDV throughout the world suggest that several panzootics have occurred in poultry since 1926. The first appeared to have spread very slowly across the globe, apparently from the Far East. It probably took over 20 years to become a true panzootic and probably never reached poultry in the USA. The beginning of the second ND panzootic was first recognised at the end of the 1960s and within four years had reached all corners of the earth. (Hanson, 1972). The reasons for the different spreading rates of the two panzootics appear to be the development of the world poultry industry and the commercialisation of poultry food production both of which lead to greater contact between separate farms because food delivery vehicles move from one to another. Another factor is the revolution that has occurred in world transport. Air transportation especially has led to a huge and growing trade in captive caged birds. There is no doubt that imported caged birds were responsible for introducing the panzooitc virus into poultry in California (Hanson, 1972; Francis, 1973) and Walker et al., (1973) were able to link most of the outbreaks occurring in the USA during 1970-1972 to importations of exotic birds.

Antigenic and genetic evidence (Alexander et al., 1997; Lomniczi et al., 1998; Herczeg et al., 2001) has indicated that there was probably a worldwide spread of a third virulent virus during the late 1970s,
Newcastle Disease Virology and Epidemiology

the start and spread of which is unclear, presumably due to the masking of disease by the almost universal use of vaccines since the mid-1970s.

Another ND panzootic occurred in the 1980s, but in racing and show pigeons (*Columba livia*) rather than in poultry, although spread of the responsible virus did occur to poultry. The world population of racing or show pigeons is enormous and at the end of the 1970s these birds were still largely unvaccinated and fully susceptible to infection with NDV. Infections in pigeons with this variant NDV strain probably began in the Middle East in the late 1970s (Kaleta *et al.*, 1985), and by 1984-5 had become a true panzootic. In many countries where outbreaks occurred there was also spread to feral pigeons and doves. The way pigeons are kept and raced has meant that this panzootic has proven difficult to control and in several countries it probably remains endemic in racing and possibly also in feral pigeons.

The effect panzootics of ND have had on the poultry populations of different countries has not always been well recorded. Alexander (2001) documented the history of ND in Great Britain in detail and considered it a good example of the effect ND may have on the poultry industry in a developed Western country where eradication policies have been employed.

**Aetiology**

The three virus families *Rhabdoviridae*, *Filoviridae* and *Paramyxoviridae* form the order Mononegavirales; i.e. viruses with negative sense, single stranded and non-segmented RNA genomes. ND is caused by avian paramyxovirus serotype 1 [APMV-1] viruses, which, with viruses of the other eight APMV serotypes [APMV-2 to APMV-9], have been placed in the genus *Avulavirus*, sub-family *Paramyxovirinae*, family *Paramyxoviridae*, in the current taxonomy (Lamb *et al.*, 2000; Mayo 2002).

Antigenic variation of ND viruses [APMV-1] detectable by conventional haemagglutination inhibition [HI] tests has been reported, although only rarely (Arias-Ibarrondo *et al.*, 1978; Hannoun, 1977, Alexander *et al.*, 1984). One of the most noted variations of this kind has been the virus responsible for the panzootic in racing pigeons. This ND virus, referred to as ‘pigeon APMV-1 [PPMV-1]’, was demonstrably different from standard strains in haemagglutination inhibition tests, but not sufficiently different antigenically that conventional ND vaccines were not protective (Alexander and Parsons, 1986). In recent years antigenic variations detected by monoclonal antibodies and genetic variations detected by nucleotide sequencing of the virus genome have proved invaluable in understanding the epidemiology of ND (Alexander *et al.*, 1997; 1999; Herczeg *et al.*, 1999; 2001).

**CURRENT WORLD SITUATION**

In many respects, it is extremely difficult to assess the prevalence of ND in the world at any given time. In some countries or areas disease is not reported at all or only if it occurs in commercial poultry, while its presence in village chickens or backyard flocks is ignored. Even in poultry reared commercially, estimations of the geographical distribution of NDV are confused by the use of live vaccines in all but a few countries throughout the world. In some countries the distribution is especially complicated by using, as live vaccines, viruses that are considered sufficiently virulent in other countries to warrant the current definition of ND.
When countries or areas are declared free of ND, further complications are caused by the definition of the type of ND virus described as harmless although this is being addressed by the new definitions and codes to be adopted by the Office International des Epizooties. Even in countries that have long been recognised as free of ND, monitoring surveys often reveal symptomless infections with avirulent viruses which have presumably spread from waterfowl or other wild birds. However, there can be little doubt that the highly pathogenic form of ND is a serious problem, either as an enzootic disease or as a cause of regular, frequent epizootics throughout Africa, Asia, Central America and parts of South America (Copland, 1987; Spradbrow, 1988; Rweyemamu et al., 1991; Alders & Spradbrow, 2001a). In other areas such as Europe, the situation appears to be one of sporadic epizootics occurring despite vaccination programmes (Kaleta & Heffels-Redmann, 1992).

In Western Europe there was a marked increase in reported outbreaks during the early 1990s, peaking with 239 outbreaks in European Union [EU] countries in 1994. The distribution overtime suggests a single epidemic from the early to mid-1990s, but, in fact, antigenic and phylogenetic evidence indicates that several strains of virus were responsible for these outbreaks. During 1991-1995 the majority of outbreaks in the EU occurred in the Benelux countries and Germany, predominantly in backyard poultry and most of the outbreaks since 1995 have been in these types of birds. One of the most extensive epidemics in Western Europe occurred in Italy in 2000 when 254 outbreaks of ND were confirmed, again mainly in backyard poultry.

One notable aspect of the outbreaks during the 1990s concerned those that occurred in countries that had been free of the disease for many years. Between 1995 and 1999, there were 18 outbreaks in Denmark, 2 in Finland and 27 in Northern Ireland. There was also 1 in Sweden, 1 in Norway and 1 in the Republic of Ireland. These were all areas of Western Europe that had been declared free of ND and which were monitored regularly by serological testing and had no evidence of ND virus infections other than occasional incursions of avirulent viruses typical of spread from wild birds.

From the time of the 1932 outbreak (Albiston & Gorrie, 1942) to 1998, Australia had been free of virulent ND virus. Since 1966, however, it has been recognised that viruses similar to those placed in the "asymptomatic enteric" pathotype group (Westbury, 1981; Spradbrow, 1987) are present in wild birds in Australia and on occasions have spread to commercial poultry flocks. Two outbreaks of virulent ND occurred in Australia in 1998 and further outbreaks were reported in 1999 and 2000 (Kirkland, 2000; Westbury, 2001).

**DISEASE AND PATHOGENICITY**

**Newcastle disease**

The clinical signs seen in birds infected with NDV vary widely and are dependent on factors such as: the virus, the host species, age of host, infection with other organisms, environmental stress and immune status. In some circumstances infection with the extremely virulent viruses may result in sudden, high mortality with comparatively few clinical signs. Although none of the variable clinical signs can be regarded as pathognomonic, certain signs do appear to be associated with particular viruses. This has
Newcastle Disease Virology and Epidemiology

resulted in the grouping of viruses into five "pathotypes" on the basis of the predominant signs in affected chickens (Beard and Hanson, 1984):

- **Viscerotropic velogenic**: viruses responsible for disease characterized by acute lethal infections, usually with haemorrhagic lesions in the intestines of dead birds.
- **Neurotropic velogenic**: viruses causing disease characterized by high mortality which follows respiratory and neurological disease, but where gut lesions are usually absent.
- **Mesogenic**: viruses causing clinical signs consisting of respiratory and neurological signs, with low mortality.
- **Lentogenic**: viruses causing mild infections of the respiratory tract.
- **Asymptomatic enteric**: viruses causing avirulent infections in which replication appears to be primarily in the gut.

These groupings are by no means clear-cut, and even in experimental infections of specific pathogen-free [SPF] chickens, considerable overlapping occurs (Alexander & Allan, 1974). In addition, in the field exacerbating factors may result in the clinical signs induced by the milder strains mimicking those of the more pathogenic viruses.

In general terms, ND may consist of signs of depression, diarrhoea, prostration, oedema of the head and wattles, nervous signs, such as paralysis and torticollis, and respiratory signs (McFerran & McCracken, 1988). Fall in egg production, perhaps leading to complete cessation of egg laying, may precede more overt signs of disease and deaths in egg-laying birds. Virulent ND strains may still replicate in vaccinated birds, but the clinical signs will be greatly diminished in relationship to the antibody level achieved (Allan et al., 1978).

As with clinical signs, no gross or microscopic lesions can be considered pathognomonic for any form of ND (McFerran & McCracken, 1988). Carcasses of birds dying as a result of virulent ND usually have a fevered, dehydrated appearance. Gross lesions vary with the infecting virus. Virulent panzootic ND viruses typically cause haemorrhagic lesions of the intestinal tract. These are most easily seen if the intestine is opened and may vary considerably in size. Some authors have reported lesions most typically in the proventriculus, while others consider them to be most prominent in the duodenum, jejunum and ileum. Even in birds showing neurological signs prior to death, there is usually little evidence of gross lesions in the central nervous system. Lesions are usually present in the respiratory tract when clinical signs indicate involvement. These generally appear as haemorrhagic lesions and congestion; airsacculitis may be evident. Egg peritonitis is often seen in laying hens infected with virulent NDV.

Microscopic lesions are not considered to have any diagnostic significance. In most tissues and organs where changes occur, they consist of hyperaemia, necrosis, cellular infiltration and oedema. Changes in the central nervous system are those of nonpurulent encephalomyelitis.

**Molecular basis of pathogenicity of ND**

During replication, NDV particles are produced with a precursor glycoprotein, F0, which has to be cleaved to F1 and F2 for the virus particles to be infectious (Rott and Klenk 1988). This post translation
cleavage is mediated by host cell proteases (Nagai et al. 1976a). Trypsin is capable of cleaving F0 for all NDV strains and *in vitro* treatment of noninfectious virus will induce infectivity (Nagai et al., 1976b).

The cleavability of the F0 molecule was shown to be related directly to the virulence of viruses *in vivo* (Rott, 1979; Rott, 1985). It would appear that the F0 molecules of viruses virulent for chickens can be cleaved by a host protease or proteases found in a wide range of cells and tissues. This allows these viruses to spread throughout the host, damaging vital organs. In contrast F0 molecules in viruses of low virulence appear to be restricted in their sensitivity to host proteases resulting in restriction of these viruses to growth only in certain host cell types.

Since the initial studies comparing the deduced amino acid sequences at the cleavage site of the F0 precursor of a number of virulent and avirulent ND strains (Collins et al, 1993), a large number of studies has confirmed the presence of multiple basic amino acids at that site in virulent viruses. Usually the sequence has been 113RQK/RR ↓ F117 in virulent viruses and most have had a basic amino acid at position 112 as well. In contrast, viruses of low virulence usually have the sequence 113K/RQG/ER ↓ L117.

The major influence on the pathogenicity of NDV is therefore the amino acid motif at the F0 cleavage site, the presence of basic amino acids at positions 113, 115 and 116 and phenylalanine at 117 in virulent strains means that cleavage can be effected by protease or proteases present in a wide range of host tissues and organs. For viruses of low virulence, cleavage can occur only with proteases recognizing a single arginine, i.e. trypsin-like enzymes. Such viruses are therefore restricted in the range of sites where they are able to replicate to areas with trypsin-like enzymes, such as the respiratory and intestinal tracts, whereas virulent viruses can replicate in a range of tissues and organs resulting in a fatal systemic infection (Rott, 1979).

**Definition of Newcastle Disease**

Although it is likely that the vast majority of birds are susceptible to infection with ND viruses of both high and low virulence for chickens, the disease seen with any given virus may vary enormously from one species to another. Many other factors also affect the course of disease (see above). ND viruses show a considerable range of virulence for susceptible hosts such as chickens. Generally, variation consists of clusters around the two extremes in tests used to assess virulence, but, for a variety of reasons, some viruses may show intermediate virulence [mesogenic]. Equally, the very virulent viruses may infect and replicate in vaccinated birds without causing clinical disease (Parede & Young, 1990; Guittet et al., 1993; Capua et al., 1993). This enormous variation in virulence and clinical signs means that none can be regarded as pathognomonic and that it is necessary to define carefully what constitutes ND for the purposes of trade, control measures and policies.

The current OIE definition (OIE, 2000a) is:

*Newcastle disease is defined as an infection of birds caused by a virus of avian paramyxovirus serotype 1 (APMV-1) that meets one of the following criteria for virulence:

a) The virus has an intracerebral pathogenicity index (ICPI) in day-old chicks (Gallus gallus) of 0.7 or greater.*
b) Multiple basic amino acids have been demonstrated in the virus (either directly or by deduction) at the C-terminus of the F2 protein and phenylalanine at residue 117, which is the N-terminus of the F1 protein. The term ‘multiple basic amino acids’ refers to at least three arginine or lysine residues between residues 113 to 116. Failure to demonstrate the characteristic pattern of amino acid residues as described above would require characterisation of the isolated virus by an ICPI test.

In this definition, amino acid residues are numbered from the N-terminus of the amino acid sequence deduced from the nucleotide sequence of the F0 gene, 113–116 corresponds to residues –4 to –1 from the cleavage site.”

**Origins of Virulent ND Viruses**

The emergence of ND as a highly pathogenic disease in poultry since 1926, (initially predominantly in South East Asia), suggests that some sudden major change has occurred either in the virus or in its hosts. Hanson (1972) considers that the various hypotheses which have been put forward can be grouped into three categories:

- The virulent virus has always existed in poultry in South East Asia, but it was not until the beginning of the commercialisation of the industry in that part of the world that the disease, with its enormous economic impact, was noticed as a significant problem.
- The virus is enzootic in different species, possibly inhabiting tropical rain forests, and spread to domestic poultry because of the incursion of man into that habitat.
- There is a major mutation of a precursor virus of low virulence.

The first explanation remains a possibility. Some consider it unlikely that the disease would have gone unreported if it was enzootic in village chickens, but even today village chickens throughout Africa, Asia and the Americas often show high levels of mortality, either regularly or as large die-offs every few years which go largely undiagnosed. Similarly, there have been occasional descriptions of disease outbreaks prior to 1926 that are very similar to ND.

The second explanation has, until recent years, been generally accepted as the most likely. The reason is mainly the discovery that during the 1970-73 panzootic, movement of captive caged birds, particularly psittacines which may be resistant excreters of NDV, was, to some extent, responsible for the introduction and spread in some countries, particularly California (Francis, 1973, Walker *et al.*, 1973). However, as discussed above, viruses isolated from feral birds are usually of low virulence and it has been suggested that caged birds are most probably infected after they have been trapped. Maintenance of the virus in any feral bird species seems unlikely because of the effect that infection is likely to have on the bird’s survival.

The third explanation has usually been dismissed out of hand as probably representing a mutation too big to be within the bounds of probability, especially without any apparent evolutionary advantage that would result from such selection. However, viruses isolated from ND outbreaks in Ireland and Australia during the 1990s have suggested that this may be how some virulent ND viruses emerge.
In 1990 in Ireland two outbreaks of ND occurred in egg laying birds. The viruses isolated were highly virulent and apparently identical (Alexander et al., 1992). They were very closely related antigenically and genetically (Collins et al., 1998) to viruses of low virulence normally isolated from feral waterfowl but known to have infected chickens in Ireland in 1987 (McNulty et al., 1988). The group formed by these viruses was both antigenically and genetically distant from all other ND viruses. Collins et al (1993) has shown that the virulent virus had four nucleotide differences at the site coding for the F0 cleavage site compared to the related viruses of low virulence (Table 1.1.), which would explain the higher virulence for chickens. However, the distinctiveness of this group of viruses from other ND viruses support the theory that the virulent viruses arose by mutation from those of low virulence.

Phylogenetic studies have shown all the virulent viruses responsible for the outbreaks in Australia from 1998 to 2000 are extremely closely related to each other and to the endemic virus of low virulence. This suggests their emergence by mutation which, in this instance, required only two point mutations (Table 1.2., Westbury, 2001).

If mutations to virulence do occur, it is not clear whether these take place in feral birds and are then passed to poultry or whether they occur once the virus has been introduced to poultry. The lack of virulent isolations from feral birds, however, suggests that the latter is the more likely.

If virulent ND strains can emerge from those of low virulence by mutation, this may have important repercussions on the current methods of control of ND – mainly because of the enormous amounts of live vaccines used throughout the world.

Table 1.1. Nucleotide/amino acid sequences at F0 cleavage site of virus of high virulence [34/90] isolated from poultry in Ireland compared to antigenically and genetically closely related virus of low virulence isolated from ducks

<table>
<thead>
<tr>
<th>Virus</th>
<th>Virulence</th>
<th>Nucleotide/amino acid sequence at F0 cleavage site</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC110</td>
<td>low</td>
<td>GAA CGG CAG GAG CGT CTG [112\textit{ERQER}^{*}L]^{117}</td>
</tr>
<tr>
<td>34/90</td>
<td>high</td>
<td>AAA CGG CAG AAA CGT TTT [112\textit{KQKR}^{*}F]^{117}</td>
</tr>
</tbody>
</table>

Table 1.2. Nucleotide/amino acid sequence at F0 cleavage site of virus of high and low virulence isolated in Australia in 1998

<table>
<thead>
<tr>
<th>Virus</th>
<th>Virulence</th>
<th>Nucleotide/amino acid sequence at F0 cleavage site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1154/98</td>
<td>low</td>
<td>GGA AGG AGA CAG GGG CGT CTT [111\textit{RQGR}^{*}L^{117}]</td>
</tr>
<tr>
<td>1238/98</td>
<td>high</td>
<td>GGA AGG AGA CAG AGG CGT TTT [111\textit{RQRR}^{*}F]^{117}</td>
</tr>
<tr>
<td>1249/98</td>
<td>high</td>
<td>GGA AGG AGA CAG AGG CGT TTT [111\textit{RQRR}^{*}F]^{117}</td>
</tr>
</tbody>
</table>
Newcastle Disease Virology and Epidemiology

EPIDEMIOLOGY

Host Range

ND viruses have been reported to infect animals other than birds, ranging from reptiles to man (Lancaster 1966). Kaleta and Baldauf (1988) concluded that NDV infections have been established in at least 241 species of birds representing 27 of the 50 Orders of the class. It seems probable that all birds are susceptible to infection but, as stressed by Kaleta and Baldauf, the disease seen with any given virus may vary enormously from one species to another.

Wild birds

NDV isolates have been obtained frequently from migratory feral waterfowl and other aquatic birds. Most of these isolates have been of low virulence for chickens and similar to viruses of the "asymptomatic enteric" pathotype. The most significant outbreaks of virulent NDV in feral birds have been those reported in double-crested cormorants (Phalacrocorax auritus) in North America during the 1990s. Earlier reports of ND in cormorants and related species had been in the late 1940s in Scotland (Blaxland, 1951) and in Quebec in 1975 (Cleary, 1977). Recent outbreaks in cormorants in North America were first seen in 1990 in Alberta, Saskatchewan and Manitoba in Canada (Wobeser et al., 1993). In 1992 the disease re-appeared in cormorants in western Canada, around the Great Lakes and North mid-west USA, in the latter case spreading to domestic turkeys (Mixson & Pearson, 1992; Heckert, 1993). Antigenic and genetic analyses of the viruses suggested that all the 1990 and 1992 viruses were very closely related despite the geographical separation of the hosts. Disease in double-crested cormorants was observed again in Canada in 1995 and in California in 1997 and in both instances NDV was isolated from dead birds; as before, these viruses appear to be closely related (Kuiken, 1998).

Thirty-eight outbreaks of ND in commercial poultry were confirmed in 1997 in the United Kingdom (Alexander et al., 1998). There were also outbreaks caused by genetically similar viruses in Scandinavian countries in 1996 (Alexander et al., 1999). These, linked to the unusual patterns of movement of migratory birds at the end of 1996 and the beginning of 1997, suggest that migratory birds may have been responsible for the primary introduction of the causative virus into Great Britain (Alexander et al., 1998).

Caged "pet birds"

Virulent NDV isolates have often been obtained from captive caged birds (Senne et al., 1983). Kaleta and Baldauf (1988) thought it unlikely that infections of recently imported caged birds resulted from enzootic infections in feral birds in the countries of origin. They considered that the infections probably originated at holding stations before export, either as a result of enzootic NDV at those stations or of spread from nearby poultry such as backyard chicken flocks. Panigrahy et al., (1993) described outbreaks of severe ND in pet birds in six states in USA in 1991. Illegal importations were assumed to be responsible for the introductions of the virus.
**Domestic poultry**
Virulent NDV strains have been isolated from all types of commercially reared poultry, ranging from pigeons to ostriches.

**Racing and show pigeons**
In the late 1970s, an NDV strain, PPMV-1, showing some antigenic differences from classical strains, appeared in pigeons. It probably arose in the Middle East and subsequently produced a true panzootic, spreading in racing and show pigeons to all parts of the world (Alexander, 1997).

**Introduction and spread**

**Transmission between birds**
Apart from predatory birds or the practice of feeding poultry with untreated swill containing poultry meat, spread from bird to bird appears to occur as the result of either inhalation of excreted droplet particles or the ingestion of infective material such as faeces. Although it is clear from the administration of live vaccines by aerosol that infection may be established via the respiratory route, there is remarkably little experimental evidence that infected birds pass on the virus to susceptible birds in this way, even over short distances. The success of this route of transmission depends on many environmental factors, such as temperature, humidity, and stocking density. In contrast, it is easily demonstrated that virus infection can be passed from one bird to another via contaminated faeces. It seems most likely that the pigeon variant virus, the "asymptomatic enteric" viruses, and other viruses which fail to induce significant respiratory signs in infected birds, are transmitted primarily in this way (Alexander et al., 1984).

Several reviews have dealt with the way in which the ND virus may be introduced into a country or area and then subsequently spread from flock to flock (Lancaster, 1966; Lancaster and Alexander, 1975; Alexander 1988b, 1995). In summary, the main methods by which virus can be spread are:

**Movement of live birds**
Migratory feral birds may be responsible for the primary introduction of infection, but nearly all NDV isolates obtained from feral birds have been of low virulence. A more significant role of such birds may be the spread within an area once NDV infections have already occurred in poultry. Exceptions to the presence of the virus of low virulence in migratory birds have been discussed in the Host Range section above.

World trade in captive caged birds is enormous and in many countries virulent NDV has been isolated frequently from such birds held in quarantine. For example, 147 virulent NDV isolations were made from 2 274 lots of captive birds held in quarantine in the USA during 1974-1981 (Senne et al., 1983). Some infected psittacines have been shown to excrete virulent virus intermittently for extremely long periods, in some cases for more than one year (Erickson et al., 1977). This further emphasises the potential role these birds may have in the introduction of NDV to a country or area.

There is also considerable international trade in game birds, which are often imported for immediate release.
The potential for racing pigeons to carry and introduce ND into a country or area has been highlighted by the panzootic in such birds over the last ten years.

Trade in backyard flocks and other birds kept for recreational purposes (hobby birds) has been implicated in the introduction and spread of ND in the outbreaks in European Union countries during 1991-1994.

Modern methods of slaughter of commercial poultry, marketing of poultry meat and veterinary inspection, have reduced the movement of live commercial poultry (with the exception of day-old chicks) in many European and other developed countries. However, in many countries, the normal method of trade is by live poultry markets. Such markets, where birds of many different species may be placed in close contact with each other, represent ideal opportunities for viruses to be disseminated. The movement of village chickens from one village to another, whether directly or through live bird markets, is the main method of spread of ND [see below].

**Movement of people and equipment**
Secondary spread during most epizootics of ND in recent times has been the result of the movements of personnel or equipment. Human beings may be infected with NDVs, but their most likely role is the transfer of infective poultry faeces from one site to another via clothing, footwear, crates, feed sacks, egg trays or vehicles.

**Movement of poultry products**
In the past, poultry meat has been seen as the main vehicle for the introduction and spread of NDV. Modern methods of poultry carcass preparation as well as legislation on the feeding of untreated swill to poultry have greatly diminished the risk from poultry products, but the possibility of spread in this way still remains.

**Contaminated poultry food or water**
In the British Isles, outbreaks of ND in commercial poultry have been associated with food contaminated with infective faeces from feral pigeons infected with the ND virus (Alexander *et al*., 1985; O'Reilly *et al*., 1994). Similarly, water contaminated with infective faeces may introduce NDV to a flock.

**Airborne spread**
In recent years, the significance of airborne transfer of viruses has been the subject of some debate. During the 1960s and 1970s, this was considered a major method of spread and Smith (1964) considered it the most logical explanation of spread in outbreaks occurring in 1960 and 1962 in Great Britain. In the same country, Dawson (1973) considered windborne spread to be of major significance during the 1970-1972 outbreaks that were noted for the severe respiratory signs and unusual patterns of spread. But in the 1971-1973 epizootic in California, with ostensibly the same virus, respiratory signs were not especially prominent and Utterback and Schwartz (1973) considered airborne spread to be of little significance.
There have been few attempts to assess the survival of airborne virus, but Hugh-Jones et al., (1973) were able to detect virus 64 metres but not 165 metres downwind of infected premises. These authors stressed the importance of environmental conditions, particularly relative humidity, with regard to the likelihood of airborne spread.

It is possible that when climatic conditions have been right and poultry farms sufficiently concentrated, as in Northern Ireland in 1973 (McFerran, 1989), airborne spread may have played a significant role in epidemics of ND. But in recent years, airborne spread has not been an issue in reported outbreaks and there has nearly always been an alternative and more likely cause, particularly the movement of poultry and humans.

**VACCINES**

Good manufacturing practices should ensure that vaccines are highly unlikely to be carriers of virulent ND virus. However, in the past, birds have become infected by vaccines for other diseases being contaminated with ND and also as a result of failure to properly inactivate vaccines prepared from virulent ND virus. In 1996-1997, a series of ND isolates of low virulence were obtained from poultry flocks in Denmark, a country which pursues a non-vaccinating policy for ND. It was demonstrated that these viruses were the result of contamination of avian virus vaccines with vaccinal ND viruses (Jorgensen et al., 2000). This episode further emphasises the potential of spread of ND in this way.

**Non-avian hosts**

This is likely to be by mechanical transfer of infective faeces, for example, by insects, rodents or scavenging animals. In hot countries, reptiles may enter poultry houses and should not be ignored as potential spreaders of NDV, as their susceptibility to infection has been reported.

**BIOSECURITY AND HYGIENE IN THE CONTROL OF ND**

In countries or areas that are free of virulent NDV, the primary aim should be to prevent the introduction of the virus. Because migratory and other feral birds frequently carry NDV strains of low virulence, which spread from time to time to domestic poultry, it is usual to exclude such viruses from control policies. Vaccinal viruses are somewhat different, as some are sufficiently virulent to cause disease in fully susceptible birds.

In some countries there is legislation designed to reduce the likelihood of outbreaks from specific sources. For example, on the island of Ireland there has been a legal requirement to heat treat poultry feed to reduce the possibility of introduction of NDV by this route.

On commercial farms, control measures should attempt to prevent viruses from infecting the flock. It is of paramount importance that good hygiene and biosecurity measures aimed at preventing the introduction of viruses by the routes described above are practised at all times on poultry farms.

Biosecurity aimed at preventing disease should begin at the planning stage of commercial poultry farms. Farms and flocks should be well separated, hatcheries should be isolated from poultry farms, different species should be reared on different sites, and there should be an adequate fresh water supply,
preferably one that does not draw on surface water. Often in developed countries such practices are
difficult to impose as the poultry industry may already be established in areas with high concentrations of
poultry flocks and with little opportunity to change due to limitations of available land. But in countries
where the commercialisation of poultry farming is at a developmental stage, these points should be
adopted.

On the farms the following points should be observed:

- Houses, food stores and water tanks should be bird-proofed.
- Movements on and off the farm should be kept to a minimum.
- All equipment, especially vehicles, should be disinfected before access to the site is permitted.
- Movements between different farms for egg collection, carcass collection, food delivery and the like
  should be confined to a specified collection and delivery point away from the poultry flocks.

Unfortunately, as poultry farming has become industrialised and its profits marginalised, the move has
been away from such precautions which are often considered an expensive luxury.

Visits by personnel such as bleeding or vaccination teams, inseminators and veterinarians are the most
likely method of introduction of ND and if such visits are unavoidable, regimens of clothing change,
equipment disinfection and other basic hygiene controls must be enforced.

Possibly the greatest aid to implementing biosecurity and hygiene measures that will assist in the
prevention or control of ND is the education of farmers and those working with poultry with respect to
the spread of virus and measures to avoid it. The best tool for the control of ND at any level, international,
national or local farm, may well be an efficient, well-manned poultry extension service.
CHAPTER 2

DIAGNOSIS OF NEWCASTLE DISEASE

The methods used in the diagnosis of ND are detailed in the OIE Manual of Standards (OIE 2000a) and prescribed for European Union countries in Directive 92/66/EEC (CEC, 1992). Detailed descriptions of the tests which are outlined below can be obtained from these publications.

CLINICAL SIGNS AND LESIONS

For a definitive diagnosis of ND, both virus isolation and laboratory characterisation are necessary. Nevertheless, if the disease is known to be present in a given area, signs and lesions may be considered highly suggestive, especially for village chickens. Typical clinical signs are: a state of prostration and depression in the birds, with ruffled feathers; greenish white diarrhoea; and, in survivors, the head turned to one side, a condition known as torticollis is very often seen, as are paralysis of the legs, wings or other neurological signs. Other typical characteristics of the disease include: rapid spread; death within 2-3 days; a mortality rate of over 50 percent in naïve populations; and an incubation period of 3-6 days or, on rare occasions, 2-15 days (Beard and Hanson, 1984).

On necropsy, typical lesions are mucus in the trachea, and usually haemorrhages in the intestine, particularly in the proventriculus. It should be borne in mind that all the preceding signs and lesions can be caused by other diseases.

SEROLOGICAL DIAGNOSIS

In the absence of vaccination, the presence of specific antibodies against the ND virus indicates that the bird has been infected by the virus at some time, but not necessarily that it was suffering from the disease at the time of sampling. In practice, a high antibody titre is indicative of a recent infection. Two methods are used to measure antibody titres: the haemagglutination inhibition (HI) test, and the enzyme-linked immunosorbent assay (ELISA). For both, it is necessary to collect blood samples from the chickens. Catching village chickens for this purpose can present a problem. There are two approaches: where overnight housing is used, they can be retained in the morning; or children can be persuaded to catch them. Blood samples are taken from the wing veins – a detailed description of the method is given in Alders and Spradbrow (2001a). Cocks are usually harder to sample than hens. Blood can be drawn directly into a syringe, or collected into a tube after piercing the vein with a needle. In both cases, the sample is subsequently placed nearly horizontally to allow clotting and to permit separation of the serum sample, which should be straw coloured. The serum sample should be kept cool until it can be frozen in the laboratory.

The haemagglutination inhibition test

The HI test is based on the principle that the haemagglutinin on the viral envelope can bring about the agglutination of chicken red blood cells and that this can be inhibited by specific antibodies. V-bottomed microtitration plates are used. The serum samples are diluted in serial twofold dilutions in phosphate
buffered saline and then a fixed quantity of viral antigen is added to each well. Usually 4 Haemagglutination Units are used, according to the method of Allan and Gough (1974). Following incubation, a suspension of red blood cells is added to each well and the plate is incubated again. In the absence of any antibody against the virus, haemagglutination occurs, appearing as a diffuse red colour at the bottom of the well. In the wells where the antibody against the virus is of a sufficient level, haemagglutination is inhibited and the red blood cells sediment and appear as a small pellet at the bottom of the well. The presence or absence of agglutination is accurately assessed by tilting the plates. Only those wells in which the RBCs stream at the same rate as the control wells (containing RBCs and PBS only) should be considered to show inhibition. The HI titre is the reciprocal of the highest dilution of serum which completely inhibits haemagglutination and is usually and most conveniently expressed as the logarithm to the base 2. Although the test is difficult to standardise between laboratories, the HI titre gives an indication of the immune status of the bird. A titre of log$_2$3 is indicative of protection and a titre of log$_2$6 or more suggests a recent infection by the virus. If no vaccination has taken place, diagnosis of the infection can be made on this basis, although it cannot be determined exactly when it took place. Sequential samples taken at different times can indicate whether the titre is rising – indicative of a recent infection – or declining.

When the HI titre is used as a measure of immunity (for example, when testing flock immunity following vaccination), it is recommended that an avirulent strain such as V4 or Ulster 2C be used as the viral antigen. The La Sota antigen has been found to be unsuitable for this purpose when vaccination is done by the same strain as it results in an overestimation of protective serum antibody titres (Maas, et al. 1998).

The ELISA works on the principle of recognition of anti-NDV antibodies, attached to a plate coated with viral antigen, by antibodies produced in another species against chicken antibodies. This anti-chicken antibody is conjugated to an enzyme that catalyses a reaction, causing a change of colour which can then be read quantitatively on a photo spectrometer designed to read microtitration plates. The Animal Production & Health Section of the Joint FAO/IAEA Division has produced an ELISA kit for antibodies against NDV which is designed to be easily transportable and give uniform results under widely varying ambient temperatures. HI and ELISA titres show a good degree of correlation and ELISA titres can be interpreted in a similar way to HI titres (Bell, et al., 1991).

**VIRUS ISOLATION**

The definitive diagnosis of ND is done through isolation and identification of the virus (Alexander, 1998). Tracheal and cloacal swabs are good sources of virus for isolation from living birds without having to kill them. A cotton-covered stick is inserted into the trachea or cloaca, and then put into a vial containing phosphate buffered saline plus penicillin and streptomycin. It is important to ensure that cloacal swabs are coated with faeces. These samples must be kept cool during transport to the laboratory where they should be stored at 4°C if they are to be processed within 48 hours or frozen at least at -20°C until the isolation attempt. Although cloacal swabs or faeces should always be sampled, virus can also be isolated from homogenised organs from dead birds, chosen to reflect the clinical signs. Nine-day-old embryonated
fowls’ eggs are injected with 0.1mL of the suspension into the allantoic cavity and returned to incubation. The eggs are candled twice daily. As dead eggs occur, they are chilled, together with all eggs after 5-7 days incubation, are chilled at 4°C at which point the allantoic fluid is then harvested and tested for its ability to haemagglutinate chicken red blood cells. Diagnosis is based on the inhibition of haemagglutination by specific anti-NDV serum. This proves infection of the bird by the virus, but does not indicate whether the virus is a pathogenic or avirulent strain.

**PATHOGENICITY TESTS**

The full diagnosis of ND requires an assessment of the virulence of the virus. As indicated above (Section 1.4), the current definition allows either molecular characterisation by nucleotide sequencing and deduction of the F0 cleavage site amino acid sequence or an *in vivo* estimation of virulence.

The recommended *in vivo* test is the intracerebral pathogenicity index (ICPI) test in day-old chicks (OIE 2000a). This involves the inoculation of virus derived from fresh infective allantoic fluid into the brain of ten day-old chicks from specific pathogen-free parents. Each bird is examined at 24-hour intervals for eight days and graded zero if normal, one if sick and two if dead. The index is the mean score per bird per observation over the 8-day period. The most virulent viruses give ICPI values approaching the maximum score of 2.0, while lentogenic viruses give values of, or close to, 0.0.

Where day-old chicks are not available, the mean death time (MDT) in eggs (i.e. the mean time in hours for the minimum lethal dose to kill all the inoculated embryos), can be used as a guide to virulence. The MDT has been used to classify ND virus strains into velogenic (taking under 60 hours to kill); mesogenic (taking 60 to 90 hours to kill); and lentogenic (taking more than 90 hours to kill).
INTRODUCTION
Vaccination, initially with inactivated virus, was considered a possibility for the control of ND at the time of the apparent emergence of the virus. However, after the 1933 outbreak in England, an attenuated live vaccine was produced which was called strain H. Later, the naturally occurring USA isolates of low virulence, Hitchner B1 (HB1) and La Sota, became the most used veterinary vaccines throughout the world. Fifty years or more have passed since vaccine was first used to protect village poultry against ND. (Placcidi and Sentucci, 1952). During this time, a wide variety of types of vaccine have been developed. Many, but not all, have been tested on village poultry. It is the purpose of this chapter to present an overview of the different kinds of vaccine available. It is not the intention to recommend a particular vaccine, but rather to try and outline the relative advantages and limitations of each, with particular reference to its use in the village situation and giving examples of how the different vaccines are employed.

The principle of vaccination against a viral disease is well-known: to elicit an immunological response against the virus in a way that does not cause the disease. The simplest way to do this is to take the virus, kill it, and then inject it into the bird. This is an inactivated vaccine. Another approach is to select a naturally occurring virus that is not virulent enough to cause serious disease, and infect the birds with this virus. This is a live vaccine. This latter approach can be taken further by taking a non virulent natural virus and selecting a clone from the virus population with desirable properties, such as lack of vaccinal reactions, or heat tolerance. This is a cloned live vaccine. Finally, it is possible to genetically engineer a vaccine by, for example, taking part of the genetic material of the virus that codes for a surface antigen, and inserting this into another, different, virus to produce a recombinant vaccine.

These different approaches to vaccination have been applied to ND. There are three types of vaccines used for ND: live lentogenic, live mesogenic and inactivated vaccines. Live lentogenic vaccines are usually derived from field viruses that have been shown to have low pathogenicity for poultry but produce an adequate immune response. Typical vaccine strains are HB1, La Sota and F strain and some viruses from the asymptomatic enteric pathotype, which are usually based on the V4 or Ulster 2C viruses. However, these viruses have been frequently subjected to selection pressures by manufacturers in order to improve their immunogenicity or to enable their use by a particular method of application.

INACTIVATED VACCINES
Inactivated vaccines are produced by growing a ND virus in eggs, and then treating the infective allantoic fluid with an inactivating agent, such as formalin or betapropiolactone. An adjuvant, such as mineral oil, is usually then added to make the inactivated virus more immunogenic. Since the vaccine is no longer capable of replication or spread, it has to be injected individually into every bird needing vaccination. It is normally injected into the back of the thigh muscle (sometimes the breast muscle is used), using 0.3 or 0.5 ml per bird. This requires some training, and cannot be done by every keeper of chickens without prior
demonstration. Inactivated vaccines produce very high levels of antibodies against NDV, and provide good protection against the virulent virus.

In intensive poultry production, inactivated vaccines are usually applied after an initial priming vaccination with a live vaccine. In village poultry, however, good results in the absence of an initial vaccination with live vaccine have been reported (Bell et al., 1990). The reason for this is probably, as serological surveys have shown where they have been carried out (Bell and Mouloudi, 1988), that antibodies to the virus are already present in the village poultry as a result of previous infection by the wild virus.

Inactivated vaccines have been used extensively in village poultry, for example, in a successful project in Burkino Faso (Verger, 1986). Although inactivated vaccine gives good protection, it is relatively expensive to produce. It also carries a slight risk to the user of accidental self-injection. While inactivated vaccines are, to some extent, heat sensitive, they are much less so than conventional live vaccines which makes transporting them to villages more feasible.

**LIVE VACCINES**

Live vaccines differ from inactivated vaccines in that they can replicate in the host. This is both an advantage and a disadvantage. It is an advantage in that it is not necessary to vaccinate every bird individually; the vaccinal virus can spread on its own from one bird to another. It is, however, a disadvantage in that, since an infection with a live virus is involved, this may result in clinical signs because of the innate virulence of the vaccine virus or by exacerbating other organisms that may be present, especially in the respiratory tract. The severity of this reaction depends therefore on the particular vaccinal strain used (Westbury et al., 1984) and the presence or otherwise of concurrent infection with other pathogens.

Another advantage of live vaccines compared to inactivated vaccines, is their ease of application as they can be applied to the drinking water or with an eye-dropper.

Although NDV has essentially only one serotype, there is a wide difference in the pathogenicity of different strains, ranging from those that cause virtually no signs to those that kill within a few days. These have been classified, in order of increasing pathogenicity, into asymptomatic enteric, lentogenic, mesogenic and velogenic strains. The majority of live vaccines are derived from asymptomatic enteric or lentogenic strains, although some vaccines derived from mesogenic strains are still in use.

**Conventional lentogenic vaccines**

The level of vaccine reaction is an important consideration for intensive commercial poultry and because HB1 has very mild vaccinal reactions, it has been widely used for initial vaccination of intensive poultry. In a controlled trial in village poultry, HB1 provided effective protection against ND (Bell et al., 1990). La Sota produces moderate vaccinal reactions, especially in immunologically naive birds and is not usually recommended for primary vaccination. In theory, La Sota would also be unsuitable for vaccinating a multi-age population, including young chicks which is inevitably seen in the village situation. This is because the virus spreads and it is not practical to isolate the adults from the chicks. In
practice, the degree of reaction from La Sota as a primary vaccine depends on the residual level of antibodies, which could protect the birds from vaccinal reactions, and on the extent of other concurrent infections, such as *Mycoplasma* spp, pathogenic *E. coli*, or infectious bursal disease virus and other respiratory viruses. In intensive systems, vaccination using spray delivery systems which produce small particle sizes, may also exacerbate the vaccine reaction.

Some lentogenic vaccines have been cloned by taking a single infectious virus and growing a homogenous population from it, with the aim of selecting a virus which gives less vaccinal reactions than a La Sota-like virus, while retaining its superior immunogenicity compared to a HB1-like virus. An example of this kind of vaccine is “clone 30”.

All conventional live vaccines have the disadvantage of needing to be kept at low temperatures to maintain their efficacy. This is not a problem for intensive poultry production in an industrial setting, but the maintenance of the “cold chain” during distribution can be very difficult in village settings, particularly where there is high ambient temperature.

Another problem that is often encountered when using commercial vaccines in the village situation is that they are sold in vials containing 1 000 or 500 doses, many more than the average village farmer needs. In fact, the packaging is a major component of the cost of manufacturing them, because a vial containing a smaller number of doses would not necessarily reduce the cost proportionally.

Oil adjuvant, normally used with inactivated vaccines to improve immunogenicity, has also been tested with live vaccines and found to improve immunogenicity (Peleg *et al.*., 1993), but this combination has not been tested with village chickens.

**Heat tolerant vaccines**

Some asymptomatic enteric viruses have been noted for their greater heat resistance than more conventional lentogenic viruses. This property has been enhanced by selection and cloning in the laboratory to produce heat tolerant vaccines. These have a distinct advantage in the village situation because it is possible to transport the vaccine without a cold chain. The most extensively used vaccine has been the NDV4-HR vaccine, which was pioneered in Malaysia, where a significant proportion of the village poultry was eventually covered by this vaccine (Ibrahim *et al.*, 1992). The application was in feed, which, because of its thermostability, it was possible to pre-coat with the vaccine. The advantage of this method is that it is not necessary to catch the chickens before vaccinating them. The same vaccine has also been tried in other countries in South East Asia, but not always with the same success as in Malaysia. Tests of its application on a variety of foodstuffs have produced variable results (Spradbrow, 1992). The vaccine was also tested in some African countries, but applied by eye-drop and gave good protection against the virulent virus (Saglid and Spalatin, 1982; Bell *et al.*, 1995). Given the difference between African and Asian feeds, the variety of feeds within Africa, and the variable results with some feedstuffs in Asia, it seems that application of this type of vaccine is best done by eye-drop. It can also be argued that the additional security provided by the vaccine is an incentive to invest in some form of housing, in which case catching the chickens is no longer a problem.
More recently, a similar vaccine to NDV4-HR, called I-2 (Bensink and Spradbrow 1999), has been made available for local production in non-industrialised countries, which has the significant advantage of low cost. In trials in Ghana, Mozambique, Tanzania and Vietnam village chickens, vaccinated with strain I-2, were protected against artificial and field challenge with virulent virus (Amakye-Anim et al., 2000; Dias et al. 2001; Tu et al., 1998; Wambura et al., 2000).

Mesogenic vaccines
Mesogenic strains have long been used for vaccination in the village situation. These produce severe vaccinal reactions in an immunologically naïve population, and the use of this kind of vaccine is not advisable in situations where chickens are without any immune protection against the virus. Normally mesogenic vaccines, such as Komarov (Saifuddin et al., 1990) and Mukteswar (Alexander, 1997) are used as secondary vaccines after a primary vaccination with a lentogenic vaccine.

RECOMBINANT VACCINES
NDV has two surface glycoproteins, fusion [F] and haemagglutinin/neuraminidase [HN]. The genes coding for either of these can be inserted into a different kind of virus to make a recombinant vaccine. For example, the fusion gene inserted in herpes virus of turkeys produced a vaccine which gave good protection against virulent NDV (Morgan et al., 1993). One advantage of this technique is that the host virus may have better stability than NDV. Another advantage is that antigens for multiple different pathogens can be inserted into the same host virus to produce a single vaccine against several different diseases. Perhaps the most significant advantage for field use is that it is possible to monitor the response to the vaccine independently of the wild virus but in its presence, and conversely, it is possible to detect antibodies against the wild virus in the presence of vaccination. This is done by using an enzyme-linked immunoabsorbent assay (ELISA) that uses a purified antigen, and comparing the results with those of an ELISA using a whole virus antigen. For example, Makkay et al. (1999) prepared an ELISA using only nucleocapsid protein of NDV as antigen. This detected antibodies against wild virus, but not antibodies against a recombinant fowl pox virus expressing HN glycoprotein. A parallel ELISA using whole virus as antigen detected antibodies against the vaccine.

A disadvantage of recombinant vaccines is that where they have been developed commercially the cost is high.

VACCINE APPLICATION
Mass administration methods
In intensively developed commercial poultry industries, an important cost of vaccination is the administration. For this reason, mass application methods have been developed, primarily for live vaccines. Various forms of equipment are manufactured to generate coarse sprays, which allow mass application with minimum adverse reaction, although in some circumstances, mass application by fine sprays and aerosols are employed (Kouwenhoven, 1993).
Application of live vaccines via drinking water is still employed in some areas, although in the commercial sectors, this gives some problems in preparing and cleaning the drinking water system, with a tendency for a less than uniform uptake (Kouwenhoven, 1993).

Administration to village chickens
Vaccine administration to village chickens is not comparable to intensively reared commercial chickens as the birds are rarely housed and seldom in large numbers. However, labour is usually available at little or no cost which means that individual methods of vaccine administration are feasible.

Eye-drop administration
Application of the vaccine by eye-drop methods is probably the most effective for live lentogenic vaccines (Fig. 1). It ensures that the vaccine reaches the individual bird and, as a consequence, titres obtained are usually uniform throughout the flock.

Correct dilution of the vaccine is critical. If eye-droppers are being used, they should be calibrated beforehand (see Alders and Spradbrow 2001a). In the absence of suitable eye-droppers, it is also possible to use the tip of a feather or a syringe (preferably a 1 mL syringe) to administer the drop. However, these two options should be seen as last resorts as they are inaccurate and cause considerable wastage of vaccine. Most live ND vaccines require re-vaccination at 3-4 monthly intervals.

Eye-drop administration provides good protection because the vaccine passes to the Harderian gland just behind the eye, which in chickens is a key organ in the development of the immune response.

Figure 1 Eye-drop administration. When using an eye-dropper, hold it in a vertical position. Eye-droppers are calibrated according to the size of the drop that forms when the dropper is held in a vertical position (Alders and Spradbrow 2001a).
Administration of the vaccine via drinking water

Vaccination by placing the live vaccine virus in the drinking water is easier than application to individual birds, but it provokes a lower level of immunity than eye-drop administration, has less uniform uptake and requires more frequent application. The vaccine should be given twice, initially 2-3 weeks apart, with re-vaccination at least every three months.

It is important to:

- remove drinking water from the chickens for 1-2 hours before the administration of the vaccine.
- mix the vaccine with a volume of water that the chickens will be able to drink during one hour (usually 5-7 mL of water per bird).
- always use fresh and clean water.

It is important not to:

- use metal water receptacles.
- use disinfectants to clean water receptacles as they will inactivate the vaccine virus.
- use treated tap water. If there is only access to treated tap water, it is advisable to let the treated tap water stand overnight to allow the chlorine to dissipate, or add one teaspoon of powdered milk per 10 litres of water to neutralise the effects of the chlorine.
- place water receptacles containing vaccine directly in sunlight or in hot areas.
- allow other animals access to the vaccine. It should be restricted to chickens.

In rural areas, it is best to give the drinking water in the morning just as the chickens are released from the chicken house. In areas with abundant surface water, chickens find their own source of drinking water and vaccination via water is not appropriate.

Administration via feed

Oral vaccination of chickens with thermostable vaccines (i.e. NDV4-HR and I-2) has been successful in some developing countries. Good veterinary services, local availability of suitable grains and recovery of virus from the grain are important considerations for successful oral vaccination. One problem with food-based ND vaccination is the low recovery of virus from some grains (especially maize), a consequence of either binding or inactivation. This method should be thoroughly tested before being used widely in the field. The vaccine must be given more often when administered via feed, making it more expensive, and survival rates in the face of an outbreak are lower than those achieved by eye-drop administration. Food used in any vaccination campaign should therefore be recommended by the Veterinary Authority. 7-10 grams of food per bird should be well mixed with the corresponding number of doses of appropriately diluted vaccine. With most grains, 1 ml. of fluid will efficiently moisten 10 grams of grain. The treated food is best given in the morning as the birds are leaving the roost. The vaccine should be given twice, initially 2-3 weeks apart, with re-vaccination at least every 2-3 months.
**Administration via injection**

Inactivated ND vaccines are administered by intramuscular or subcutaneous injection only (in the breast or the leg). Inactivated vaccines should be allowed to reach ambient temperature (approximately 28°C) and the contents should be well shaken prior to use. If stored in a cool, dark location, an inactivated vaccine may retain its activity for 1-2 weeks outside a refrigerator.

Inactivated vaccines are more effective in chickens which have previously received a living vaccine. Re-vaccination is usually done every 6 months.

Accidental injection into the vaccinator of inactivated vaccines based on emulsions formed with mineral oil can cause a serious localised reaction. These usually require incision and washing. Expert medical advice should be sought at once, and the doctor must be informed that the vaccine was a mineral oil emulsion.

In many parts of Asia, mesogenic strains (for example, Mukteswar) of the ND virus are used and can be administered by injection only. This vaccine should be used in birds over eight weeks of age and following a primary vaccination with a lentogenic strain such as F strain.

**DISCUSSION**

The inactivated and recombinant vaccines have the advantage of not inducing vaccinal reactions. The heat tolerant clones produce almost no vaccinal reactions whereas the other live vaccines produce slight to moderate reactions, depending on the vaccine strain and the immune status of the population vaccinated.

Inactivated vaccines are, however, the most difficult to apply and whether using needle and syringe or automatic equipment, training is necessary before any injection technique is mastered.

For transportability, heat tolerant vaccines appear to be best and can be transported to even remote villages under high ambient temperatures without a cold chain. The inactivated vaccine is second best, having a better heat tolerance than the conventional live vaccines.

In choosing a vaccine for use in the village situation (Bell, 2001), one factor to take into consideration is previous experience with that type of vaccine. There has been extensive village experience in the use of both heat tolerant and inactivated vaccines. Live mesogenic vaccines have also been used in villages, particularly in Asia. The other live vaccines, with the possible exception of some clones, have, at least, been formally tested in villages.

Finally, cost is an important factor. All the live vaccines are relatively cheap, and can be even cheaper if they are produced locally. Inactivated vaccines are more expensive and recombinant vaccines are likely to be very expensive when produced commercially.

The choice of vaccine and how to administer it depends not only on the preceding factors, but also on the conditions in each region, such as the structure of veterinary services, previous experience, the population distribution, the communication infrastructure and the climate.
NEWCASTLE DISEASE IN VILLAGE CHICKENS

INTRODUCTION

In many developing countries, chickens are the livestock most commonly owned by rural families. Many of these families have scarce resources and many may be headed by women. Increasing the productivity of their chickens would make a significant contribution towards increasing their food security and their ability to have secure livelihoods. Village chickens provide meat and eggs, food for special festivals, offerings for traditional ceremonies, pest control and petty cash to, for instance, purchase medicines or pay school fees (Alders and Spradbrow, 2001a).

Food security is achieved efficiently when people produce or have access to sufficient quantities of affordable, high quality food. It is generally acknowledged that poultry production is the most efficient and cost-effective way to increase the availability of high-protein food (FAO, 1987). Eggs can be stored under village conditions more easily than most foods of animal origin. For decades, the egg has represented the standard reference food, perfectly balanced, containing most essential amino acids, large amounts of calcium, phosphorus, magnesium, iron and zinc. It represents one of the main sources of vitamin A and of vitamin B complex. One egg provides approximately 11.5 percent of daily protein requirements and 5 percent of daily energy requirements (Branckaert et al., 2000).

Village chickens are also one of the few types of livestock that cause little impact on the environment and that require few inputs in order to yield a significant output in terms of meat and eggs (Alders and Spradbrow, 2001a). They are the livestock most likely to be owned and cared for by women and children (Guèye, 2000; Spradbrow 1993-94).

By common agreement of all but a very few of those who have studied village poultry, ND is the single greatest constraint on the production of village poultry (Alders and Spradbrow, 2001b; Alexander, 1988a, 2001; Kitayi, 1998; Spradbrow, 1993-94). It is endemic in village poultry populations in Africa and Asia. Serological surveys indicate the presence of the virus in village poultry in countries throughout these continents, and where virus isolation has been attempted, virulent strains have been found (Spradbrow, 1993/94). ND can cause up to 100 percent mortality in susceptible populations during devastating outbreaks and sporadic losses throughout the year where the disease is endemic. In areas where ND is endemic, the disease is generally well-recognised by farmers and it discourages them from investing time and money in improving the standard of their poultry husbandry (Spradbrow, 1996). In such areas, control of ND will result in substantial increases in village chicken numbers (Alders and Spradbrow, 2001a, 2001b). However, where ND control has been undertaken as part of a development project, control activities have rarely continued after the end of the project. This lack of sustainability may have been due in part to the fact that projects concentrated on technical issues and paid little attention to social, cultural, administrative and economic issues such as community participation, gender sensitive extension activities, facilitation of government policies, training of staff and farmers, cost-recovery, and distribution and marketing networks. In many countries, rural families who keep village chickens will have had little contact with veterinary services and have little contact with the formal
economy. It is well-recognised that resource poor people are the least likely to take risks and, as a result, adopt new technologies only once they are sure of an adequate return on their investment of both time and money (AFFHC, 1987).

SPECIFIC EPIDEMIOLOGICAL CONSIDERATIONS FOR ND IN VILLAGE CHICKENS

Chicken production systems
Village chicken production is vastly different from that practised in the large-scale commercial poultry industry and the peri-urban semi-intensive poultry production found in many developing countries (see Table 4.1). The output of traditional village chickens in terms of weight gain and number of eggs per hen per year is low, but it is obtained with minimum input in terms of housing, disease control, management and supplementary feeding (Alders and Spradbrow, 2001a; Kitalyi, 1998). Village chickens may be provided with rudimentary housing and occasional supplementary feed. Flocks are usually small, containing 5-20 birds per household (Guèye, 1997) with all age groups represented (Alders and Spradbrow, 2001a). In Tanzania, the average ratio of chicks to growers to adults is 10:5:6 (Minga et al., 2001).
Table 4.1. Comparison of village, smallholder producer and commercial chicken flocks.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Village flocks</th>
<th>Smallholder producer flocks</th>
<th>Commercial flocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flock size</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td>Age</td>
<td>Mixed age</td>
<td>Single age</td>
<td>Single age</td>
</tr>
<tr>
<td>Housing</td>
<td>Trees, simple chicken houses used for overnight shelter</td>
<td>Built to house chickens constantly.</td>
<td>Large chicken units</td>
</tr>
<tr>
<td>Source of replacement stock</td>
<td>Natural incubation</td>
<td>Purchase of day old chicks</td>
<td>Artificial incubation or purchase of day old chicks</td>
</tr>
<tr>
<td>Feed source</td>
<td>Scavenging, Feed Resource Base, household scraps, cereals when available</td>
<td>Commercial balanced ration used when available, occasionally ration prepared from local feeds</td>
<td>Commercial balanced ration</td>
</tr>
<tr>
<td>Farming system</td>
<td>Integrated farming system involving extensive crop and livestock production</td>
<td>Usually single enterprise, intensive</td>
<td>Single enterprise,</td>
</tr>
<tr>
<td>Veterinary inputs</td>
<td>None, vaccination against ND</td>
<td>Control of viral, bacterial and parasitic diseases essential for efficient production</td>
<td>Control of viral, bacterial and parasitic diseases essential for efficient production</td>
</tr>
<tr>
<td>Production</td>
<td>Low; could improve with better nutrition, disease control and shelter from predators</td>
<td>Moderate if all essential inputs available.</td>
<td>High; but requires a high level of inputs.</td>
</tr>
<tr>
<td>Access to urban markets</td>
<td>Limited</td>
<td>Moderate</td>
<td>Extensive</td>
</tr>
<tr>
<td>Genetic diversity</td>
<td>Extensive</td>
<td>Moderate to limited</td>
<td>Limited</td>
</tr>
</tbody>
</table>

Spread of disease in village chickens
The introduction of the ND virus to a village is most likely to occur when infected live chickens are introduced (Martin, 1992; Spradbrow, 1993-94). Live bird markets are often involved in the movement of the disease (Alexander, 1988b; Spradbrow, 1993-94). Outbreaks of epizootic disease are readily noticed and occur in flocks where there are large numbers of birds susceptible to ND. Enzootic forms of ND that causes only occasional deaths may occur in village chickens (Alders and Spradbrow, 2001a).
Figure 2 These village poultry traders in Dakar, Senegal, sell birds (chickens, guinea fowl, ducks) that have been collected from many different farms and many different parts of the country.

The reservoir of ND virus in the typical village is not well understood and Martin (1992) states that the following factors can play a part, depending on the prevailing conditions in each village:

- **Cycling of infection within the village chicken population** – under village conditions, a ND outbreak can take weeks to pass through a flock and months to pass through a village.

- **Other domestic birds** – domestic birds such as ducks, doves, turkeys, geese, guinea fowl, etc. can harbour the ND virus. These birds can be infected with the virus and become a source of infection for chickens. They may or may not develop clinical ND, depending on the strain of virus and the bird species.

- **Carrier chickens** – It is uncertain whether chickens can become long-term carriers of the ND virus. However, ND vaccines may induce an immunity that prevents clinical disease but that does not necessarily prevent ND. This means that chickens vaccinated against ND can become infected by virulent ND virus without developing clinical signs and then spread the virus to other birds.
• **Wild birds** – Strains of ND virus of varying virulence have been found in many species of wild birds (Alexander, 1988b), but the role of ND infected wild birds in the epidemiology of the disease in village chickens remains unclear.

• **The physical environment** – Infected birds shed virus in their faeces, where it can survive perhaps up to 3 months at temperatures of 20-30ºC and longer at cooler temperatures.

### CONTROLLING ND IN VILLAGE CHICKENS

Much has been written about ND and its control in the commercial poultry sector. Comparatively little literature is available on ND in the family sector although most authors agree that it is a major constraint to village chicken production (Sonaiya, 2000; Spradbrow, 1993-94). While the basic characteristics of the ND virus encountered in the commercial and family sectors are similar, it is the production systems used to raise village chickens and the socio-economic status of their owners that make ND control in the family sector a very complex issue.

The control of ND in the family sector, as in the commercial sector, requires a multifaceted approach. In the commercial sector, ND control consists of (Alexander, 1997):

- **International control policies** – details are available from the OIE (2001).
- **National control policies** – these vary from country to country and include eradication policies requiring the compulsory slaughter of infected birds, and obligatory vaccination of all birds. Higgins and Shortridge (1988) stress the importance of tailoring control policies to the country and warn against the dogmatic application of policies successful in one country to another which may differ socially, economically and climatically.
- **Biosecurity at the farm level** – a discussion of sanitation and security practices for commercial poultry units may be found elsewhere (Zander et al., 1997).
- **Vaccination** – Alexander (1997) emphasised that there are no circumstances in which vaccination can be regarded as an alternative to good management practice, biosecurity or good hygiene in rearing domestic poultry.

While the details may vary, in general, these four components also apply to the control of ND in the family sector. The challenge is to develop an effective ND control programme for the family sector that is sustainable, both economically and socially.

Animal Disease laws in most countries make no distinction between the commercial and family sectors. When such legislation is being revised, all sectors should be consulted to ensure that the legislation is relevant to the prevailing national conditions and that it will promote the improvement of livestock production through the effective control of disease (Sonaiya, 2001).

In countries where farmers are not compensated for the loss of their livestock, the quarantine and mandatory slaughter of affected birds (“stamping out”) in the face of an ND outbreak will rarely be successful. In such circumstances, ND is more likely to be controlled in rural areas if farmers are encouraged to use husbandry practices that can limit the spread of the disease while salvaging some part of the affected birds (see Figure 3). Stringent Animal Disease laws can also contribute to the under-
reporting of ND as farmers see no reason to report outbreaks to the government authorities (Tsibane, 2001).

![Figure 3](image.jpg)

**Figure 3** This Mozambican village chicken farmer is providing moistened maize bran to her chickens that have ND. Some chickens that contract mesogenic strains of ND will recover and palliative care provided by owners improves the survival rate.

Compulsory vaccination against ND will meet with success only if the vaccine is offered free of charge. Even when free, an extension campaign will be required to assure farmers that the vaccine is safe and inform them how and when the vaccine should be administered. Where funding is limited, small-scale farmers must contribute to the cost of vaccination. In most cases farmers will place a higher value on the vaccine if they are required to purchase it and such payments will assist the overall sustainability of the ND control programme. Consequently, attention must be given to raising the awareness of farmers with regards to the prevention of ND by vaccination and ensuring that the vaccine used is efficacious, safe, appropriate to local conditions, available and affordable.

In order for the control of ND to make an ongoing contribution to the well-being of village chicken farmers and their families, the control activities must bring together the key stakeholders and they must fully appreciate the complexity of the exercise that they are about to commence. In areas where a cold chain is lacking, the use of thermostable ND vaccine will make the vaccination of chickens possible. These same areas will frequently be characterised by a lack of infrastructure in general and limited human resource capacity. Therefore the vaccination and improved husbandry of chickens must be accompanied by appropriate organisational, training, communication and economic practices.
Experience has shown that a sustainable ND control programme has four essential components (Alders et al., 2001b):

- an appropriate vaccine and vaccine technology;
- effective extension materials and methodologies that target veterinary and extension staff as well as community vaccinators and farmers;
- simple evaluation and monitoring systems of both technical and socio-economic indicators;
- economic sustainability based on the commercialisation of the vaccine and vaccination services and the marketing of surplus chickens and eggs.

**Organisation**

Farmers, extension workers, veterinary services staff, private business people (including chicken traders), livestock and social scientists and non-governmental organisations (NGOs) are the stakeholders who should be involved in ND control activities from the outset (Alders, 2001). All stakeholders must work together to ensure that a suitable vaccine is available in the field at the required time, that the users of the vaccine have received sufficient training to enable them to use it with success, that the costs associated with the production (or importation) of the vaccine are covered and that the ND control activities are monitored. These activities will be implemented with greater ease if the relevant national and provincial government agencies are supportive and create an enabling policy environment, particularly with regard to cost-recovery.

As with all endeavours, it is best to start small and build on each success. In most cases, farmers will be expected to pay for the ND vaccine and so it is critical that the first vaccination be successful. Most farmers will not want to try a second time. The best way of ensuring good results is to prepare thoroughly before commencing with vaccinations in the field and to have the will and the resources to ensure that subsequent campaigns are implemented at the recommended intervals. (Alders and Spradbrow, 2001a)

**Community Participation**

The farmers are the clients of any ND control programme and the programme should be designed to meet their needs and expectations. Farmer participation is usually not achieved easily. Farmers communicate more easily with people who display knowledge and understanding of the local farming system and who are willing to spend quality time with them. It is essential that the priorities and knowledge of farmers be respected (Alders, 1998). All activities should be discussed and then presented to representative groups of farmers.

In addition, it is essential that farmers should not be seen as a homogeneous group. Demographic studies should be done to determine the various groups involved with village chicken production, and care should be taken to ensure that each of the key groups is given a chance to contribute to the discussion. Groups may vary according to gender, age, religion, wealth status, ethnicity or role in the production system.

The various roles in the production system should be investigated. Roles will vary within households. Who will administer the vaccine to village chickens? Some farmers will become community vaccinators
or community livestock workers - CLWs (these workers will receive wider training and be able to treat a range of livestock diseases). Who will be involved in the distribution of the ND vaccine - government agencies or private traders? Village chicken traders are often neglected in ND control activities but they also suffer huge financial losses due to ND, particularly when traders travel long distances and are forced to keep birds from different flocks together for several days prior to sale.

In many cases, NGOs will be well-placed to facilitate connections between communities and government agencies. In areas where the private sector is not well developed, government agencies will need to facilitate farmer access to the vaccine.

**Coordination between Government Services**

Many countries are currently moving towards a unified agricultural extension service. This process is often not without difficulties and every attempt should be made to ensure that those with relevant experience and responsibility within the extension services and the veterinary services are able to contribute.

If Government services are involved in the distribution of the vaccine, then it is useful if representatives of the relevant administrative sections are invited to assist with the development of a robust cost-recovery and accounting system.

Links should also be established with the Ministries of Education and Health. Appropriate extension packages on the control of ND in village chickens can be designed for use in primary schools and human nutrition and literacy programmes.

**Co-ordination between Government, the Private Sector and NGOs**

The privatisation of veterinary services is being promoted in many countries. In the case of the control of ND in village chickens, it is doubtful whether the local production of ND vaccine or its administration in the field would generate sufficient profit to make it attractive to private companies, veterinarians or animal husbandry experts (Alders, 2001). To ensure a supply of ND vaccine of suitable quality for the family sector, it may be best to consider the commercialisation of vaccine production in appropriate government laboratories in the short term. With regard to administration and distribution, village chicken farmers can be trained as community vaccinators and governments must decide whether to allow the sale of ND vaccines by private operators. In each case, governments will have to assume responsibility for the supervision of community vaccinators and private operators to ensure that the quality of services and vaccine being provided is acceptable. NGOs often support disease control activities in rural areas and it is essential that the approach used conforms to government policy and can be readily integrated into government and private sector activities at the end of the project.

The recommendations above require ongoing government involvement in ND control activities in the short to medium term (Alders, 2000). This involvement can be considered a “public good” as the improved household production of village chickens will:
• **Improve household food security** – increased protein intake by children will decrease malnutrition and enable their mental capabilities to develop to their full potential (Pinstrup-Andersen, *et al.*, 1993) thus ensuring a more productive working life.

• **Improve household income** – increased sales of chickens will enable families to resolve other problems such as the need for medicines, school fees, etc.

• **Increase access to chickens in urban and peri-urban areas** – once chicken traders identify areas where ND vaccination takes place regularly, they will choose to trade with chicken farmers in that location. If mortalities among purchased chickens decrease and the number of chickens available for purchase increases, the unit sale price of chickens should decrease. Consequently, the number of urban consumers who can afford to purchase chickens will increase.

**Communication**

With the introduction of a new intervention, all involved with the work should receive information appropriate to their role to enable them to make sound decisions that will support the successful implementation of activities (Alders, 2001). In the case of ND control in village chickens, information packages should be prepared for every link in the chain between the production of the vaccine and the chicken that is to be vaccinated. Senior national and international decision makers require concise information concerning the benefits to be gained from the control of ND in village chickens and the policies required to facilitate the sustainable implementation of control activities. Extension workers, veterinarians and project managers need detailed information to help them design, implement, monitor and evaluate ND control activities. Provincial and district staff benefit from practical guides to the implementation and supervision of field activities. In many cases, farmers must initially be informed of the existence of ND vaccines, be convinced of their efficacy and then provided with appropriate training to enable them to benefit from the technology.

**Data collection**

Livestock disease control activities generally commence with the collection of data concerning the status of the disease and the livestock population at risk. A number of farmer questionnaires have been developed which focus on ND and village chicken production (see Alders and Spradbrow, 2001a; IAEA 1999; Kitalyi, 1998). In order to better target the communication packages, information should also be gathered to enable the construction of a demographic profile of farmers and the educational level and experience of staff to be involved.

**Agricultural Extension**

A comprehensive extension package should be developed for use with all available communication options, in particular, radio, newspapers, group meetings, field days, drama, and school lessons. Such a package has been developed in Mozambique and is available for adaptation for use in other countries.

Where literacy levels are low, more attention should be given to audiovisual and non-formal means of communication. Adequate time and resources must be invested in the development and evaluation of the
extension material. The effectiveness of the extension material is critical in situations where farmers are to pay for the vaccine.

**Participatory techniques**
Participatory methodologies provide a wide range of information and help to focus attention on those aspects most important to farmers. These methodologies may assist with situation analyses from the farmers’ point of view, the collection of ethnoveterinary knowledge and participatory technology development. Care must be taken to ensure that participatory techniques are used in a gender-sensitive manner. Regular analyses of farmers’ perception of the ND control programme should be conducted and should take into account other household activities. Participatory methodologies that can improve our understanding of village poultry farmers and village poultry production have been discussed elsewhere (Alders and Spradbrow, 2001a).

The frontline extension staff must be encouraged to accompany the ND control activities and identify other constraints that limit poultry production. Extensionists should work with farmers in a process of continuous improvement using approaches that facilitate adult learning (Klatt, 1999; Van Veldhuizen et al., 1997). This process will also assist with effective evaluation and monitoring of ND control activities.

**Gender issues**
Gender is defined as the socially determined differences between women and men, as opposed to the word “sex” which denotes physical differences. Gender differences are historically determined, culturally specific and dynamic. They define how women and men interact in a specific context, and what is considered appropriate for women and men to do, thus determining their respective development options and constraints (Gujit, 1994).

Experiences to date show that participatory techniques are not automatically gender-sensitive (Gujit, 1994). Those using participatory methods in the field carry with them personal biases, experiences and agendas, all of which shape the final analysis. Therefore, without gender-sensitive field workers, gender issues are not likely to be raised.

To improve village chicken production, it is necessary to learn who does what and then help them do it better. Collecting gender-disaggregated data helps to determine how the tasks associated with village poultry production are divided within households (Alders and Spradbrow, 2001a). It is well-known that direct communication with the person who actually does the work is more effective.

**Clear consistent messages**
With regards to the vaccination of family chickens in particular, extension messages must be simple, clear and consistent (Bagnol, 2000).

**Pre-testing of extension material**
It is vital that new extension material be pre-tested in the field prior to widespread diffusion to ensure that it will effectively communicate the desired message(s) to farmers. Pre-testing does cost money but it can
be done in relatively simple and inexpensive ways. The amount is insignificant compared to the actual production costs and money can be saved by avoiding the production of materials that are not understood or accepted. (Bertrand, 1978; Dudley and Haaland, 1993; Haaland, 1984; Zimmerman et al., 1996).

Since women have had less access to Western means of communication and often have more difficulty than men in interpreting material presented in Western ways, it is essential that extension material is specifically pre-tested with both male and female farmers (Alders and Bagnol, 2000).

**Training**

Better results will be achieved if relevant training is provided for all involved in ND control. Seminars and short courses for key national and provincial decision makers will help to familiarise people with concepts and assist in bringing people together as a team. Workshops for staff involved in the training of extension workers and community vaccinators should include both theoretical and practical sessions to ensure that the trainers understand and appreciate the work to be undertaken in the field. Trainees should understand the key principles of adult education and how they differ from approaches commonly used to teach children in schools (Klatt, 1999).

The training programme for extension workers and community vaccinators should include both training sessions and refresher courses. Components of the training should include the characteristics, handling and administration of the chosen vaccine, how to organise a vaccination campaign and how to monitor progress (see Alders and Spradbrow, 2001a; Alders et al., 2001a). In the early stages of the ND control programme, the refresher courses provide an opportunity for trainers to get feedback from the field on how the training can be improved.

While vaccines may be the method of choice for controlling ND in village chickens, training packages for field personnel should include information on general husbandry practices that assist with the prevention of disease. Good husbandry will reduce the impact of other diseases and predation while improving production through strategic supplementary feeding.

**Vaccination**

**Vaccine Selection**

The selection of a ND vaccine for use in family poultry will depend on the local conditions in each country. Selection criteria will include:

- Ease of use
- Thermostability (where the cold chain is non-existent or unreliable)
- Cost
- Immunogenicity
- Transportability
- Availability

In circumstances where the cold chain is weak or absent, the only reliable option may be the use of thermostable ND vaccines; i.e. the live vaccines NDV4-HR (Ideris et al., 1987) and I-2 (Bensink and Spradbrow, 1999), or inactivated vaccines. In most cases, farmers contribute wholly or partially to the
cost of the vaccine and the price of the vaccine is therefore a major factor. The lower the price of the vaccine, the greater will be the number of farmers able to afford it and, consequently, the greater the vaccination coverage. The lowest cost thermostable ND vaccine is generally produced locally I-2 “wet” vaccine. Locally produced freeze-dried I-2 ND vaccine is usually cheaper than imported freeze-dried live and inactivated vaccines, but more expensive than the “wet” vaccine. The freeze-drying process, the special vials, caps and labels all increase the cost of the vaccine. However, freeze-dried vaccine does have a longer shelf life than “wet” vaccine.

To facilitate the vaccine selection process, it is advisable to conduct a risk assessment of the options available. The risk assessment will also form part of the vaccine registration process. This assessment should be done in sufficient detail for all stakeholders to understand the risks and benefits associated with each option. The economic implication of each option should also be determined. The assessment will require more time and investigation in countries that choose to produce the ND vaccine locally.

**Local production**

ND vaccine of a quality acceptable for use in village chickens can be produced in the laboratories of some developing countries (Alders *et al.*, 2000; Buza and Mwamuhehe 2001; Dias *et al.*, 2001; Tu, 2001). In these cases, the vaccine is produced in eggs which are not specific-pathogen-free (SPF), but which come from healthy flocks that are screened for key poultry diseases (such as pullorum disease) that can be transmitted through eggs.

In countries where ND is endemic, the high mortalities associated with ND outbreaks will most likely indicate that the risks of not controlling the disease are far greater than the possible risks associated with using a ND vaccine that is locally produced. The lower price of the locally produced vaccine (particularly the “wet” I-2 vaccine) will increase the number of birds that can be vaccinated with the funds available. In addition, locally produced vaccine requires less foreign exchange.

Where funding is not limited, it is best to use SPF eggs or high quality minimal disease flock (MDF) eggs. However, it is unlikely that freeze-dried ND vaccine produced locally in imported SPF eggs would be cheaper than that produced by the two commercial companies currently producing the NDV4-HR vaccine. However, this is true only if foreign exchange issues are not a limitation (Alders and Spradbrow 2001a). There may be a cost advantage if SPF eggs are used to produce “wet” vaccine.

**Quality control of vaccine**

It is vital that the vaccine used in the field be efficacious. Veterinary Authorities should verify that the vaccine being used is of appropriate quality to ensure that chickens will be protected against ND with a minimal risk of other complications. Whether vaccine is produced locally or imported, each batch should be tested to confirm that the vaccine has an adequate titre of ND virus. The titre of live ND vaccines can be determined via titration in embryonated eggs. It is not possible to determine the titre of inactivated vaccines, but an estimate of potency can be determined by monitoring antibody response to vaccination in chickens. Certification that the vaccine is free of key poultry pathogens that can be transmitted vertically should be sought.
Live, thermostable ND vaccines
A thermostable vaccine enables distributors and users to reduce the problems associated with inadequate cold chains in the field. It is essential that users understand that a thermostable vaccine must still be treated with some of the respect due to a biological product, for example, the vaccine cannot be exposed to sunlight or frequent shifts in temperature and still be expected to remain active. (Alders and Spradbrow, 2001a)

NDV4-HR vaccine
The heat resistant V4 (NDV4-HR) vaccine against ND has yielded encouraging results in many countries in Africa (Alders and Spradbrow, 2001a) and Southeast Asia (Spradbrow, 1993–94).

NDV4-HR vaccine is a living vaccine with the following characteristics:
• it is thermostable, retaining its activity for 12 weeks at a temperature of 28°C in freeze-dried form (Ideris et al., 1987);
• it can be administered via eye-drop (intraocular), nose-drop (intranasal), oral drench, or drinking water; mixed with certain feeds or by injection (Spradbrow, 1993–94; Anon, 1991);
• its ease of administration makes it suitable for use by village farmers;
• the vaccine strain can be transmitted by contact from vaccinated to non-vaccinated birds (Alders et al., 1994; Spradbrow, 1993–94)
• it is avirulent and can be safely administered to chickens of any age from day-old chicks to adult birds (Spradbrow, 1993–94; Anon, 1991)
• its biological safety is superior to that of other living ND vaccine strains such as B1 or La Sota (Anon, 1991).

ND I-2 vaccine
The Australian Centre for International Agricultural Research (ACIAR) commissioned workers at the Virus Laboratory in the University of Queensland to produce a seed virus similar to NDV4-HR that could be made available without cost to laboratories in developing countries (Bensink and Spradbrow, 1999). Forty-five isolates of avirulent ND were examined for antigenicity, safety and ability to spread. The most promising of these isolates were checked for their thermostability and the more resistant isolates selected for enhanced heat resistance. The result was strain I-2, which was amplified in eggs from a disease-free flock to form a master seed. The seed was tested for safety and for freedom from bacterial contamination.

Strain I-2 has undergone laboratory tests in several countries and has proved to be protective against local virulent strains of the ND virus (Alders and Spradbrow, 2001b). In Vietnam, after extensive laboratory and village trials, it has been officially recognised as the ND vaccine for village chickens (Tu et al., 1998). In Tanzania, it has given protection for at least two months after vaccination (Wambura et al., 2000). Field records in Mozambique indicate that I-2 ND vaccine provides approximately 80 percent
protection in the field in the face of an outbreak, when given every four months via eye-drop (Alders and Spradbrow, 2001a).

ND vaccine of acceptable standard can be produced from strain I-2 in central laboratories or even regional laboratories in developing countries. The vaccine can be produced in eggs which are not specifically pathogen-free, but which come from a flock that is regularly screened for key poultry diseases. It can be produced and stored in liquid form, and suitably diluted in a protective solution such as 1 percent gelatin (in which the vaccine will maintain its activity for at least twelve weeks at 22°C; Bensink and Spradbrow, 1999) before use. The thermostable vaccine is then best administered via eye-drop. The I-2 vaccine produced in Mozambique will retain its activity for eight weeks at 28°C when freeze-dried and stored in the dark.

Storage and transport conditions for thermostable ND vaccines

If users have access to normal cold chain facilities, these should be used, even when dealing with a thermostable vaccine. Freeze-dried vaccine stored at 4-8°C will retain high titre for a longer period than that stored at ambient temperature. At 4-8°C, the vaccine should maintain an adequate titre for at least one year.

When taking the vaccine to the field, it should be placed in a cool box with ice or an ice pack. The vaccine should not be frozen (unless the instructions specifically indicate that it may be frozen). Freeze-dried vaccine packaged under vacuum rather than with nitrogen will lose the vacuum and gain moisture if the vial is frozen. The rubber cap on the vial contracts when frozen, enabling moist air to enter the vial. When this occurs, the shelf life of the vaccine is reduced.

These vaccines are thermostable, but attention to the conservation of the vaccine once removed from refrigeration will ensure optimal results:

- The vaccine should always be kept away from sunlight.
- When transporting the vaccine in the field, it should be wrapped in a damp cloth and carried in a covered open-weave basket. This allows evaporative cooling which helps to keep the vaccine cool and the cover prevents contact with sunlight.
- The date the vaccine leaves the cold chain should be recorded as it will remain effective for 2-3 months only.
- The vaccine should be stored in a cool, dark location, for example, near the base of a clay water pot.

Administration of thermostable ND vaccines

Standard dose - As with other live ND vaccines such as La Sota, a minimum of \(10^6\ EID_{50}/\text{bird}\) is required to produce an adequate level of protection. EID\(_{50}\) (50 percent embryo infectious dose) is a laboratory measure of the content of living infectious virus in a vaccine. It has been demonstrated that birds that received a higher oral dose of the NDV4-HR vaccine generated a higher immune response when confined in cages with wire floors (Spradbrow et al., 1988). This means that even though the thermostable vaccine can survive at ambient temperatures, attempts to improve its conservation will result in a slightly higher
vaccine titre at the time of vaccination and consequently a higher and longer-lasting immunity. This is particularly important when birds are not housed together at night.

**Administration route** - These vaccines can be administered via eye-drop, drinking water, certain feeds and injection. Field trials in Mozambique indicated that almost all farmers preferred eye-drop administration even though it entails the capture of birds. In their opinion, eye-drop administration produces a greater survival rate, has a lower frequency of administration and is easy. It is important that the eye-dropper used be made of virus-friendly plastic and that it is calibrated to ensure that one drop contains one dose. Calibration of the eye-dropper and administration of the eye-drop to the bird is done with the dropper in a vertical position to make sure that drops of a uniform size are produced.

**Age of bird** - The same dose is given to birds of all ages, from day-old chicks to adults.

**Vaccination schedule** - For eye-drop administration, the vaccine should be administered once, with re-vaccination every 3-4 months. Via drinking water, the vaccine should initially be given on two occasions, 2-3 weeks apart, with re-vaccination at least every three months.

**Dilution and use of thermostable ND vaccines**

These vaccines may be diluted using locally available potable water. It is recommended that the water is boiled and left to cool overnight in a non-metallic container before use.

Chlorinated tap water is unsuitable. If, however, this is the only water available, the treated tap water should stand overnight to allow the chlorine to dissipate or one teaspoon of powdered milk per 10 litres of water should be added to neutralise the effects of the chlorine.

Once the freeze-dried vaccine has been diluted, it is advisable to follow these simple rules for eye-drop administration:

- **Day 1** 1 drop per bird (i.e. on the first day of the vaccination campaign).
- **Day 2** 2 drops per bird
- **Day 3** discard

**Horizontal spread of thermostable live ND vaccine virus**

The thermostable live ND vaccines spread from vaccinated to unvaccinated birds when they are housed together (Alders *et al*., 1994; Bensink and Spradbrow, 1999; Tu *et al*., 1998, Spradbrow, 1993-94). The degree of spread under field conditions is less when birds roost in trees and horizontal transmission should not be seen as a reliable substitute for vaccinating village birds.

**Safety issues**

The avirulent live ND vaccines such as I-2 and NDV4-HR are considered to be harmless to birds. Both the I-2 and NDV4-HR vaccines produce no evidence of clinical respiratory signs, weight loss, mortality in young chickens or egg production drop after vaccination (Bensink and Spradbrow, 1999; Heath *et al*., 1992). The safety performance of original V4 (avirulent) vaccine is superior to both the HB1 (lentogenic) and La Sota (mesogenic) vaccine strains (Table 4.2).
Genetic sequencing of thermostable live ND vaccines

Genetic analysis indicates a relationship between the chemical structure of surface proteins of limited areas of the genome of strains of ND virus and the virulence of these strains. An area of apparent importance is the cleavage site of the fusion protein on the surface of the virus particle. Particular amino acid patterns around the cleavage site in virulent strains have become known as the virulence sequence. V4 and I-2 and other vaccines such as La Sota and HB1 lack the virulence sequence (Alders and Spradbrow, 2001a).

Table 4.2. Comparative safety of Newcastle disease vaccine strains (Heath et al., 1992).

<table>
<thead>
<tr>
<th>Signs in vaccinated birds</th>
<th>Vaccine strain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V4</td>
</tr>
<tr>
<td>Sneeze test</td>
<td>Nil</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>Nil</td>
</tr>
<tr>
<td>Weight gain</td>
<td>No effect</td>
</tr>
<tr>
<td>Mortality in young chickens</td>
<td>Nil</td>
</tr>
<tr>
<td>Egg production drop</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Live partially thermostable ND vaccine

Nobilis ND Inkukhu is not a thermostable vaccine in the true sense of the word; it is a freeze-dried vaccine that is stable in freeze-dried form for up to seven days in temperatures not exceeding 30ºC. At such temperatures the infectivity titre remains stable for seven days. (Alders and Spradbrow, 2001)

Once reconstituted with a diluent, it should be treated as any standard freeze-dried ND vaccine, i.e. on dilution, the vaccine should be used within one hour. Furthermore, once removed from refrigeration for an extended period, it must be used within the seven-day period and not returned to refrigeration for further storage. The expiry date printed on each vial is valid only when the vaccine is kept constantly under refrigeration.

This product is distributed in South Africa by Intervet and is aimed primarily at the small-scale commercial farmer in outlying areas. It offers this type of farmer the ease of transporting the vaccine from the supplier (with refrigeration) to his/her farm (which often has no refrigeration) without the cold chain required for conventional freeze-dried vaccines.
The vaccine strain is ND Clone LZ.58, originally marketed by Mycopharm in the Delvax range. The vaccine Delvax ND Clone LZ.58 has proven its efficacy in numerous poultry producing countries as a primer and booster vaccine against ND. It is a clone of the Hitchener strain and will induce some post-vaccinal reactions in chickens. Post-vaccinal reactions occur during the first week following vaccination and include a mild snick and a very slight rise in mortality (less than 0.2 percent).

Inactivated thermostable ND vaccine
Inactivated oil emulsion ND vaccines are less heat sensitive than the conventional live ND vaccines, making their transport to villages more feasible (Bell, 2001).

These vaccines must be injected and the volume injected varies according to the age of the bird. One manufacturer has stated that their inactivated ND vaccine will maintain its activity for several days at temperatures of 15-25ºC (LAPROVE T, 1992). These vaccines must not be frozen. Prior to use, the vaccine must be slowly brought to room temperature and shaken well to ensure that the emulsion is fluid and the contents are evenly distributed.

Although inactivated vaccine gives good protection (the standard re-vaccination interval is six months), it is relatively expensive to produce (Alexander, 2000; Bell, 2001; Cessi and Nardelli 1974). Quality control of inactivated vaccine is often difficult, and mineral oils may cause serious problems to the vaccinator if accidentally injected (Alexander, 1997). Adverse reactions to inactivated vaccine post-vaccination are rare (Alexander, 1997).

Inactivated ND vaccines have been used successfully in village chickens, for example, in West Africa (Rémond and Quinet, 2000; Verger, 1986).

Live mesogenic ND vaccines
Mesogenic live vaccines tend to be used in countries where virulent NDV is widespread and maintenance of high antibody titres is important to prevent serious disease (Alexander, 2000). Mesogenic live vaccines can cause very severe post-vaccinal reactions and are pathogenic for birds less than eight weeks of age (Meulemans, 1988). The use of this type of vaccine is not recommended in circumstances where chickens do not have sufficient immune protection against the virus, on account of post-vaccinal reactions (Bell, 2001).

These vaccines are administered by injection after a primary vaccination with an apathogenic or lentogenic ND vaccine. In Asia, the strain most commonly used is Mukteswar, with the Komarov strain being more commonly used in some countries in Africa.

These vaccines are sufficiently virulent to fall within the new OIE definition of ND (Alexander, 2000).

Distribution of vaccine
A distribution system, ensuring the availability of the vaccine when farmers need it and also enabling payment for the vaccine to be returned to the producing or importing agency, is a major challenge in
situations where the cold chain does not extend far into the field (Alders, 2001). In such situations, it is best to consider conducting ND vaccination campaigns. Campaigns should be carried out during specific months of the year and every effort should be made to ensure that the vaccine is available locally in the period immediately prior to the start of the campaign. For instance, in Mozambique, it is recommended that the I-2 ND vaccine should be administered by means of eye-drop in March, July and November. It is a major task to ensure that the freeze-dried I-2 vaccine (which cannot go without refrigeration for longer than two months), is available at the district level in the month prior to the campaigns. In areas where projects are being implemented, it is very tempting to rely on project staff to bring the vaccine into the area at agreed times. However, when the project ends, the supply of vaccine ends as well. Although more time consuming initially, it is important that options for the sustainable distribution of vaccine should be pursued in the field at the same time that ND vaccination commences. People who travel regularly from towns to the villages are the chicken traders. Would it be feasible for them to take the vaccine to the villages?

Where the cold chain is only lacking at the level of the farmers’ household, the ND vaccine may be held in stock locally and purchased by farmers and vaccinators as required. The cold chain may be provided by veterinary services, human health services or the private sector. If farmers in ND endemic areas are able to vaccinate their flocks four times a year rather than the three times as is recommended in Mozambique (mainly for logistical reasons), then losses of chicks hatched between ND vaccination campaigns will decrease.

Distribution of the ND vaccine by government agencies or by private pharmacies requires supervision. A system that allows samples of vaccine to be sent back to central laboratories for periodic testing to confirm that it still contains an adequate titre, is recommended. Once the existence of a thermostable vaccine against ND becomes well-known, counterfeit vaccine may appear in local markets. Vaccine labels should be distinctive and users and suppliers must be encouraged to report counterfeit products to authorities.

Community Vaccinators

The person to administer the vaccine to the village chickens needs to be chosen carefully. In many cases, the most cost efficient option is the farmer or a community vaccinator. This option not only decreases costs, but also contributes to the increase of knowledge and expertise of the farmers.

The selection of community vaccinators will be critical to the success of the control programme. Vaccinators must be chosen and respected by the community that they are to serve. However, the vaccination of chickens alone will not be sufficiently lucrative for vaccinators who have no other means of income. It has been observed that vaccinators who raise chickens themselves are most likely to be successful community vaccinators as the protection of their own chickens is of economic benefit to them. The income gained from vaccinating the chickens of others with the remaining vaccine is an additional benefit, but not a substantial one in most countries.

While it is essential that women should be involved in the ND control activities, it is not always beneficial to train only women as community vaccinators. For vaccinators to be effective, they must be
able to travel without encountering problems in buying and administering the vaccine. Travelling away from home can sometimes be difficult for women. Giving preference to women to be trained as vaccinators is commendable, however, other selection criteria must also be considered to ensure that the people selected will perform effectively. It is recommended that a community vaccinator should be:
- respected by the community.
- able to work with both male and female farmers and different groups within the community.
- able to travel the distances required to purchase vaccine and vaccinate chickens.
- able to read, write and do basic calculations.
- a village chicken farmer – protecting his/her own chickens from ND – will provide the community vaccinator with a substantial economic incentive. (Alders, et al., 2001a).

Developing and implementing ND vaccination campaigns
In most cases, farmers will be expected to pay for the ND vaccine, so it is critical that the first vaccination campaign is a success (Alders and Spradbrow, 2001a). Most farmers will not try a second time. The best way of ensuring good results is to prepare thoroughly before commencing with vaccinations in the field and to have the will and the resources to ensure that subsequent campaigns will be implemented at the recommended intervals.

Situation analysis
- **Awareness of officials, veterinarians and extension workers**
  Is the control of ND in village chickens seen as a priority by decision makers? What information do they need to help them understand the importance of vaccinating regularly against ND? Will existing government policies (on cost recovery, for instance) facilitate the development of a sustainable ND control programme?
- **Farmer awareness**
  Is ND a priority for farmers in the area where you plan to vaccinate? Do they know that a vaccine against ND exists?
- **Village chicken population**
  Obtain an estimate of village chicken numbers and, if farmers are to pay for the vaccine, make an estimate of the percentage of farmers likely to do so. This will enable you to order an appropriate quantity of vaccine.
- **Training requirements**
  Even if you plan to use a thermostable ND vaccine, it will not compensate for poorly trained personnel. For good results, make sure that all participants in the vaccination campaign have received the appropriate training. Training will vary according to the function of the individual:
  - veterinary services staff
  - extension staff
  - community livestock workers or community vaccinators
• **Seasonality of ND outbreaks**
  When are ND outbreaks most likely to occur? If a seasonal pattern to outbreaks is suspected, ensure that the campaign starts at least one month before the outbreaks are expected.

• **Agricultural and climatic calendar**
  Plan campaigns to coincide with those times of the year when farmers are not very busy in their fields and access to the area is possible.

• **Gender analysis**
  The campaigns will meet with better success if arrangements are made with the person in the family who owns and cares for the chickens.

• **Cost-recovery options**
  The majority of farmers are willing to pay for a product if they believe they will get a good return on their investment. Discuss payment options with the farmers and always give them advance notice so that they can arrange funds prior to the campaign.

• **Inputs**
  Always make sure that you know where you can get the supplies necessary for the vaccination campaign and that the material is in stock:
  - vaccine, of appropriate quality and quantity;
  - eye-droppers (see Alders and Spradbrow, 2001a for a description of suitable eye-droppers);
  - field allowances, etc. Even if you plan to work with CLWs, you will need to train and supervise them. These activities require funds and these funds must be confirmed before you begin your activities in the field.

**Preparatory phase**

• **Appropriate extension materials**
  Prepare, pre-test and duplicate the necessary extension material.

• **Training of personnel**
  Train personnel well in advance of the campaign. They need time to go back to their respective areas to raise farmer awareness, collect information and make their own preparations.

• **Timing of campaign**
  Decide in consultation with the staff, CLWs and farmers. Consider weather conditions, the farmers’ annual work plan and the pattern of ND outbreaks.

• **Extension activities**
  Start at least one month prior to the campaign.

• **Vaccine administration options**
  Use eye-drop administration whenever possible when using live ND vaccine. However, in certain circumstances farmers may opt for oral administration. Consider whether the vaccinator is to travel to individual houses or if farmers should bring their birds to pre-arranged points.
• Inputs
Vaccine, eye-droppers and syringes, per diems, transport, registration books, cool boxes or baskets and cloth must be procured.

Recommendations for ND vaccination campaigns
• Commence campaigns at least one month prior to the season when ND outbreaks are more common.
• Postpone the vaccination campaign if it is suspected that an outbreak of ND is in progress.
• Vaccinate healthy chickens only.
• Always inform farmers of the need to revaccinate their birds.
• Campaigns are best held during the weekends or school holidays.
• Cost-recovery, at least partial, is essential
• Never promise a 100 percent protection of chickens.
• Emphasise that the vaccine protects against ND only.

Implementation
On the first day of the vaccination campaign, you will have:
• trained teams;
• vaccine and other inputs;
• decided, in coordination with farmers, the site of vaccination:
  - house-to-house visits; or
  - central vaccination points;
• participating farmers registered;
• a way of identifying vaccinated chickens;
• a system in place for the vaccinator to register the number of birds vaccinated and payment received.

Economic sustainability
Cost-Recovery
For ND control activities to be sustainable in the long term, all costs associated with the production (or importation), distribution and use of the vaccine must be covered. In some instances, village chicken farmers may be expected to pay all of the costs. In many cases, government agencies may subsidise some aspects of the control activities with the remainder being paid for by farmers.

Cost Minimization
While not recommended, some governments or projects may wish to provide inputs such as ND vaccine free of charge. In such circumstances, the emphasis needs to be on cost minimization rather than cost recovery. The main costs associated with the control of ND using locally produced vaccine are: production costs, distribution costs and administration costs. With the production of freeze-dried vaccine, there must be a trade off between the most cost-efficient number of doses of vaccine per vial and the
number of doses that can realistically be used per day in the field. Where “wet” vaccine is produced, thought should be given to the most cost-efficient type of vials to be used to store and transport the vaccine. Community vaccinators or CLWs are likely to be the most cost-efficient means of administering the vaccine at village level.

It is advisable to consider a number of cost-minimization issues when producing vaccine locally. These issues include:
- the number of vaccination campaigns per year;
- the optimal number of doses per vial;
- the quality of eggs used to produce the vaccine;
- the quality of labels and leaflets produced to accompany the vaccine;
- conservation of the vaccine during transport; and
- conservation of vaccine in storage.

**Number of vaccination campaigns per year**

It is generally not possible to predict when an outbreak of ND will occur. ND vaccination schedules should be developed to ensure that most chickens have protective antibody titres throughout the year.

Field studies have shown that where ND is endemic, vaccination campaigns that promote the administration of single eye-drop of live ND vaccine every 3-4 months (without a booster vaccination after 2-3 weeks as occurs in the commercial sector), provides adequate protection (Bell *et al*., 1995; Dias *et al*., 2001). When inactivated vaccines are used, these should be administered every six months.

The number of doses of vaccine per vial is an important issue to consider when using freeze-dried vaccine (Alders *et al*., 2001a). Most rural families keep only a small number of chickens and would like to buy the vaccine in small doses. Unfortunately, it is not possible to produce vials of freeze-dried vaccine containing a small number of doses at low cost. Most of the costs in the production of freeze-dried vaccine are for the vial, the metal cap, the rubber stopper and the label. The vaccine itself is relatively inexpensive. Consequently, the price per dose increases as the number of doses per vial decreases. For example:

<table>
<thead>
<tr>
<th>Number of doses per vial</th>
<th>Cost price per vial (USD)</th>
<th>Cost price per dose (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 doses</td>
<td>USD 1.05</td>
<td>USD 0.0105</td>
</tr>
<tr>
<td>250 doses</td>
<td>USD 1.25</td>
<td>USD 0.0050</td>
</tr>
<tr>
<td>1000 doses</td>
<td>USD 1.50</td>
<td>USD 0.0015</td>
</tr>
</tbody>
</table>

In Mozambique, community vaccinators have managed to vaccinate up to 300 birds in one day. Consequently, a vial containing 250 doses was produced to enable the vaccinators to use one vial per day with a cost price per dose of approximately USD 0.005.

**Quality of eggs used to produce the vaccine**

Fertile eggs are used to produce I-2 vaccine and the cost of these eggs contributes to the overall cost of vaccine production. Where funding is not limited, it is best to use specific pathogen-free (SPF) eggs.
However, SPF eggs are expensive to produce or purchase, and problems with embryo viability have been reported (Allan et al., 1978).

In many countries the cost of ND vaccine production or importation will be borne by the end user of the vaccine – the owners of small flocks of village chickens who live in rural areas. The price of the vaccine will have a great influence on the number of smallholder farmers able to purchase the vaccine. It is important that those considering the local production of I-2 vaccine for use in village chickens weigh the risks of using an affordable vaccine of acceptable quality produced in MDF eggs against the losses farmers will experience when ND is not controlled because a vaccine produced in SPF eggs is too expensive for them to purchase.

**Quality of vaccine labels and leaflets**

In order to reduce production costs, it is recommended that all printed material be produced in black and white. Black and white material also yields better quality photocopies and so facilitates the copying of original material in the field.

**Conservation of the vaccine during transport**

The amount of time that the vaccine can be conserved in the field will depend on the integrity of the cold chain. Where the cold chain is unreliable or absent, the vaccine should only leave the cold chain when it is to be used within a short period of time.

The quality of materials used will depend on how quickly the vaccine will be used in the field. The manufacturing laboratory should provide adequate information to help buyers to conserve the vaccine appropriately. Thermostability trials should be used to determine how long the vaccine will retain its activities at various ambient temperatures. Data loggers can be used to study temperatures encountered by vaccine during transport and storage in the field under a range of conditions (for example, various containers, quantities of vaccine and various types and quantities of ice packs).

**Data Loggers**

A data logger contains a measuring circuit to measure temperature, a microprocessor to convert the measurement to numerical data and a memory to store the measurements. The data logger is setup using compatible software on the computer and the interval between measurements (for example, from one second to six hours) is chosen. The logger is then disconnected from the computer and works as a standalone unit, measuring temperature at the set interval. The logger is a small, plastic coated, usually waterproof device. After data has been collected, the logger is reconnected to the computer to display the temperature variation as a graph.

**Conservation of vaccine in storage**

Freeze-dried vaccine that is stored under vacuum is best stored at 2-8ºC. If frozen, the shelf life of the vaccine will be reduced as moist air may enter the vial when the stopper contracts away from the glass neck of the vial.
Marketing and utilisation of products

In most countries where village chickens are raised, informal marketing networks are well established. These networks may require some assistance to improve their efficiency as the number of chickens and eggs to be sold increases (Alders et al., 2001a, b). Consideration should be given to notifying chicken traders in central markets about areas where farmers are vaccinating against ND. ND also causes problems for chicken traders, because it can be difficult for them to buy birds at a reasonable price after an outbreak. Traders can also lose money if birds purchased from many different houses and areas become infected with ND and die before reaching the market. Encouragement should be given to the local communities to select their own chicken traders. Just as the community can choose community vaccinators, they can also choose the people to take their surplus birds and eggs to central markets to be sold. In this way, farmers are more likely to get a fair price for their birds and the profits involved in chicken trading are more likely to stay within the community. Training may be required to ensure that sales are fairly distributed and that trips to central markets are made when buyers are more likely to have money (for example, the first week after government salaries are paid) and when major festivals are about to take place (religious or secular holidays).

In many areas, farmers are reluctant to eat surplus chickens or eggs and in some regions, the consumption of eggs by women and children is traditionally prohibited (Alders et al., 2001a, b). The conservation of eggs and the hatching of chickens is important in situations of high chicken mortality, where replacement birds are essential. If sustainable ND control programmes can be implemented and chicken numbers increase, the consumption of eggs then becomes an option and a very good use of resources. The egg provides a range of nutrients apart from protein and can make a substantial contribution to the nutrition of children and pregnant women. Collaboration with colleagues working with human nutrition within the Ministries of Health and Education can raise the awareness of families with regard to good eating practices and the contribution that chickens and eggs can make to good health.

Benefit-cost assessments

The benefit-cost ratio of ND vaccination in small, scavenging flocks of village chickens has been shown to be high. Benefit-cost calculations done for the Tigray region of Ethiopia indicated that ND vaccination was more economically beneficial than the provision of daytime housing, supplementary feeding, cross breeding and control of broodiness (Udo et al., 2001). In Namibia, Paskin (1995) noted the negative food security implications of ND in rural flocks and concluded that the control of ND through prophylactic vaccination was highly beneficial with a benefit:cost ratio of 14:8.

An impact assessment study commissioned by the Australian Centre for International Agricultural Research (ACIAR) in 1998 concluded that benefits from research on the control of Newcastle disease in village chickens had already exceeded the total project costs by a factor of 15 (ACIAR, 1998).
Sustainable Livelihoods and the Distribution of Benefits

According to the Sustainable Livelihood Approach, a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with, and recover from, stresses and shocks and maintains or enhances its capabilities and assets both now and in the future, while not undermining the natural resource base. (DFID, 2000).

ND control in village chickens promotes sustainable livelihoods in rural areas in several ways. Village chickens are the livestock most likely to be raised by poor households. Household food security and income generation is increased with increased chicken numbers. Compared to ruminant species, chickens are more likely to be consumed, or to be sold to resolve immediate family needs such as medicines or school fees. The level of understanding of disease control in livestock and improved husbandry is increased. A study in the Southern Province of Zambia found that households with chickens were better able to survive drought and recover the following year than households without chickens (Songolo and Katongo, 2000).

The community as a whole also gains. For example, in Mozambique where community vaccinators administer the I-2 ND vaccine, two-thirds of the price of the vaccination stays in the community. This occurs because the price of vaccination includes the cost of the vaccinator’s labour and the cost of the vaccine. The labour cost per bird is twice that of a dose of vaccine. The ratio of labour costs to the price of the vaccine may vary from country to country, depending on the price of the vaccine and the ability and willingness of farmers to pay. Community benefits will be further increased if some community members become chicken traders and supply local chickens to markets beyond their immediate vicinity.

Urban communities also gain from increased numbers of village chickens. If mortalities among chickens purchased by traders decrease and the number of chickens available for purchase increases, the unit sale price of chickens should decrease. The chicken farmer will sell more birds and so make more money than was possible prior to the introduction of ND vaccination and the number of urban consumers who can afford to purchase chickens will increase as the unit sale price decreases.

The gains for local people in cases where the ND vaccine is locally produced are many. The equipment required to produce the vaccine is almost identical to that required for quality control procedures. Therefore, quality control of ND and some other vaccines can be done before vaccines are dispatched to the field. Employment is provided for local staff and the knowledge required for production of vaccine of a quality suitable for use in village chickens remains in the country. Many of the costs associated with local production also stay in the country, as only some of the inputs need to be imported. The instructions that accompany the vaccine are produced in the local language making them accessible to more people in countries where English is not spoken. Those responsible for the local production of the vaccine are more likely to ensure that the product is of an adequate quality if control activities are implemented in a participatory fashion. When the service or product provider is directly answerable to the client, work is usually of a higher quality.

Extension and veterinary services gain increased prestige and more work when ND control activities are successfully implemented. As noted by Bagnol (2001), most farmers who practice both agricultural
and livestock production seek to increase the number of livestock species that they raise when surplus numbers of chickens permit such purchases.

While the use of vaccine is the best way of controlling ND, training packages for field personnel should include information on general husbandry practices that assist with the prevention of disease. Good husbandry will reduce the impact of other diseases and predation, while improving production through strategic supplementary feeding.

**Other important considerations in the control of ND**

- Avoid the introduction of new birds to flocks during the periods of the year when ND occurs more frequently.
- Do not return from the market with chickens that have failed to sell. Instead, arrange to keep them in another place.
- Sick chickens should not be sold or given away.
- Avoid contact with people, cars and animals that have been in contact with the virus and other parts of infected chickens (eggs, feathers, etc.). Dogs and cats can also spread the virus if they have access to chickens killed by ND.
- Minimize contact between chickens and other poultry, such as ducks, pigeons, turkeys and guinea fowl.
- Good housing can reduce disease transmission. An elevated chicken house that is well ventilated allows faeces to fall through to the ground and so minimizes contact with various infectious agents. Keep chickens and chicks away from the base of the chicken house where the faeces have accumulated or clean the area regularly. Encourage the use of local remedies to control ectoparasites (for example, fleas and mites) in the houses when commercial insecticides are not available.
- House hens with young chicks in a clean, safe chicken house.
- Provide some supplementary feed, such as maize bran, ground grains, green leaves, ground seashells, insects, insect larvae and worms. Good nutrition will give chickens a better chance of combating infections. Supplementary feeding is especially important for chicks, and a creep feeder can be made from local materials to ensure that chicks are able to receive food without greatly increasing the amount of food given to the household poultry flock. A creep feeder also provides chicks with shelter from flying predators.
- Always provide fresh, clean water.

**Control measures during an outbreak:**

- Isolate all sick chickens.
- Slaughter chickens that are very ill. Do not transport chickens that are ill or dead to other areas that are free of the disease.
- Bury or burn all dead chickens or any part of a chicken.
- Do not vaccinate chickens that are showing signs of illness.
Once an ND outbreak has commenced in a village, it is best not to vaccinate, as it is impossible to identify birds that are incubating the disease but not yet showing signs of illness. Farmers will often associate the vaccine with the death of chickens that are vaccinated in the face of an outbreak.

- Advise farmers to wait for at least one month after the last mortality before re-stocking.
- Advise farmers to contact the Veterinary Services Officer, Extension Worker or Community Livestock Worker in their area when they notice any signs of illness.

Monitoring and evaluation

Every aspect of the ND control programme must be monitored to ensure that the programme is working efficiently (see Table 4.3). All stakeholders involved with ND control should participate in the monitoring and evaluation process and should help to define the indicators of success. Stakeholders may include community representatives (male and female), government officials, private sector representatives and NGO representatives.
Table 4.3. General inputs and activities required to mount a ND control programme and indicators that can be used to evaluate the efficiency of the programme (Alders, 2001a).

<table>
<thead>
<tr>
<th>Input/Activity</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procure appropriate vaccine</td>
<td></td>
</tr>
<tr>
<td>- Import</td>
<td>Quantity of vaccine produced or imported.</td>
</tr>
<tr>
<td>- Produce locally</td>
<td>Value of vaccine sales in comparison to actual costs of importation or production.</td>
</tr>
<tr>
<td>Vaccine Quality Control</td>
<td></td>
</tr>
<tr>
<td>- Efficacy</td>
<td>Quality Control test results.</td>
</tr>
<tr>
<td>- Potency</td>
<td></td>
</tr>
<tr>
<td>- Safety</td>
<td></td>
</tr>
<tr>
<td>Central store of vaccine</td>
<td>Maintenance of central cold store.</td>
</tr>
<tr>
<td>Central data bases (veterinary and socio-economic)</td>
<td>Nº of doses &amp; vials of vaccine distributed nationally.</td>
</tr>
<tr>
<td></td>
<td>Value of vaccine sales nationally.</td>
</tr>
<tr>
<td></td>
<td>Nº of chickens vaccinated nationally.</td>
</tr>
<tr>
<td></td>
<td>Nº per year and timing of vaccination campaigns.</td>
</tr>
<tr>
<td></td>
<td>Incidence of ND outbreaks.</td>
</tr>
<tr>
<td></td>
<td>National village chicken population.</td>
</tr>
<tr>
<td></td>
<td>Monitor socio-economic indicators.</td>
</tr>
<tr>
<td>Distribution of effective vaccine and extension material</td>
<td>Maintenance of provincial cold store.</td>
</tr>
<tr>
<td>- Appropriate accounting procedures</td>
<td>Appropriate extension material available for farmers, field staff and decision makers.</td>
</tr>
<tr>
<td>- Vaccine conservation</td>
<td>Nº of doses &amp; vials of vaccine distributed in each province.</td>
</tr>
<tr>
<td>- Information package</td>
<td>Value of vaccine sales per province.</td>
</tr>
<tr>
<td></td>
<td>Nº of chickens vaccinated in each province.</td>
</tr>
<tr>
<td></td>
<td>Nº per year and timing of vaccination campaigns. Incidence of ND outbreaks per province. Provincial village chicken population.</td>
</tr>
<tr>
<td>Informed and motivated support staff</td>
<td>Nº of staff (male and female) involved in ND control activities.</td>
</tr>
<tr>
<td></td>
<td>Nº of staff with acceptable knowledge of ND control.</td>
</tr>
<tr>
<td></td>
<td>Nº of meetings between supervisors and extension workers and community vaccinators.</td>
</tr>
<tr>
<td></td>
<td>Quantity and type of refresher courses.</td>
</tr>
<tr>
<td></td>
<td>Value of vaccine sales per district and per vaccinator.</td>
</tr>
<tr>
<td></td>
<td>Identification of other diseases and production constraints.</td>
</tr>
<tr>
<td>Informed and enthusiastic farmers</td>
<td>Nº of farmers (male and female) participating in and paying for vaccination.</td>
</tr>
<tr>
<td></td>
<td>Nº of community vaccinators (male and female) working one year after initial training.</td>
</tr>
<tr>
<td></td>
<td>Nº of community vaccinators working one or two years after the end of the project.</td>
</tr>
<tr>
<td>Ongoing and systematic administration of effective vaccine to healthy chickens.</td>
<td>Nº of chickens vaccinated per household.</td>
</tr>
<tr>
<td></td>
<td>Nº of chickens vaccinated per locality and district.</td>
</tr>
<tr>
<td></td>
<td>Nº of doses and vials of vaccine used by vaccinators.</td>
</tr>
<tr>
<td></td>
<td>Nº per year and timing of vaccination campaigns in each locality.</td>
</tr>
<tr>
<td></td>
<td>Vaccination costs (price of one dose and administration fee per chicken).</td>
</tr>
<tr>
<td>Increased Nº of chickens and eggs</td>
<td>Village chicken population per locality and per district.</td>
</tr>
<tr>
<td></td>
<td>Incidence of ND outbreaks per locality and per district.</td>
</tr>
<tr>
<td></td>
<td>Nº of chickens and eggs sold.</td>
</tr>
<tr>
<td></td>
<td>Nº of chickens and eggs consumed.</td>
</tr>
<tr>
<td></td>
<td>Nº and type of livestock owned by male and female staff.</td>
</tr>
<tr>
<td></td>
<td>Nº of children attending school.</td>
</tr>
<tr>
<td></td>
<td>Malnutrition rate in villages.</td>
</tr>
</tbody>
</table>
Ethno-veterinary knowledge and Newcastle disease

Ethnoveterinary medicine (sometimes also called veterinary anthropology) deals with folk beliefs, knowledge, skills, methods and practices pertaining to the health care of animals (Guèye 1999; Mathias-Mundy and McCorkle, 1989). Collecting information on ethnoveterinary knowledge in particular regions enables veterinarians to understand farmers’ knowledge of the disease transmission process, local remedies that may be worthy of further study and the type of animal husbandry currently being practiced (Alders and Spradbrow, 2001a).

Sources of further information on Ethnoveterinary knowledge

- Ethnoveterinary knowledge and Newcastle disease
  (Alders and Spradbrow, 2001a)
- Ethnoveterinary medicine against poultry diseases in African villages
  (Guèye, 1999)
- Ethnoveterinary Medicine: An Annotated Bibliography
  (Mathias-Mundy and McCorkle, 1989)
- Improvements in Rural Poultry in Developing Countries Website
  (http://www.vsap.uq.edu.au/RuralPoultry)
- Traditional Veterinary Medicine Website
  (http://pc4.sisc.ucl.ac.be/prelude.html)

General Recommendations

- Field activities must be built on the involvement of farmers and community vaccinators.
- The fewer the inputs provided at the start of a ND control programme, the more likely it is to be sustainable. While the livelihoods of village chicken farmers will improve as chicken numbers increase with the control of ND, the overall economic situation of the region is unlikely to change dramatically in the short term. Any input provided by a project (for example, cold chain, provision of transport for the distribution of vaccine, etc.) can continue after the project finishes only if the local infrastructure and local economy can maintain them.
- The characteristics of the ND vaccine selected for use in campaigns must be well-known and the necessary inputs must be available to enable the administration of effective vaccine to chickens in the field.

Further information on family poultry available on the Internet

The International Network for Family Poultry Development Website

Improvements in Rural Poultry in Developing Countries Website
http://www.vsap.uq.edu.au/RuralPoultry

Network for Smallholder Poultry Development Website
The ND control extension package produced in Mozambique contains:

An ND field manual - a 112 page manual entitled 'Controlling Newcastle disease in village chickens: A Field Manual' which aims to provide information to senior veterinarians and veterinary field staff on ND and its control.

An ND training manual – contains a three-day course to train farmers to become successful community vaccinators.

An ND laboratory manual – details the small-scale production and quality control of live, thermostable ND vaccine.

A flip chart - an illustrated A3 flip chart, with clear, largely self-explanatory line drawings and an accompanying narrative. It can be used for training to explain the characteristics of the vaccine and its application. Local frontline extension staff can translate the narrative into the appropriate local language.

A poster – a large black and white line drawing of a rooster, ND vaccine vials and an eye-dropper. The poster provides space for the local vaccinator to write the place, date, time and contact person for the next ND vaccination campaign.

A pamphlet - provides an introduction to ND and its control. It is printed on both sides of an A4 sheet and is easily reproduced. It is useful for front line extension staff, literate farmers, farmers’ associations and school children.

An ND vaccination calendar - this highlights the months in which vaccination campaigns should be implemented, prompts vaccinators to place their orders for vaccine well before the campaign begins and reminds distributors when they should have the vaccine in stock.

An ND vaccination song - recorded in Portuguese and three African languages by the Mozambican Musicians Association, the song was conceived after visiting one of the vaccine field trial sites. Its words are included in the Portuguese version of the ND field manual.

An audio-cassette with radio programmes - a radio drama and a question and answer programme in Portuguese and four African languages are broadcast, together with the ND vaccination song on national and community radio. The text of the programmes is included in the Portuguese version of the ND field manual to facilitate the local recording of programmes in other African languages.

A play - this was developed by a local theatre group with experience in community development after visiting one of the vaccine field trial sites in Mozambique. The play runs for 20 minutes and covers most aspects of ND control including the need to vaccinate before chickens get sick and how to pay for the vaccine. As the drama's text is included in the Portuguese version of the ND field manual, it can be used, in the form of role-plays, during the training of extension workers and community vaccinators. Role plays developed and performed by participants are encouraged during training sessions.
The English version of this ND control extension package is available from:

Improvements in Rural Poultry in Developing Countries
Website: Internet: http://www.vsap.uq.edu.au/RuralPoultry
The Australian Centre for International Agricultural Research
G.P.O. Box 1571
Canberra ACTS 2601 Australia
Fax: +61-2-62170501
E-mail: aciar@aciar.gov.au
Internet: http://www.aciar.gov.au

Portuguese version available from:
The National Veterinary Research Institute
C.P. 1922
Maputo, Mozambique
Fax: +258-1-475172
E-mail: inive@teledata.mz or inive@cfmnet.co.mz
Internet: http://www.vsap.uq.edu.au/RuralPoultry

French version available from:
Food and Agriculture Organisation of the United Nations

Developing Health and Family Planning Materials for Low-literate Audiences: A Guide
This booklet, prepared by the Programme for Appropriate Technology in Health (PATH), provides clear guidelines for the preparation of extension materials and gives information on establishing the target audience. Although the examples in the booklet refer to health and family planning issues, the approaches used may be easily adapted for use with livestock owners. The guide is available free of charge to developing country organisations or individuals from:

Communication Department
PATH
1990 M Street, N.W., Suite 700
Washington DC  20036  USA
Fax: +1-202-4571466
E-mail: info@path-dc.org
Internet: http://www.path.org

Quote from the OIE Manual of Standards for Veterinary Vaccines:
“Regulatory authorities in different countries have developed various approaches to ensuring the quality of vaccines. Although alike in their ultimate goal, these systems may vary in the emphasis given to control of the production process (process standards) in comparison with control through testing of the
final product (performance standards). The control procedures selected should be those that best fit the conditions under which vaccines are being produced.

The control standards and procedures established for a product define the risk or possibility of producing and releasing a product that is worthless, contaminated, dangerous, or harmful. The acceptable degree of risk may depend on the benefits to be gained by having the product available to prevent disease losses. Thus standards may justifiably vary from country to country or product to product, depending on local animal health conditions.

The optimal quality assurance system should address both production procedures and final product testing in proper balance. An absolutely fail-safe system that would result in no risk of releasing an unsatisfactory product would probably be too expensive to produce with regard to cost of production as well as control. Thus regulatory officials and manufacturers of vaccines must select control procedures that are capable of ensuring an acceptable low level of risk in relation to hazard. Such procedures, however, must not be burdensome to the extent that they inhibit the development and availability of the products needed to provide proper preventative medical care at a cost that is acceptable to the consumer.” OIE (2000b).
BIBLIOGRAPHY


