WORK METHODS AND PROCEDURES FOR
PLAGUE SURVEILLANCE AND CONTROL IN SOUTH AFRICA

by

Hongxing Zhou

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Supervisor: Dr H.J. Maarschalk

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ABSTRACT

Plague is a classic zoonosis caused by the bacterium *Yersinia pestis* and is subject to the *International Health Regulations, 1969*. In the last two millennia, plague has become widespread, with three pandemics occurring in the 6th, 14th and 20th centuries. Currently, plague outbreaks and epidemics still occur worldwide. This study attempts to develop formal work methods and procedures for plague surveillance and control by environmental health practitioners as a strategy to ensure that field data can be integrated within the municipal, provincial and national spheres of government.

A qualitative, explorative, descriptive, inductive and deductive research design was followed. A documentary research approach was employed as the primary method of data collection. To obtain additional information, both semi-structured personal interviews and physical observations during plague surveillance were adopted by the researcher.

The organisational structure of the health care system in South Africa was analysed to identify and explain the role and functions of relevant decision-makers related to the surveillance and control of plague within the different spheres of government. Legislative measures regarding plague surveillance and control were also presented.

As a prerequisite for the development of work methods and procedures for plague surveillance and control, the epidemiology of plague was discussed with emphasis on the distribution and characteristics of the disease in South Africa. Important rodent reservoirs and flea vectors of plague in South Africa were identified. Clinical manifestations, diagnosis and treatment of plague were described and discussed.

Within this qualitative study an attempt has been made to develop work methods
and procedures for plague surveillance and control in South Africa. Relevant field data forms to be used during plague surveillance and control strategies were also developed. Recommendations emanating from the study can be found in the final chapter.

**KEY WORDS:** Plague; Surveillance; Control; Work methods; Work procedures.
CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND AND PURPOSE OF THE STUDY

Plague is a classic zoonosis of animals and humans caused by the bacterium *Yersinia pestis* and is subject to the *International Health Regulations*, 1969. Over recorded history, plague has caused widespread pandemics among humans with high mortality rates. Between the middle of the 11\textsuperscript{th} century and the 14\textsuperscript{th} century, a plague pandemic referred to as the ‘Black Death’ occurred, causing an estimated 50 million deaths. Plague outbreaks and epidemics still occur worldwide. In South Africa, the last reported outbreak of plague was in Coega in the Eastern Cape Province in 1982, affecting 18 persons with one death.

The National Department of Health is currently developing *National plague guidelines*, to be used by Provincial Health Departments and municipalities for the development of plague surveillance and control strategies. The draft guidelines do not provide for detailed work methods and procedures on how to conduct the required epidemiological surveys. The draft guidelines also do not provide details on the control strategies to be performed once an outbreak of plague occurs (National Department of Health, 2004a). This is problematic because the scope and nature of the plague field data in each province/municipality will be different and therefore it will not be possible to integrate the data between the different spheres of government. The implication of this is that each province/municipality will develop its own work methods and procedures for conducting surveillance and control strategies. As a result, it will be impossible to consolidate the data within any of the three spheres of government, because the scope and nature of the data will not be the same.
From the above, it can be deduced that the work methods and procedures for plague surveillance and control must be exactly the same within each of the nine provinces for valid decisions to be made. Thus, the general purpose of this qualitative study is to develop formal work methods and procedures for plague surveillance and control by environmental health practitioners, as a strategy to ensure that field data can be integrated within the municipal, provincial and national spheres of government in South Africa.

1.2 SIGNIFICANCE OF THE STUDY

The development of formal work methods and procedures for plague surveillance and control are important, because they render legality and legitimacy to the actions of environmental health practitioners. The work methods and procedures to be developed will compel environmental health practitioners to unite and coordinate their efforts. They should also ensure that everyone cooperates in attaining set objectives (Maarschalk, 2003, p.10). The formal work methods and procedures to be developed will make the actions of environmental health practitioners lawful and legal. They will also eliminate confusion amongst plague surveillance and control personnel and make the actions of environmental health practitioners more purposeful and facilitate goal-directed training (Maarschalk, 2003, p.10; Botes, Brynard, Fourie & Roux, 1996, p.25). Formal work methods and procedures will enable the different spheres of government to integrate their data and to make information available from local municipal, health subdistrict, health district, provincial and national perspectives.

From the above, it can be deduced that it is important for South Africa to have effective plague surveillance and control strategies in place. The results of this study will contribute to a comprehensive knowledge of plague surveillance and control from a South African perspective.
1.3 RESEARCH OBJECTIVES

The primary and secondary objectives of the study will be identified in the following sections.

1.3.1 Primary objective

With this qualitative study an attempt will be made to develop formal work methods and procedures for plague surveillance and control by environmental health practitioners in the municipal, provincial and national spheres of government in South Africa. These work methods and procedures relate to:

- Human case surveillance and control;
- flea surveillance and control; and
- rodent surveillance and control.

In the next section, the secondary objectives of the study are discussed.

1.3.2 Secondary objectives

In terms of Section 1 of the National Health Act, 2003 (Act 61 of 2003), it can be deduced that plague surveillance and control are functions of environmental health practitioners in the municipal sphere of government. Since there are a number of role-players in national and provincial spheres whose decisions may influence the efficiency and/or effectivity of plague surveillance and control in the municipal sphere of government, it becomes important to analyse the organisational structure of the health care system in South Africa.

The surveillance and control of a disease is dependent on its epidemiology. It is
therefore important to have a thorough knowledge of the epidemiology of a disease when attempts are made to develop or improve work methods and procedures for its surveillance and control. The two secondary objectives of this study are therefore:

- To analyse the national health system of South Africa with specific reference to the organisational structure of plague surveillance and control; and
- to analyse and describe the epidemiology of plague, focusing on the distribution and characteristics of the disease in South Africa as a prerequisite for the development of formal work methods and procedures for the surveillance and control of plague in South Africa.

1.4 LITERATURE REVIEW

According to Leedy and Ormrod (2005, p.64), a literature review describes theoretical perspectives and previous research findings regarding the problem at hand. Creswell (2003, p.30) states that a literature review provides a framework for establishing the importance of the study as well as a benchmark for comparing the results of a study with other findings. With qualitative research, a literature review shows that the researcher has identified some gaps in previous research and that the proposed study will fill a demonstrated need (De Vos, Strydom, Fouché & Delport, 2002, p.263). In the following sections a review of the related literature on work methods and procedures, the national health system in South Africa, the epidemiology of plague, and plague surveillance and control will be presented.

1.4.1 Work methods and procedures

Booyens (2001, p.47) states that a procedure shows how a policy must be carried out and supplies a more specific guide for action than a policy does. Functions of procedures are communication, understanding, standardization and coordination.
Doty (1989, p.86) states that work methods should be developed so that a task can be performed in the shortest possible time, with the greatest possible ease, and with the most possible satisfaction to the operator. However, the said authors do not explain how to develop work methods and procedures. The revision and analysis of work methods and procedures are discussed in *Public administration and management: A guide to central, regional and municipal administration and management* (Botes, et al., 1996).

The need for formal work procedures is sufficiently illustrated in a publication by Cloete (1993), namely *Administration and management of health services*. The development of work procedures and the factors that inhibit their revision is discussed by Cloete (1996) in *Public administration and management*. The process for developing work methods and procedures for medical practitioners is presented by Andrews (1990) in *Medical practitioners and nursing professionals as public managers*. From an information system perspective the development of work methods and procedures for environmental health practitioners is discussed by Maarschalk (2003) in *A conceptual framework for the development of a South African environmental health information system for decision-making*, which provides detailed definitions for work methods and procedures from an environmental health viewpoint.

However, previous literature on work methods and procedures for plague surveillance and control are not available. A qualitative research design was applied by the researcher to develop formal work methods and procedures from a plague surveillance and control perspective.

### 1.4.2 National health system in South Africa

The South African government follows the Primary Health Care (PHC) philosophy
for health care service delivery. A single comprehensive, equitable and integrated national health system is being established in South Africa, based on national guidelines, priorities and standards (National Department of Health, 2004a). The organisational structure of the national health system is discussed in a publication by the National Department of Health, namely *A National Health Plan for South Africa* (African National Congress, 1994). Since 1995 various documents have been produced to provide guidance and to assist in implementing the new health system in South Africa. Documentation includes relevant legislation, articles in journals and newspapers, publications by relevant role-players and internet sources (Health Systems Trust, 2002).

In South Africa the policy guiding the District Health System (DHS) has developed steadily since 1994 (African National Congress, 1994). After 1994 the *Whiter Paper for the Transformation of the Health System in South Africa* advanced a wide range of policy measures in order to fundamentally transform health care service delivery in the country. Annually, the Health Systems Trust publishes the *South African Health Review*, which provides an annual and longer-term review of the development of the health care system in South Africa.

There are nine provinces within the provincial sphere of government in South Africa; each has its own provincial legislature. The organisational structure of health care services delivery may vary between provinces due to different provincial health legislations (Hall, Haynes & McCoy, 2002, pp.10-11). The generic organisational structure of health services in the nine provinces is similar to that of the national sphere of government, but it differs from a provincial perspective (Health Systems Trust, 1996, p.38). Both the *Local Government Municipal Systems Act, 2000* (Act 32 of 2000) and the *Local Government Municipal Structures Act, 1998* (Act 117 of 1998) are important legislative documents for analysing the health care system in the municipal sphere of government.
However, the organisational structure of the national health system in South Africa has not been researched from a plague surveillance and control perspective. Legislation forms the foundation of the health care system in any democratic country. In this study relevant legislative documents for plague surveillance and control will be reviewed and discussed. The *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996) and the *National Health Act, 2003* (Act 61 of 2003) are primary legislative documents of the national health system in South Africa. According to Section 1 of the *National Health Act, 2003* (Act 61 of 2003), the surveillance and prevention of communicable diseases, including vector control, are two of the functions of environmental health practitioners in the municipal sphere of government. It can be deduced that plague surveillance and control take place via its health care system in South Africa. In this study the organisational structure of the national health system will be presented from a plague surveillance and control perspective. The relevant role-players relating to plague surveillance and control within different spheres of government will be presented and discussed.

### 1.4.3 The epidemiology of plague

Plague is a communicable disease caused by the bacterium *Yersinia pestis* and is subject to the *International Health Regulations, 1969* (World Health Organisation, 1983). Humans are extremely susceptible to plague and may be infected either directly or indirectly. There are three main forms of plague in humans, namely bubonic, septicaemic and pneumonic plague. The bubonic form is the most common, and is the result of a bite from an infected flea. Pneumonic plague is acquired by inhaling respiratory droplets from infected humans or animals (such as dogs and cats). The pneumonic form is often fatal within 48 hours. The mortality rate is approximately 50 to 60 percent for treated cases, and nearly 100 percent for untreated cases. The general clinical knowledge of the disease is presented in *Plague: Current, comprehensive information on pathogenesis, microbiology,*
Plague was known as the ‘Black Death’ during the fourteenth century, causing an estimated 50 million deaths. Outbreaks and epidemics still occur worldwide. The current status of human plague can be obtained from the *Weekly Epidemiological Reports* published by the World Health Organisation (2004a). In a fact sheet of plague occurrence compiled by the World Health Organisation, nine countries reported 2 118 cases and 182 deaths in 2003. Ninety-nine percent of these cases, and 98.9 percent of the deaths, were reported from Africa (World Health Organisation, 2005a). A new resource list on the epidemiology of plague was updated by the Infectious Diseases Society of America (IDSA) and the Centers for Disease Control and Prevention (Center for Infectious Disease Research and Policy, 2005b).

The epidemiology of plague in South Africa is described and analysed in *Plague guidelines* (draft) and in the *Plague Manual* (National Department of Health, 2004a; World Health Organisation, 1999a). The last reported outbreak of plague in South Africa was from Coega in the Eastern Cape Province in 1982, during which 18 cases with one death were reported (Tikhomirov, 1999, p. 30). In South Africa a number of natural foci of plague (namely the Eastern and Northern Cape, Free State, Mpumalanga and Gauteng) have been identified, and relevant prevention and control measures have been developed which have made it possible to prevent plague outbreaks (South African Department of Health and Welfare, 1982).

In this study, the epidemiology of plague will be discussed with the focus on characteristics in South Africa. Information on South African rodent reservoirs can be obtained from a number of sources, such as *The complete book of Southern African mammals* (Mills & Hes, 1997) and *The rodents of southern Africa: Notes on*
their identification, distribution, ecology and taxonomy (De Graaff, 1981). The flea vector in South Africa was introduced in *Siphonaptera of Southern Africa: Handbook for the identification of fleas* (Segerman, 1995). The abovementioned books were compiled from a zoological perspective. This study will identify rodent reservoirs and flea vectors from a plague surveillance and control perspective.

### 1.4.4 Plague surveillance and control

A comprehensive knowledge of plague was introduced by Pollitzer in *Plague* (Pollitzer, 1954). In 1999 a *Plague Manual* was published by the World Health Organisation to deal with the epidemiology, surveillance and control of the disease from an international perspective. In addition, the basic requirements and suggestions on how responsibilities for various surveillance tasks should be allocated to local, regional or national health spheres are described in the said manual (World Health Organisation, 1999a). From both national and provincial perspectives the responsibilities of the different spheres of government, as well as the duties of plague outbreak response teams, are described in the *Guidelines for outbreak response and epidemic management* (National Department of Health, 2000).

A guideline for plague case definitions can be found in *Case definitions for infectious conditions under public health surveillance* (Centers for Disease Control and Prevention, 1997). In 2002 a report entitled *Plague surveillance and outbreak response* was published by the World Health Organisation. Public health procedures for plague are depicted in *Interim guidelines for action in the event of a deliberate release plague* (Health Protection Agency, 2005). Recently, the World Health Organisation has enhanced its molecular epidemiology capabilities in a publication entitled *Pathogen surveillance* in order to better identify the sources and spread of strains isolated from human plague cases or outbreaks in animal populations.
A project named RatZooMan (Rodent Zoonosis Management) investigated the sanitary risks linked to the proximity of rodents in rural and peri-urban areas of South-Eastern Africa. The RatZooMan project has published two annual reports, which provide the results of the project including work methods and procedures for rodent surveillance (Leirs & Belmain, 2004). Work methods and procedures for rodent and flea surveillance are described in *Prevention and control of plague: Technical guide 103* (Harrison, 1995). Rodent trapping and processing is described and discussed in *Methods for trapping and sampling small mammals for virologic testing* (Mills, Childs, Ksiazek et al, 1995).

Information for rodent control is described in *The control of rats with rodenticides: A complete guide to best practice* (Central Science Laboratory, 2005). Flea control measures are discussed from two perspectives, namely fleas as a nuisance and fleas as vector of diseases in *Vector control: Methods for use by individuals and communities* (Rozendaal, 1997). However, these documents mentioned above do not provide for the detailed work methods and procedures on how to conduct plague surveillance and control. The results of this study will contribute to detailed work methods and procedures for the surveillance and control of plague. In the next section the research design and methodology of the study are justified and discussed.

### 1.5 RESEARCH DESIGN AND METHODOLOGY

Research methodology refers to the overall approach to the research process, from the theoretical underpinning to the collection and the analysis of data (Collis & Hussey, 2003, p.55). For the purpose of this study, the research design, methods of data collection and data analysis are discussed below.
1.5.1 Research design

According to Punch (2000, p. 52), a research design is the basic plan for research. It shows how the research questions will be connected to the data and what tools and procedures will be used in answering them. For the purpose of this study, which is to develop work methods and procedures for plague surveillance and control in South Africa, a qualitative, explorative, descriptive, inductive and deductive research design will be used.

1.5.1.1 Qualitative research

Qualitative research is typically used to answer questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participants' point of view (Leedy & Ormrod, 2005, p.94). A qualitative researcher seeks to establish the meaning of a phenomenon from the views of participants. Lancaster (2005, p.67) argues that the qualitative research approach is mainly used when the researcher needs to gather and analyse detailed data that cannot be mathematically or statistically interpreted and analysed, such as ideas, attitudes or feelings.

Creswell (2003, p. 182) argues that qualitative research is fundamentally interpretive. This means that the researcher makes interpretations of the data and then draws conclusions about their meaning, personally and theoretically. Leedy and Ormrod (2005, pp.134-135) state that qualitative research comprises the following characteristics, namely: description; interpretation; verification and evaluation. Furthermore, the qualitative researcher collects data on an instrument or gathers information on a behavioural checklist (Creswell, 2003, p.17). In order to conduct and complete this study, the researcher will study and analyse relevant documents, describe and explain the nature of plague, and finally draw conclusions to develop
work methods and procedures for plague surveillance and control in South Africa. This study is therefore based on a qualitative research approach.

1.5.1.2 Exploratory research

Exploratory research is conducted when few or no earlier studies have been undertaken that may serve as a source of verifiable data. Exploratory research assesses which existing theories and concepts may be applied to a problem, or whether new ones should be developed (Collis & Hussey, 2003, p.11). According to Silverman (2000, p.9), exploratory research is undertaken to make preliminary investigations into relatively unknown areas of research. An outstanding characteristic of exploratory research is that it is ideally undertaken when few or no earlier studies have been conducted on a research problem that may serve to verify findings (Collis & Hussey, 2003, p.10). The topic of this research, ‘work methods and procedures for plague surveillance and control in South Africa’ is relatively new and lacks previous research, therefore it conforms to the characteristics of an exploratory study.

1.5.1.3 Descriptive research

Descriptive research is research that describes phenomena as they exist. It is used to identify and obtain information on the characteristics of a particular problem or issue (Collis & Hussey, 2003, p.11). The aim of descriptive research is to describe a subject, often by creating a profile of a group of problems, people or events (Blumberg, Cooper & Schindler, 2005, p.10). Descriptive research can be qualitative or quantitative in nature. In qualitative research, according to Rubin and Babbie (2001, p.125), descriptive research refers to a more intensive examination of phenomena and their deeper meanings.
Descriptive research presents a picture of the specific details of a situation and focuses on ‘how’ and ‘why’ questions (De Vos, Strydom, Fouché & Delport, 2002, p.109). In this study the researcher will describe the current status of plague surveillance and control in South Africa, including a description of the organisational structure of the national health system and the epidemiology of plague. The work methods and procedures in relation to plague surveillance and control that will be developed will also be described. The study will therefore also comply with the characteristics of descriptive research.

1.5.1.4 Inductive research

Scientific research can be divided into two categories, namely inductive and deductive. Inductive research reflects a reasoning process in which a theory is developed from the observation of empirical reality. In addition, the empirical observations can be based on personal experience (Lancaster, 2005, p.25). According to Collis and Hussey (2003, p.15), inductive research involves moving from individual observations to statements of general patterns or laws. It is also referred to as moving from the specific to the general.

Lancaster (2005, pp.25-26) argues that inductive research is better suited to qualitative data. Inductive research and investigations begin from a description or observation and then move towards an explanation. In this study, relevant conditions/situations within the Nelson Mandela Metropolitan Municipality (NMMM) and the Eastern Cape Provincial Health Department will be analysed as specific cases in an attempt to explain the general conditions of other municipalities and provincial health departments in South Africa. For example, the organisational structure of the NMMM will be described as a model of the organisational structure in the municipal sphere of government. Furthermore, the researcher will draw conclusions on the problems investigated from the qualitative data collected. An
inductive research approach is thus appropriate in this study.

1.5.1.5 Deductive research

According to Lancaster (2005, p.22), deductive research develops theories or hypotheses and then tests the theories or hypotheses through empirical observation. For this reason, the deductive research method is referred to as moving from the general to the particular (Collis & Hussey, 2003, p.15). During this study, general theories and measures for communicable disease prevention will be used to develop work methods and procedures for plague surveillance and control. The deductive research method is therefore also employed in this study. In the following sections the methods of data collection will be discussed.

1.5.2 Methods of data collection

Qualitative research uses multiple methods that are interactive and humanistic (Creswell, 2003, p.181). The actual methods of data collection for this study will be based on the traditional qualitative research methods, namely documentary research, interviews and observations. In this study documentary research will be the primary method of data collection.

1.5.2.1 Documentary research

Documentary research is a basic method of qualitative data collection (Creswell, 2003, p.188; Mason, 1996, p.71). Documentary studies refer to documents that are being studied and analysed for the purpose of scientific research (De Vos, et al., 2002, p.322). However, McCulloch (2005, p.4) argues that social scientists have largely neglected and ignored the use of documentary research in recent years. For some research projects the focus of data collection can be entirely on documentary
research (Blaxter, Hughes & Tight, 2001, p.167). For the purpose of this study - to develop formal work methods and procedures for plague surveillance and control - documentary research is a more appropriate choice for data collection.

When documentary sources are studied, it is of cardinal importance that the researcher evaluates the documents in terms of the criteria of usefulness, namely authenticity, credibility, representativeness and meaning (Denscombe, 2003, p.220; May, 2001, p.190). In order to conduct a high quality of documentary research, the researcher will collect data from the following sources: government legislation, government publications, official statistics, other national publications and international organisation publications (Daly, Kellehear & Gliksman, 1997, pp.132-134). Furthermore, since plague surveillance and control are worldwide phenomena, the documentary research will have an international basis.

As discussed above documentary research is the primary method of data collection for this study. Relevant documentary sources will be identified and analysed in terms of the abovementioned criteria in order to obtain sufficient and valid information.

1.5.2.2 Interviews

Interviews are effective and powerful ways of accessing people’s perceptions, meanings, definitions of situations and constructions of reality (Punch, 2005, p.168). The interview is one of the main data collection methods in qualitative research. In qualitative research the inquirer seeks to examine an issue related to the opinions of individuals who are interviewed to determine how they have personally experienced the phenomena (Creswell, 2003, p.21). Interviews can be classified into three types, namely structured, semi-structured (focused) and unstructured (Punch, 2005, p.169; May, 2001, pp.121-126).
The semi-structured interview is designed to focus on the terms of the topics covered and yet is flexible enough so that it is possible to steer questions into areas that appear promising from the point of view of providing rich data and additional insights (Lancaster, 2005, p.134). The researcher uses semi-structured interviews to gain detailed information on participants’ beliefs about a particular topic. This interview technique gives the researcher and the participant much more flexibility (De Vos et al., 2002, p.302).

In order to obtain additional information (such as on the organisational structure of the health care system, current status of plague outbreak response teams, functional and managerial problems), semi-structured personal interviews with relevant role-players in the provincial and municipal spheres of government were conducted, namely with managerial and line-function personnel of the Department of Health in the Eastern Cape Province, as well as similar personnel in the Health and Environmental Health Business Unit of the Nelson Mandela Metropolitan Municipality (NMMM) in Port Elizabeth.

Letters were written to the relevant managers to ask permission to conduct interviews with managerial and line-function personnel that are responsible for plague surveillance and control (see Annexure 1 and 2). With semi-structured interviews the researcher will have a set of predetermined and open-ended questions on an interview schedule (De Vos, et al., 2002, p.302). Questions on the interview schedule are attached as Annexure 3. Not every question needs to be answered; a participant can choose which question he/she wishes to answer at a specific time. The participant is thus allowed a key role in determining how the interview proceeds (De Vos, et al., 2002, p.303). The interviews were conducted at the participants’ offices. Permission was asked from the participants to record the interviews by using a tape recorder. The researcher made notes during the interviews. After the interview, each recording was labelled with the date and name
of the participant (see a list of the interviews attached). In the following section, observation as a data collection method is discussed.

1.5.2.3 Observations

Observations offer the researcher a distinct method of data collection, since qualitative research takes place in a natural setting (Creswell, 2003, p.181; Denscombe, 2003, p.192). In this situation the researcher seeks to establish the meaning of a phenomenon from the viewpoint of the participants. Qualitative research therefore involves field observations (Creswell, 2003, pp.20-21). According to Leedy and Ormrod (2005, p.145), qualitative research approaches to observation are more unstructured. A qualitative researcher may make observations either as an outsider or a participant observer.

In order to obtain additional information on work methods and procedures for plague surveillance and control, the researcher will work with plague surveillance personnel at the Nelson Mandela Metropolitan Municipality (NMMM). Relevant environmental health staff of the NMMM are currently involved with a plague surveillance project, namely the RatZooMan project. The relevant work methods and procedures of the said personnel will be observed and manually recorded by the researcher (field notes). Informed consent should be obtained from the participants prior to the start of the study (see Annexure 4). This will enable an analysis of their current work methods and procedures to be done and to recommend alternative/improved ones.

1.5.3 Data analysis

Data analysis is referred to as the process of bringing order, structure and meaning to the mass of collected data (De Vos, et al., 2002, p. 339). Creswell (1994, pp.143-144) states that the researcher is the human instrument in a qualitative
research design. The process of qualitative data analysis will be based on data reduction and interpretation. Qualitative data analysis will be conducted as an activity simultaneously with data collection, data interpretation and narrative report writing. Qualitative data analysis is an ongoing process involving continual reflection about the data, asking analytical questions and writing memos throughout the study. Qualitative data analysis is therefore not sharply separated from the other activities in the process, such as data collection and writing of the results (Creswell, 2003, p. 190).

Qualitative research produces a large volume of data in a variety of formats, such as fieldwork notes from observations, transcripts from interviews and documents. An interactive data analysis model has been developed which comprises three components, namely data reduction, data display and drawing and verifying of the conclusions. These three components are interwoven and concurrent throughout the data analysis process. This involves three operations: coding; memoing; and developing propositions (Punch, 2005, pp.197-199).

Creswell (1998, pp.142-165) believes that the process of qualitative data analysis and interpretation can be represented in analytical circles rather than by using a fixed linear approach. Denscombe (2003, pp. 270-273) describes the procedures for qualitative data analysis in the following steps:

- Descriptive accounts of the situation;
- coding and categorizing the data;
- identification of themes and relationships;
- returning to the field to check out emerging explanations;
- developing a set of generalizations; and
- improving any relevant existing theories.
In this study qualitative data collected from the documentary research, semi-structured interviews and observations will be analysed by means of the above discussed approach. The trustworthiness of the study is discussed in the next section.

1.6 TRUSTWORTHINESS

Trustworthiness represents the measures built into the process of research by the researcher to ensure that the study is valid and that the results are reliable. Lincoln and Guba (1985, p.290) have developed a trustworthiness model that refers to the criteria of high quality research. Lincoln and Guba’s model comprises four aspects that reflect the assumptions of qualitative research, namely credibility, transferability, dependability and conformability. The trustworthiness of this study in terms of Lincoln and Cuba’s model is discussed below.

1.6.1 Credibility

Credibility concerns the internal validity, in which the goal is to demonstrate that the inquiry was conducted in such a manner as to ensure that the subject was accurately identified and described (De Vos, et al., 2002, p.351). According to Krefting (1991, pp.215-217), strategies to ensure credibility include the authority of the researcher, field experiences, interview techniques, member checking, peer examination, reflexivity and structural coherence. In this study data are mainly collected from authoritative documents (such as formal publications from the World Health Organisation). Field experiences of the researcher will enhance the credibility of the study. Furthermore, the supervisor, an expert in this field, will also monitor the credibility of the study.
1.6.2 Transferability

Transferability is the external validity and refers to the degree or extent to which the findings of the research data may be transferred to other groups other than the original study (De Vos, et al., 2002, p.352). According to De Vos (2002, p.352), the strategy of triangulating multiple sources of data can enhance a study’s transferability. This means that designing a research in which multiple cases, multiple informants or more than one data collection method are employed can strengthen the study’s usefulness for other settings. In this study the strategy of triangulating multiple sources for data collection will be used to strengthen the transferability.

1.6.3 Dependability

Dependability is related to reliability and is the criterion for consistency. This refers to the researcher’s attempt to account for the changing conditions in the chosen research phenomenon and the changes in design (De Vos et al., 2002, p.352). Strategies to ensure dependability in this study will be a dense description of research methods and triangulation (Krefting, 1991, p.217).

1.6.4 Conformability

Conformability refers to the objectivity or neutrality of the research (De Vos et al., 2002, p. 352; Lincoln & Guba, 1985, p.290). This means that no prejudice is evident in the research process and results. According to Krefting (1991, p.217), strategies to ensure conformability include conformability audit, triangulation and reflexivity. Both the research process and research results will be audited by the supervisor to ensure the conformability of the study. In the next section the pilot study will be identified and discussed.
1.7 PILOT STUDY

A pilot study is defined as the process whereby the research design for a prospective survey is tested. The pilot study can be regarded as a small-scale trial run of all the aspects planned for use in the main inquiry (De Vos et al., 2002, p. 211). According to De Vos, et al. (2002, pp. 211-215), a pilot study will involve a literature study and interviews with experts. In this study a literature study was conducted by the researcher and monitored by the supervisor to ensure that the findings and results of the study meet the purpose of the study. An interview schedule was used with participants who are working at the Nelson Mandela Metropolitan Municipality to test the questions so as to ensure that the right questions are being asked. The plan of the study is stated in the section that follows.

1.8 PLAN OF THE STUDY

Chapter One gives the background to the study, leading to the introduction and problem statement in question. The purpose, significance and research objectives of the study are presented in this chapter. A literature review is presented within the context of the study. Furthermore, the research design and methodology to be adopted for the study are explained and motivated. Chapter One also contains a section that defines important concepts used in the study.

In Chapter Two the national health care system of South Africa is analysed, with specific reference to the organisational structure of plague surveillance and control. The said organisational structure is discussed from national, provincial and municipal perspectives. Legislative documents and measures related to plague surveillance and control are also introduced.

Chapter Three provides a comprehensive discussion of plague, with specific
references to the epidemiology of the disease. This chapter deals with the historical background, geographical distribution and basic clinical knowledge of the disease from a South African perspective. The important reservoirs and vectors of plague in South Africa are introduced. This chapter provides the theoretical underpinning to develop formal work methods and procedures for plague surveillance and control.

**Chapter Four** deals with work methods and procedures for plague surveillance, namely: basic principles of plague surveillance, human plague surveillance, rodent surveillance and flea surveillance. The methods and procedures for human plague surveillance are discussed from three perspectives, namely notifiable diseases reporting, detection of a plague outbreak and investigation of an outbreak.

**Chapter Five** focuses on work methods and procedures for plague control. In this chapter plague control is discussed from four perspectives, namely basic strategies for plague control; plague outbreak control; flea control and rodent control. Outbreak response and control are identified from two perspectives, namely the establishment of a Plague Outbreak Control Team and the implementation of outbreak control strategies. In this chapter the use of pesticides for controlling flea vectors and rodent reservoirs is emphasised.

**Chapter Six** presents a conclusion with emphasis on the findings of the study. Appropriate recommendations for the study are also made.

1.9 **DEFINITION OF KEY CONCEPTS**

In the following sections the meanings of important terms and functions to be used in the study are clarified.
1.9.1 Plague

Plague is a vector-borne disease caused by the bacterium *Yersinia pestis* and is transmitted between rodents and to other animals *via* wild rodent fleas, cannibalism or contaminated soil. Plague exists in nature independent of human populations and their activity. Domestic plague is intimately associated with rodents living with humans and can produce epidemics in both human and animal populations (Tikhomirov, 1999, p.11). The Centers for Disease Control and Prevention (1997) defines plague as ‘an infectious disease of animals and humans caused by the bacterium *Yersinia pestis*.‘

1.9.2 Plague outbreak

A disease outbreak is referred to as an epidemic that is limited to a localised increase in the incidence of the disease (World Health Organisation, 1999b, p. 150). According to Connolly (2005, p.107), an outbreak is defined as the occurrence of a number of cases of a disease that is unusually large or unexpected for a given place and time. In this study a plague outbreak can be defined as a sudden occurrence of one or more confirmed human cases within a specific geographic area.

1.9.3 Plague surveillance

The World Health Organisation (1999b) defines surveillance as the systematic ongoing collection, collation and analysis of data and the timely dissemination of public health information for assessment and action, as necessary. Surveillance is also defined as ‘the process of systematic collection, orderly consolidation and evaluation of pertinent data with prompt dissemination of the results to those who need to know, particularly those who are in a position to take action’ (Thacker, 1996, p.11). Plague surveillance is therefore a continuous and systematic process of
collection, analysis, interpretation and dissemination of descriptive information of plague-monitoring activities.

1.9.4 Plague control

Control of infectious diseases refers to the actions and programmes directed towards reducing disease incidence and prevalence (Kim-Farley, 1997, p.1561). Control of plague transmission is directed at suppressing the rodent reservoirs and flea vectors of the disease (Gratz, 1999b, p.97). Plague control can therefore be defined as the actions and programmes directed toward reducing plague incidences and prevalence by suppressing the conditions that encourage rodent reservoirs and flea vectors of the disease.

1.9.5 Work methods

A method is defined as the way in which each step of a procedure is to be performed (Liebler & McConnell, 1999). It is also defined as ‘a special form of procedure’ or ‘orderliness; regular habits’ (Thompson, 1995). Work methods in this study will be defined as the procedure of a sequence of actions by environmental health practitioners to accomplish the task of plague surveillance and control.

1.9.6 Work procedures

A procedure is a series of interrelated sequential steps established for the accomplishment of a task (Kanawaty, 1992). A procedure shows how a policy must be carried out and supplies a more detailed guide to action than a policy does. According to Booyens (2001, p.47), the purpose of procedures is to be used for communication, understanding, standardization and coordination. In this study work procedures will be defined as a series of scientifically formulated and interdependent
consecutive steps which must be taken towards the achievement of a set objective (Andrews, 1990; Maarschalk, 2003).

In the following chapter the organisational structure for plague surveillance and control in South Africa will be discussed. The chapter attempts to identify and discuss the decision-makers and role-players related to the surveillance and control of plague within the different spheres of government.
CHAPTER TWO
ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE
AND CONTROL IN SOUTH AFRICA

2.1 INTRODUCTION

Plague surveillance and control are functions of environmental health practitioners in the municipal sphere of government. In order to develop work methods and procedures for the surveillance and control of plague, the relevant health care services where the activities of plague surveillance and control take place must first be clarified. Furthermore, there are a number of role-players in national and provincial spheres of government whose decisions may influence directly or indirectly the efficiency of plague surveillance and control in the municipal sphere of government. It is therefore necessary to identify and explain the role of the decision-makers and other role-players related to the surveillance and control of plague within the different spheres of government.

The purpose of this chapter is to achieve a comprehensive understanding of the function and relationship of the said role-players within the national health care system. Firstly, legislation related to the health care system in South Africa, as well as legislative measures regarding plague surveillance and control will be discussed.

Secondly, the organisational structure of the national health system in South Africa will be analysed from national, provincial and municipal perspectives. The analysis will focus on the relevant health services and important decision-makers related to the surveillance and control of plague. Since the District Health System is a fundamental organisational framework of the health care system in South Africa, the District Health System will be discussed from the health district, health subdistrict and local municipal perspectives.
Lastly, municipal health services (MHS) are emphasized. This section will also explain how the decisions of the role-players within the national and provincial spheres of government can influence the efficiency of plague surveillance and control in the municipal sphere of government. Legislation related to the health care system in South Africa is discussed below.

2.2 REVIEW OF LEGISLATION ON THE HEALTH CARE SYSTEM IN SOUTH AFRICA

According to Rensburg (2004, p.118), legislation provides certainty to the institution in its policy and establishes structures and mechanisms to put policy into practice. It is therefore necessary to discuss relevant legislation when attempts are made to analyse the organisational structure for plague surveillance and control in South Africa. The *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996) is discussed firstly.


In this study the *Constitution* means the *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996), which is the supreme law and the foundation of the health care system in South Africa. For the purpose of this study, the contents of the health right in the *Constitution* are summarised as follows (South Africa, 1996, Sections 24-28). All South African citizens have the following health rights:

- An environment that is not harmful to their health and well-being;
- access to health care services;
- emergency medical treatment; and
- basic nutrition, shelter, basic health care services and social services.
From the above it can be deduced that developing and maintaining an effective system for plague surveillance and control is important to protect the Constitutional health rights of individuals living in South Africa. The Constitution gives conspicuous expression to the fundamental right to health care for all; and also rules that the delivery of health care services is a concurrent function amongst the three spheres of government within a framework of cooperative governance (Rensburg, 2004, p.137). The Constitution prescribes the health care system from three spheres, namely national, provincial and municipal (see Annexure 5). However, the Constitution does not state or prescribe details of the health care system; these are outlined in the National Health Act, 2003 (Act 61 of 2003), which will be discussed below.

2.2.2 National Health Act, 2003 (Act 61 of 2003)

The National Health Act, 2003 (Act 61 of 2003) is important legislation for the implementation of the Constitutional health rights. According to Tshabalala-Msimang (2004), the said Act was promulgated to provide a framework for a structured uniform national health system, encompassing both the public and private health sectors within the country, taking into account the obligations imposed by the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) and other laws of the national, provincial and local governments related to health services.

One of the aims of the National Health Act, 2003 (Act 61 of 2003) is to unite the various elements of the national health system in a common goal to actively promote and improve the national health system in South Africa (South Africa, 2003, Preamble). The objectives of the National Health Act, 2003 (Act 61 of 2003) are to regulate national health and to provide uniformity in respect of health services across the nation by establishing a national health system that encompasses public and private providers of health services (South Africa, 2003, Section 2). For the
Purpose of this study, the contents of the said Act regarding the organisational structure of the national health system are shown in Table 1.

### TABLE 1:
**SECTIONS IN THE NATIONAL HEALTH ACT, 2003 (ACT 61 OF 2003) THAT DEAL WITH THE ORGANISATIONAL STRUCTURE OF THE NATIONAL HEALTH CARE SYSTEM**

<table>
<thead>
<tr>
<th>Section</th>
<th>National Health</th>
<th>Provincial Health</th>
<th>District Health System</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>General functions of national department</td>
<td>25 Provincial health services and general functions of provincial departments</td>
<td>29 Establishment of a district health system</td>
</tr>
<tr>
<td>22</td>
<td>Establishment and composition of the National Health Council</td>
<td>26 Establishment and composition of Provincial Health Councils</td>
<td>30 Division of health districts into subdistricts</td>
</tr>
<tr>
<td>23</td>
<td>Functions of the National Health Council</td>
<td>27 Functions of Provincial Health Councils</td>
<td>31 Establishment of district health councils</td>
</tr>
<tr>
<td>24</td>
<td>National Consultative Health Forum</td>
<td>28 Provincial consultative bodies</td>
<td>32 Health services to be provided by municipalities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>33 Preparation of district health plans</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>34 Transitional arrangements concerning municipal health services</td>
</tr>
</tbody>
</table>

Source: Adapted from the *National Health Act, 2003* (Act 61 of 2003).

From Table 1, it can be deduced that the *National Health Act, 2003* (Act 61 of 2003) delineates health services in three spheres of government, namely national, provincial and municipal. It also delineates the different functions and responsibilities of each sphere of government. In the following sections legislative documents
relating to the surveillance and control of plague as a disease entity are presented. The *Health Act, 1977* (Act 63 of 1977) is firstly discussed.

### 2.2.3 Health Act, 1977 (Act 63 of 1977)

Plague is one of the 33 ‘notifiable medical conditions’ listed in the *Health Act, 1977* (Act 63 of 1977). Some of these 33 notifiable medical conditions have been split into various components, resulting in over 45 distinct medical conditions (National Department of Health, 2000, p.2). The legal responsibilities of the key role-players in the notification system are stipulated in the said Act. For the purpose of this study, the relevant legal responsibilities are presented as follows (South Africa, 1977, Sections 28, 32, 45 and 47):

- Every local authority shall, at the end of each week, transmit to the Director-General, in the prescribed manner particulars of all cases of notifiable medical conditions which have been reported during the week;
- The Minister may make regulations relating to the notification by medical practitioners or other categories of persons, of cases of notifiable medical conditions, the records to be kept by local authorities of such notifications, and the transmission by local authorities of such notifications to the Director-General; and
- When a notifiable medical condition is prevalent within the district of a local authority, any person who has reason to believe that any other person has died within such district, shall as soon as possible report accordingly to the local authority concerned.

From the above it can be deduced that the current communicable disease reporting system in South Africa is based on the *Health Act, 1977* (Act 63 of 1977). As an important measure of plague surveillance, notifiable disease reporting will be
discussed further in Chapter Four (see Section 4.3.1). Currently, the *Health Act*, 1977 (Act 63 of 1977), has been replaced by the *National Health Act*, 2003 (Act 61 of 2003). However, the abovementioned sections in the *Health Act*, 1977 (Act 63 of 1977) are still applicable. The *International Health Regulations Act*, 1974 (Act 28 of 1974) is introduced in the section that follows.

### 2.2.4 *International Health Regulations Act*, 1974 (Act 28 of 1974)

The *International Health Regulations Act*, 1974 (Act 28 of 1974) describes plague as ‘a zoonotic disease affecting rodents and transmitted by fleas from rats to other animals and to humans’. One purpose of this Act is to deal with the measures applicable to the prevention of the importation of plague from infested areas by ships, aircraft, land transport, human beings and goods and the de-ratting of ships and buildings. According to the said Act (South Africa, 1974, pp.60-63):

- International travellers, suspected of significant exposure prior to their departure on an international voyage from an area where there is an epidemic of pulmonary plague, shall be placed in isolation for six days after their last exposure;
- On the arrival of an infected ship or ship suspected of infection, or an infected aircraft, travellers may be disinfected and kept under surveillance for a period of not more than six days from the date of arrival; and
- Travellers in rural areas of plague endemic regions may be at risk, particularly if camping or hunting or if contact with rodents takes place. Travellers should avoid any contact with dead or live rodents.

From the above, it can be deduced that the *International Health Regulations Act*, 1974 (Act 28 of 1974) is important legislation for the prevention and control of plague. However, the said Act does not prescribe the work methods and procedures for the
surveillance and control of plague. The *International Health Regulations*, 1969/2005 are discussed below.

### 2.2.5 *International Health Regulations*, 1969/2005

The *International Health Regulations*, 1969 is an international code of conduct to protect against the spread of serious risks to public health and the unnecessary or excessive use of restrictions in traffic or trade. In terms of Chapter I of the said regulations, plague is subject to the *International Health Regulations*, 1969. Every case must be reported to the World Health Organisation within 24 hours, while neighboring countries must be informed of the first plague case in any area previously free of the disease. Newly discovered or reactivated foci of plague among rodents should be reported as well (World Health Organisation, 1983).

The revised *International Health Regulations*, 2005 (IHR, 2005) were adopted by the 58th World Health Assembly in May 2005. The purpose and scope of the IHR, 2005 is to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade (World Health Organisation, 2005c, p.9).

One of the important characteristics of the IHR, 2005 is the establishment of a global surveillance system for ‘public health emergencies of international concern’. A public health emergency of international concern means an extraordinary event which is determined by the World Health Organisation’s Director-General with the use of risk assessment criteria to (World Health Organisation, 2005c, p.8):

- Constitute a public health risk to other States through the international spread of disease; and
potentially require a coordinated international response.

The risk assessment criteria refer to the algorithm (decision instrument) for the assessment and notification of the public health emergencies of international concern (see Annexure 6). According to the revised *International Health Regulations, 2005*, pneumonic plague is one potential international public health concern that always leads to utilisation of the algorithm. The occurrence of a suspected case in an area not known to be endemic for plague should be reported to the World Health Organisation (2005c, p.45).

The new IHR, 2005 will not come into force until 15 June 2007. In addition, the IHR, 2005 describes key elements of the surveillance process from local, intermediate, national and global perspectives (World Health Organisation, 2005c, pp.42-43). Other legislative documents for plague surveillance and control are presented in the following section.

### 2.2.6 Other legislative documents for plague surveillance and control

The *Regulations relating to communicable diseases and the notification of notifiable medical conditions*, 1987 (Regulation 2438 of 1987) were promulgated in terms of Sections 32 to 34 of the *Health Act, 1977* (Act 63 of 1977). In terms of Section 2 of the said regulations, a local authority carries the responsibility for the prevention and restriction of and control over communicable diseases when a communicable disease is present or has occurred in its area of jurisdiction. The duty and responsibility of the ‘medical officer of health’, the ‘chief administrative officer’ of a local authority and the ‘Director-General’ are described individually in the event of any communicable disease occurring. In Section 19 of the regulations the procedures of notification for ‘notifiable medical conditions’ are emphasised. In addition, the guidelines of quarantine, carriers of communicable diseases, measures
relating to the import and export of bodies, immunisation and emergency measures for communicable diseases are dealt with in the said regulations (South Africa, 1987).

From the above, it can be deduced that the *Regulations relating to communicable diseases and the notification of notifiable medical conditions*, 1987 (Regulation 2438 of 1987) constitute an important legislative document that authorises local authorities, instructs officers and individuals to prevent, control and notify the notifiable medical conditions, including plague.

The *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act*, 1947 (Act 36 of 1947) states that only products that are registered under the said Act may be applied in rodent management. Any individual or institution, such as a pest control operator, must be licensed as a pest control operator under the said Act (South Africa, 1947).

In the *Regulations Regarding the Prevention of Rodent Infestation and the Storage of Grain, Forage, etc. in Urban and Rural Areas of the Republic of South Africa*, (Regulation 1411 of 1966), local authorities are authorised to demand the prevention and control of rodent infestations or the removal of any conditions to prevent rodent infestations. The site, buildings, floors, walls, roofs and openings of a shop or store must comply with the requirements stated in the said regulation. No local authority shall pass or approve of plans or specifications for any shop or store unless they are in accordance with the requirements of the said regulation (South Africa, 1966).

The following sections will discuss the organisational structure of the health care system in South Africa with the focus on plague surveillance and control from national, provincial and municipal perspectives.
2.3 ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE AND CONTROL IN THE NATIONAL SPHERE OF GOVERNMENT

In terms of Chapter 3 of the *National Health Act, 2003* (Act 61 of 2003), it can be deduced that health service in the national sphere of government refers to services provided by the National Department of Health. The National Department of Health aims to promote the health of all citizens of South Africa through an effective national health system based on the primary health care (PHC) approach (South Africa, 2004b). The National Department of Health furthermore liaises with other countries and international organisations (such as the World Health Organisation) to effectively maintain plague surveillance and control (National Department of Health, 2004b).

The organisational structure of the National Department of Health, with specific reference to plague surveillance and control, is illustrated in Annexure 7. The following sections will identify and discuss a number of decision-makers within the National Department of Health who may have either a direct or an indirect influence on plague surveillance and control throughout South Africa. The Minister of Health is firstly introduced.

2.3.1 Minister of Health

In the national sphere of government, the National Department of Health is led by the Member of Cabinet responsible for health, namely the Minister of Health. In terms of Section 92 (2) of the *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996), the Minister of Health is accountable to Parliament for exercising of powers and performing of functions related to health. The *National Health Act, 2003* (Act 61 of 2003) gives the Minister of Health a stewardship role over the national health care system. In terms of Section 90 (1) of the said Act, the Minister of Health,
after consultation with the National Health Council, may make regulations regarding communicable diseases and notifiable medical conditions (South Africa, 2003).

From the above it can be deduced that the Minister of Health is responsible for the protection, promotion and maintenance of the health of the population. The regulations and national guidelines regarding plague surveillance and control must be subscribed to by the Minister of Health. To assist the Minister of Health in decision-making and to enable the Minister to report to the Parliament, a National Health Council has been established, which is discussed below.

2.3.2 National Health Council

In terms of Section 22 (2) of the National Health Act, 2003 (Act 61 of 2003), the National Health Council consists of (South Africa, 2003):

- The Minister of Health, who acts as chairperson;
- the Deputy Minister of Health (if there is one);
- the relevant members of the Executive Councils (MEC);
- one municipal councillor;
- the Director-General and Deputy Director-General of the National Department of Health;
- the head of each provincial health department; and
- the head of the South African Military Health Service.

In terms of Section 23 of the National Health Act, 2003 (Act 61 of 2003), the National Health Council must advise the Minister of Health on (South Africa, 2003):

- Policy concerning any matter that will protect, promote, improve and maintain the health of the population;
• guidelines for the management of health districts;
• the implementation of national health policy;
• epidemiological surveillance and monitoring of national and provincial trends with regard to major diseases and risk factors for disease; and
• the time frames, guidelines and the format for the preparation of national and provincial health plans.

From the above it can be deduced that the National Health Council (NHC) is established as the highest health policy-making body in the country. The National Health Council is responsible for the provision, development and coordination of all health care in South Africa. The role of the National Health Council regarding District Health System development is to advise the Minister of Health on developing guidelines for the management of health districts. The National Health Council also has the responsibility to advise the Minister of Health on plague surveillance and control in South Africa. In the following section the function of the Director-General of Health is identified.

### 2.3.3 Director-General of Health

As mentioned in Section 2.3.1, the Director-General of Health is a member of the National Health Council. In terms of Section 21 of the *National Health Act*, 2003 (Act 61 of 2003), the Director-General of Health must (South Africa, 2003):

- Integrate the health plans of the national department and provincial departments annually and submit the integrated health plans to the National Health Council;
- ensure the implementation of national health policy in so far as it relates to the national department and issue guidelines for the implementation of national health policy;
- coordinate and provide such health services as may be necessary to establish a
comprehensive national health system; and

- facilitate and promote the provision of health services for the management, prevention and control of communicable diseases.

From the discussion above it can be deduced that the Director-General of Health has the responsibility to supply health-related information to the Minister of Health via the National Health Council. The Director-General is also responsible for ensuring the implementation of national health policy to establish a comprehensive national health system in the country. The Director-General plays a key role in facilitating and promoting the provision of health services for the surveillance and control of plague. The following section discusses the place and role of the Directorate: Environmental Health.

2.3.4 Directorate: Environmental Health

The Directorate for Environmental Health within the National Department of Health focuses on driving national policy, strategy and research and defining norms and standards (Eales, Dau & Phakati, 2002, p.104). The said Directorate is responsible for (South Africa, 1997, p.20):

- The overall coordination and development of environmental health;
- ensuring that basic environmental needs are met and that environmental factors affecting health are minimised; and
- developing an environmental surveillance and evaluation system for monitoring the effectiveness of environmental interventions within the three spheres of government.

From the above it can be deduced that the Directorate: Environmental Health is responsible for the coordination and development of environmental health services
and to liaise closely with role-players in different spheres of government. The said Directorate plays a key role in the development and implementation of plague surveillance and control strategies. The Directorate for Communicable Diseases Control is introduced in the section that follows.

2.3.5 Directorate: Communicable Diseases Control

Communicable Diseases is a division of the Strategic Health Programmes in the National Department of Health (see Annexure 7). The Directorate for Communicable Diseases Control is responsible for the prevention and control of communicable diseases, including 'notifiable medical conditions' (National Department of Health, 2004b). It can be deduced that the said Directorate plays a key role in the surveillance and control of the disease since plague is one of the notifiable medical conditions. The National Department of Health has a supervisory function with regard to the National Health Laboratory Service. This is discussed in the next section.

2.3.6 National Health Laboratory Service

The National Health Laboratory Service (NHLS) was established in 2001 to form a single national public entity, consisting of the former South African Institute for Medical Research, National Institute for Virology, National Centre for Occupational Health, university pathology departments, and public-sector laboratories (South Africa, 2004a). The National Institute for Virology and a section of the South African Institute for Medical Research have been combined to form the National Institute for Communicable Diseases (NICD). As an important section of the National Health Laboratory Service, the National Institute for Communicable Diseases is a source of knowledge and expertise regarding regionally relevant communicable diseases for the South African government, in order to assist in the planning of policies and
programmes and to support appropriate responses to communicable disease problems and issues (National Institute for Communicable Diseases, 2005a).

Two units of the National Institute for Communicable Diseases are connected closely with surveillance and control of plague, namely the Special Bacterial Pathogens Reference Unit and the Special Pathogens Unit. The Special Bacterial Pathogens Reference Unit is a member of the World Health Organisation global network of experts and laboratories for anthrax and plague. The Special Pathogens Unit is responsible for the diagnosis and investigation of diseases associated with the so-called formidable (biohazard class four) viruses in South Africa (National Institute for Communicable Diseases, 2003, pp.8-10). The National Health Laboratory Service is thus responsible for the identification of plague pathogens and plays an important role in the national plague surveillance and control strategy. The organisational structure of the health care system in the provincial sphere of government is discussed in the next section.

2.4 ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE AND CONTROL IN THE PROVINCIAL SPHERE OF GOVERNMENT

There are nine provinces within the provincial sphere of government in South Africa, namely the provinces of the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Mpumalanga, Northern Cape, Limpopo, North West and Western Cape. In the provincial sphere of government the development of health services delivery has shifted from curative hospital-based health care to health care provided in an integrated community-based manner (South Africa, 2004b, p.351). A Provincial Department of Health is responsible for providing and rendering health services and formulating and implementing provincial health policy and legislation (South Africa, 2002, Schedule 2). It can be deduced that a Provincial Department of Health takes full responsibility for the effective rendering of health care services throughout a
The organisational structures of health care services delivery may vary between provinces due to different provincial health legislation (Hall, et al., 2002, pp.10-11). According to the Health Systems Trust (1996, p.38), the generic organisational structure of health care services delivery is similar to that of the national sphere of government but from a provincial perspective (see Annexure 8). Within a Provincial Department of Health a number of decision-makers may have an influence on plague surveillance and control in the province. The following sections identify and discuss these decision-makers. The role and functions of the Provincial Health Council are discussed firstly.

2.4.1 Provincial Health Council

In terms of Section 26 of the National Health Act, 2003 (Act 61 of 2003), a Provincial Health Council has been established in each of the nine provinces of South Africa. Every Provincial Health Council consists of (South Africa, 2003):

- The relevant member of the Executive Council, or his/her nominee, who acts as chairperson;
- one councillor from each of the metropolitan municipalities in the province;
- one councillor from each of the district municipalities in the province;
- the head of the provincial health department;
- not more than three representatives involved in the management of local government; and
- such number of other persons as the relevant members of the Executive Council may consider appropriate.

The relevant member of the Executive Council (MEC) means the member of the
Executive Council of a province responsible for health (South Africa, 2003, Section 1). In terms of Section 27 of the *National Health Act, 2003* (Act 61 of 2003), a Provincial Health Council must advise the relevant MEC on policy concerning any matter that will protect, promote, improve and maintain the health of the population within the province, including (South Africa, 2003):

- Epidemiological surveillance and monitoring of provincial trends with regard to major diseases and risk factors for diseases;
- efficient coordination of health services within the province and between neighbouring provinces;
- proposed legislation relating to health matters before it is introduced into the relevant provincial legislature;
- norms and standards for the establishment of health establishments;
- guidelines for the management of health districts; and
- the implementation of national and provincial health policy.

From the above it can be deduced that a Provincial Health Council must advise the relevant member of the Executive Council on the epidemiological surveillance and monitoring of medical notifiable diseases within the province. A Provincial Health Council will also advise the relevant member of the Executive Council on development and implementation of the regulations/guidelines for plague surveillance and control in their province. The Head of a Provincial Department of Health is discussed in the next section.

### 2.4.2 Head of a Provincial Department of Health

As mentioned above the Head of a Provincial Department of Health is a member of his/her Provincial Health Council. In terms of Section 25 of the *National Health Act, 2003* (Act 61 of 2003), the Head of a Provincial Department of Health must (South
• Plan and manage a provincial health information system;
• coordinate the funding and financial management of district health councils;
• provide technical and logistical support to district health councils;
• coordinate health and medical services during provincial disasters;
• facilitate and promote the provision of comprehensive primary health care services; and
• provide services for the management, prevention and control of communicable and non-communicable diseases.

From the above it can be deduced that the Head of a Provincial Department of Health carries the overall responsibility for the health care services in a province. When a plague outbreak occurs, the said Head must manage the activities of outbreak responses and coordinate the relationships amongst different public and private health sectors as well as other departments of the provincial government. He/She thus plays a key role in plague surveillance and control strategies. In the following section, the Deputy Director: Environmental Health in a Provincial Department of Health is discussed.

2.4.3 Deputy Director: Environmental Health

Environmental Health is a division of the Non-personal Primary Health Care Services in a Provincial Department of Health. According to the National Health Act, 2003 (Act 61 of 2003), it can be deduced that the function of environmental health services in the provincial sphere of government focuses on port health services, malaria control and hazardous substance control (South Africa, 2003). At the provincial level, the Deputy Director: Environmental Health must coordinate interventions where a crisis poses a regional health risk; provide environmental
health-related support to municipalities and monitor compliance with legislation (Hall, et al., 2002). The Deputy Director: Environmental Health therefore plays a key role in coordinating and providing specific environmental health services in a province.

According to Heinemann¹, the said Deputy Director works in close collaboration with other relevant health officers in different spheres of government, namely the Director: Environmental Health in the National Department of Health and the environmental health practitioners in the municipal sphere of government. The Deputy Director: Environmental Health is thus an important role-player whose decisions may influence the efficiency of plague surveillance and control in a particular province. In the next section the organisational structure for plague surveillance and control in the municipal sphere of government is discussed.

2.5 ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE AND CONTROL IN THE MUNICIPAL SPHERE OF GOVERNMENT

The District Health System is a fundamental organisational framework of the health care system in South Africa. In order to describe the organisational structure for plague surveillance and control in the municipal sphere of government, the District Health System must firstly be explained.

2.5.1 District Health System

The District Health System (DHS) is accepted worldwide as the most appropriate vehicle for the delivery of Primary Health Care services. The characteristics of the DHS are as follows (Hall, et al., 2002, p.1):

¹ H. Heinemann, Manager: Environmental Health Services, Department of Health, Province of the Eastern Cape, October 3, 2005.
• A number of discrete geographical sub-divisions, usually called Health Districts, each with a clearly defined population;
• clear guidelines are used for the demarcation of health districts; each has to include a Level One hospital; the population is not to exceed 500,000; geographical size to be such that the furthest clinic can be reached in approximately three hours from the district office; and be of a reasonable size so as to ensure effective management; and
• each health district has a decentralised health management team responsible for the delivery of a comprehensive and integrated health care package to the population; an appropriate referral system is to be established between the various parts of the district health system as well as with relevant services outside the health district.

In South Africa the policy guiding the District Health System has developed steadily since 1994 (African National Congress, 1994). After 1994 a Whiter Paper for the Transformation of the Health System in South Africa advanced a wide range of policy measures in order to fundamentally transform health care delivery in the country. The District Health System policy has now been encapsulated in legislation; predominantly in Chapter 5 of the National Health Act, 2003 (Act 61 of 2003). From the above it can be deduced that the District Health System is a fundamental organisational framework of the health care system in South Africa.

In terms of the National Health Act, 2003 (Act 61 of 2003), the municipal sphere of government for health care services can be divided into three tiers, namely the health district, health subdistrict and local municipalities. The health district is discussed below.
2.5.2 Health District

A Health District is defined by Owen (1995, pp.6-7) as a more or less self-contained segment of the national health system. In terms of this definition, a health district comprises first and foremost a well-defined population, living in a clearly delineated administrative and geographical area, whether urban or rural. The district must be large enough to be economically efficient, but small enough to ensure effective management that is accountable to local communities. According to Section 29 (2) of the National Health Act, 2003 (Act 61 of 2003), the District Health System consists of various health districts; the boundaries of these health districts coincide with district and metropolitan municipal boundaries. In order to achieve a clear understanding of the District Health System in South Africa, it is firstly necessary to explain the establishment of municipalities in the country. In terms of Section 155 of the Constitution (South Africa, 1996), there are three categories of municipality, namely:

- Category A (metropolitan municipality): A municipality that has exclusive municipal executive and legislative authority in its area;
- Category B (local municipality): A municipality that shares municipal executive and legislative authority in its area with a category C municipality within whose area it falls; and
- Category C (district municipality): A municipality that has municipal executive and legislative authority in an area that includes more than one municipality.

A province is therefore divided into a number of geographically coherent health districts whose boundaries are coherent with the Category A (metropolitan) and Category C (district) municipalities. If the boundaries of these municipalities change, then the boundaries of the health districts automatically also change (Owen, 1995, p.7). Each metropolitan and district municipality is thus known as a Health District. In
terms of Sections 155 and 156 of the *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996), a province must assign to a municipality by agreement and subject to any conditions, the administration of health services if the municipality has the capacity to administer them. A Provincial Department of Health is responsible for developing the health districts and supporting them logistically and technically (South Africa, 1996).

In terms of the *Constitution Twelfth Amendment Act of 2005*, (Act 1262 of 2005), it can be deduced that the six metropoles (Category A), together with 46 district (Category C) municipalities constitute the health districts (a total of 52) in South Africa (South Africa, 2005). From a District Health System perspective, the organisational structure of the health care system in South Africa is illustrated in Figure 1.

**FIGURE 1:** ORGANISATIONAL STRUCTURE OF THE HEALTH CARE SYSTEM IN SOUTH AFRICA


From Figure 1, it can be deduced that the Eastern Cape Province is divided into
seven health districts (six district municipalities and one metropolitan municipality). Heinemann (see Page 44) states that the generic organisational structure of a Health District is similar throughout the country, due to the shared legislative foundation. According to Oliphant\(^2\), each Health District has an environmental health manager who is responsible for the coordination of environmental health services delivery within his/her Health District. The said manager is also responsible for the provision and management of plague surveillance and control within his/her Health District (a district or metropolitan municipality). The organisational structure for plague surveillance and control in the Nelson Mandela Metropolitan Health District is illustrated in Annexure 9. The next section describes the functions of a District Health Council.

### 2.5.3 District Health Council

In terms of Section 31 of the *National Health Act, 2003 (Act 61 of 2003)*, the relevant member of the Executive Council (MEC), after consultation with the MEC responsible for local government in the province in question and the municipal council of the relevant metropolitan or district municipality, must establish a District Health Council for every health district in their province. A District Health Council consists of the following members (South Africa, 2003):

- A member of the metropolitan or district municipal council situated in the health district in question, nominated by the relevant council;
- a person appointed by the relevant MEC to represent him/her;
- a member of the council of each local municipality within the health district, nominated by the members of the relevant council; and
- not more than five other persons, appointed by the relevant MEC after

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consultation with the municipal council of the metropolitan or district municipality.

In terms of Section 31 of the *National Health Act, 2003 (Act 61 of 2003)*, provincial legislation must at least provide for the functioning of district health councils. A District Health Council must (South Africa, 2003):

- Ensure the coordination of the planning, budgeting, provisioning and monitoring of all the health services that affect the residents of the health district;
- advise the relevant MEC on any matter regarding health or health services in the health district for which the council was established; and
- ensure that each health district and each health subdistrict is effectively managed.

From the above it can be deduced that the District Health Council is responsible for the overall coordination and development of environmental health service delivery. The District Health Council also plays an important role in maintaining the efficacy of plague surveillance and control within a Health District. A Health District can be legally divided into a number of health subdistricts, which are explained and discussed in the next section.

2.5.4 Health subdistricts

In terms of Section 30 of the *National Health Act, 2003 (Act 61 of 2003)*, the relevant member of the Executive Council (MEC) may divide any Health District into health subdistricts and may determine and change the boundaries of such subdistricts, with the concurrence of the MEC responsible for local government in the province. The purpose of dividing a health district into health subdistricts is to devolve comprehensive Primary Health Care management and control at a lower level, compatible with rational planning, administration and the maintenance of good

A Health Subdistrict Council coordinates and supports the activities of health care delivery within the health subdistrict. A Health Subdistrict Council consists of the political representatives or councillors representing the wards in the subdistrict area (South Africa, 1998). Each health subdistrict should comprise the total area of one or more local municipalities in non-metropolitan areas. In metropolitan areas a health subdistrict should comprise the total area of several wards (National Department of Health, 2005, p.8).

At the health subdistrict level variations may occur between the provinces due to different provincial health legislation (Hall, et al. p.9). For example, the Cacadu District Municipality (a Category C municipality in the Eastern Cape Province) has been divided into three health subdistricts, namely Camdebo, Makana and Kouga (Eastern Cape Department of Health, 2005). According to Oliphant (see Page 48), each health subdistrict has an environmental health manager who is responsible for the coordination of environmental health services delivery within his/her health subdistrict. A health subdistrict of a Category C municipality (district municipality) can be further divided into local (Category B) municipalities, which is discussed in the section that follows.

2.5.5 Local municipalities

As mentioned above (see Section 2.5.3), a District Health Council comprises a member from each ‘local municipal council’ within a health district. In terms of Section 16 of the Local Government Municipal Systems Act, 2000 (Act 32 of 2000), a local municipality must develop a culture of municipal governance that complements formal representative government with a system of participatory governance (South Africa, 2000). For this purpose, the local municipality must
encourage and provide conditions conducive to the local community in order to participate more effectively in the affairs of the municipality. A member of the local community represented on the local municipal council can therefore be represented on the District Health Council.

The Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) categorizes a local municipality as a Category B municipality (see Section 2.5.2). In terms of Section 1 of the Local Government Municipal Structures Act, 1998 (Act 117 of 1998), a local municipality is defined as a municipality that shares municipal executive and legislative authority in its area with a Category C municipality (district municipality) within whose area it falls. In terms of health care service delivery, a Category B municipality is referred to as a subunit of a health subdistrict of a Category C municipality. Each health subdistrict consists of at least one local municipality. For example, the Kouga Health Subdistrict in the Eastern Cape Province consists of two local municipalities, namely Kouga and Kou-Kamma (Maarschalk, 2003, pp.134-135). In total, there are 231 Category B municipalities (local municipalities) in South Africa (Nicholson, 2001, p.12).

In terms of Section 156 of the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996), local government is responsible for the delivery of municipal health services. However, the said Constitution does not provide a definition of municipal health services. These are identified and discussed in the next section.

2.5.6 Municipal health services

In the municipal sphere of government, defining and demarcating the scope of municipal health services (MHS) constitutes a distinct reform within the new health care system. In the National Health Bill, 2002, ‘municipal health services’ are limited to ‘environmental health services’. This narrow definition of MHS had a significant
impact on environmental health services delivery, allowing municipal health services to focus exclusively on environmental health services (Haynes, 2004).

In terms of Section 1 of the *National Health Act, 2003* (Act 61 of 2003), it can be deduced that municipal health services are identified as environmental health services and include the following (South Africa, 2003):

- Water quality monitoring;
- food control;
- waste management;
- health surveillance of premises;
- surveillance and prevention of communicable disease, excluding immunizations;
- vector control;
- environmental pollution control;
- disposal of the dead; and
- chemical safety.

Section 1 of the said Act excludes port health, malaria control and control of hazardous substances from the range of municipal health services. The latter three functions belong to the environmental health services in the provincial sphere of government. From the above it can be deduced that plague surveillance and control are functions of environmental health practitioners in the municipal sphere of government (‘surveillance and prevention of communicable diseases’ and ‘vector control’). For example, plague surveillance is a function of the Ecological, Pest and Animal Control Unit in the Nelson Mandela Metropolitan Health District (see Annexure 9).

From the above it can be deduced that environmental health services are vested in local government as municipal health services. The responsibility for environmental
health services is transferred from provinces to the Categories A and C municipalities. According to Mbonda \(^3\), the relevant environmental health practitioners must liaise with other medical personnel in investigating and preventing plague outbreaks in the municipal sphere of government.

Basic plague surveillance data are mainly collected by the environmental health practitioners in the municipal sphere of government. Plague data must be available within different spheres of government because relevant decision-makers require sufficient data/information to enable them to make decisions to contribute to effective plague surveillance and control. At the national level plague data should be centrally stored and analysed. Then regular feedback will be provided to the relevant personnel in the provincial and municipal spheres of government. Results of the plague data analysis will provide information that will enable the decision-makers to make future decisions on relevant environmental health policy (i.e. the budget for plague surveillance and control), norms and standards. The decision-makers in the national and provincial spheres may thus influence the efficiency of plague surveillance and control in the municipal sphere of government.

### 2.6 SUMMARY

The *Constitution of the Republic of South Africa, 1996* (Act 108 of 1996) and the *National Health Act, 2003* (Act 61 of 2003) are the legislative foundation of the health care system in South Africa. The said legislations create the organisational structure of the health care system in the national, provincial and municipal spheres that allow them to work together in the planning of health care service delivery and the implementation of relevant health policies and programmes. In this chapter, to

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\(^3\) H. Mbonda, Supervisor: Pest Control and Plague Surveillance Section, Environmental Health Business Unit, Nelson Mandela Metropolitan Municipality, September 21, 2005.
obtain a comprehensive background, a number of legislative documents related to plague surveillance and control were presented. These documents include:

- **National Health Act, 2003** (Act 61 of 2003);
- **Health Act, 1977** (Act 63 of 1977);
- **International Health Regulations Act, 1974** (Act 28 of 1974);
- **International Health Regulations, 1969/2005**;
- **Regulations relating to communicable diseases and the notification of notifiable medical conditions**, 1987 (Regulation 2438 of 1987);
- **Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947** (Act 36 of 1947); and
- **Regulations Regarding the Prevention of Rodent Infestation and the Storage of Grain, Forage, etc. in Urban and Rural Areas of the Republic of South Africa** (Regulation 1411 of 1966).

Environmental health practitioners must implement the activities of plague surveillance and control under the abovementioned legislation. Within the different spheres of government a number of decision-makers and role-players may directly or indirectly influence the efficiency of plague surveillance and control. In the national sphere of government the said decision-makers and role-players within the National Department of Health include the Minister of Health, the National Health Council, the Director-General of Health, the Directorate: Environmental Health and the Directorate for Communicable Diseases Control. The National Health Laboratory Service is responsible for the identification of plague pathogens and plays an important role in the national plague surveillance and control strategy.

In the provincial sphere of government the generic organisational structure of health care services is similar to that of the national sphere of government, but from a provincial perspective. A Provincial Department of Health takes full responsibility for
the effective rendering of health care services throughout its province. In terms of the *National Health Act, 2003* (Act 61 of 2003), the Provincial Department of Health is also responsible for developing the health districts and supporting them logistically and technically. The District Health System is a fundamental organisational framework of the health care system in South Africa. A province is divided into a number of geographically coherent health districts, whose boundaries are coherent with the Category A (metropolitan) and Category C (district) municipalities. The South African health care system comprises a total of 52 health districts throughout the country’s nine provinces.

In terms of the *National Health Act, 2003* (Act 61 of 2003), a health district may be divided into health subdistricts, which should comprise the total area of one or more local municipalities in non-metropolitan areas. At the health subdistrict level, variations may occur between the provinces and even within a province. The health subdistrict of a Category C municipality (district municipality) can be further divided into Category B (local) municipalities. Each health subdistrict consists of at least one local municipality. In total there are 231 Category B municipalities (local municipalities) in South Africa.

In the provincial sphere of government environmental health services focus on port health, malaria control and control of hazardous substances. Plague surveillance and control are functions of environmental health practitioners in the municipal sphere of government (‘surveillance and prevention of communicable diseases’ and ‘vector control’).

The surveillance and control of a disease is dependent on its epidemiology. As a secondary objective of this study the epidemiology of plague will be presented in the next chapter.
CHAPTER THREE
THE EPIDEMIOLOGY OF PLAGUE

3.1 INTRODUCTION

Epidemiology is the foundation for the surveillance and control of a disease. It is therefore necessary to study the epidemiology of plague in order to develop formal work methods and procedures for plague surveillance and control. This chapter focuses on the epidemiology of plague as a disease entity.

Firstly, the historical background of plague is explained with emphasis on the three pandemics that occurred in the past. In this section the incidence of plague in South Africa is presented as well as the history of plague outbreaks.

Secondly, the global geographic distribution of natural foci of plague is described. The characteristics and geographic distribution of plague natural foci in South Africa are also described and discussed.

Thirdly, since plague is a classic zoonosis of animals and humans caused by the bacterium *Yersinia pestis* (*Y. pestis*), the mechanisms of plague transmission are explained. The discussion of plague cycles will focus on three basic elements, namely the pathogen (*Y. pestis*), the reservoir (rodents) and the vector (fleas).

Fourthly, it is impossible to maintain plague surveillance and control effectively if the relevant personnel do not have a thorough knowledge of the disease. The clinical manifestations, diagnosis and treatment of human plague are therefore discussed. The historical background of the disease is presented in the section that follows.
3.2 HISTORICAL BACKGROUND OF PLAGUE

Plague is an ancient disease that originated in the cradle of human civilization in Central Asia (Tikhomirov, 1999, p.12). The Bible may be the oldest documentary source of bubonic plague. According to the Bible (I Samuel, Chapters V and VI), the first plague epidemic was the outbreak among the Philistines in 1320 BC (Pollitzer, 1954, p.11). In the last two millennia, plague has become widespread, with three pandemics occurring in the 6th, 14th and 20th centuries.

The first pandemic, known as Justinian's plague, originated in 542 A.D. in Egypt, which was a leading centre for trade between the East and the West. At that time, the main trade routes between Europe and the East were across the Mediterranean Sea and overland through Turkey, Germany and France. The infection of plague spread to every country along these routes, from Asia to Ireland. At the height of the epidemic, the mortality rate was 5 000 persons daily (Meyer, 1963, pp.527-528). Between 542 and 546 A.D., about 100 million people died from the pandemic. Repeated, smaller epidemics followed the first pandemic after about 200 years.

The second plague pandemic is the well-known ‘Black Death’, which originated in Mesopotamia in about the middle of the 11th century, and attained its height in the 14th century. According to Gottfried (1983, pp.xiii-xiv), a number of theories attempt to explain the Black Death. Some authors believe that Mongolian horsemen or the environment of Mongolia was crucial to the spread of the disease. Other authors contend that infested fleas on the fur of marmots probably entered Europe via the trans-Asian Silk Road (McGovern & Friedlander, 1997, p.481).

The Black Death was a combination of bubonic, pneumonic and septicaemic plague strains. It caused about 50 million deaths, half of them in Asia and Africa, and the other half in Europe, where at least a quarter of the population succumbed.
(Tikhomirov, 1999, p.12). According to Meyer (1963, p.528), the Black Death caused, or accelerated marked political, economic, social, and cultural changes. The second plague pandemic resulted in a number of outbreaks that ravaged Europe and Africa till the end of the 17\textsuperscript{th} century.

The third plague pandemic originated in 1894 in China (Canton and Hong Kong) and spread rapidly throughout the world via modern merchant fleets. This pandemic is supposed to have originated in the Yunnan Province in China where the rebellion of the Mohammedans in 1855, and possibly the movement of refugees, propagated the spread of the disease (Meyer, 1963, p.529). Within nine years (1894 to 1903) plague entered 77 ports on five continents: Asia (31 ports), Europe (12), Africa (8), North America (4), South America (15) and Australia (7). The third plague pandemic spread to Bombay (a city in India) in 1898, and during the next 50 years, more than 13 million Indians succumbed. Many deaths in a number of other countries were also claimed during the third pandemic (Tikhomirov, 1999, p.13). The third plague pandemic ended in the 1950s, although a low incidence of the disease still occurs in many parts of the world.

According to the World Health Organisation (2004a, p.302), at least three geographical areas experienced outbreaks of human plague after silent periods of about 30 to 50 years, namely India (1994 and 2002), Indonesia (1997) and Algeria (2003). Currently, plague still occurs within some areas with high mortality rates. Examples include the following (World Health Organisation, 2005a):

- During the period 1989 to 2003, 38 310 cases (2 845 deaths) were recorded in 25 countries;
- in 2002, Peru and the United States of America reported four cases of human plague;
- in 2003, one case was reported in the United States of America;
in Asia, five countries reported 99 cases, with six deaths in 2002; and

in 2003, three countries (China, Kazakhstan and Mongolia) reported 26 cases of plague, including two deaths.

Currently, most of the reported human cases of plague occurred on the African continent (World Health Organisation, 2005a):

- In 2002, human plague was reported in six countries in Africa, amounting to a total of 1,822 cases with 171 deaths. This represents 94.6 per cent and 96.6 per cent of the corresponding world totals;
- In 2003, five African countries (Algeria, Democratic Republic of the Congo, Madagascar, Mozambique and Uganda) reported 2,091 cases, with 180 deaths; and
- an outbreak of plague in the Democratic Republic of the Congo started during December 2004. A total of 130 suspected cases, including 57 deaths, have been reported (World Health Organisation, 2005b).

Plague was first imported into South Africa through harbours during the third pandemic in 1900. Plague-infected rodents carried on the ships from the Far East and South America caused outbreaks in the major South African ports, namely Cape Town, Port Elizabeth, East London and Durban. Plague soon spread inland by the movement of people and materials during the Anglo-Boer War. The last outbreak of plague in urban areas during this period (the so-called murine phase) was in Durban in 1912 (South African Department of Health and Welfare, 1982, p.3). From 1914 onwards, outbreaks were noted in remote rural areas in South Africa. The total incidence of plague from 1914 to 1918 was 189 cases, with 132 deaths (Pollitzer, 1954, pp.46-47). The incidence of plague in South Africa from 1921 to 2005 is illustrated in Table 2.
From Table 2, it can be deduced that the most recent reported outbreak of plague in South Africa was in 1982, during which 18 cases with one death were reported. According to Tikhomirov (1999, p.30), the said outbreak occurred in the Coega area in the Eastern Cape Province. The next section deals with the geographical distribution of the disease, with specific reference to the natural foci in South Africa.

### 3.3 GEOGRAPHICAL DISTRIBUTION OF PLAGUE

Tikhomirov (1999, pp.13-14) states that the plague natural foci are situated in a broad belt in the tropical and subtropical latitudes and the warmer parts of the temperate latitudes around the globe between the parallels 55 degrees North and 40 degrees South. The natural foci of plague are found on all continents, except Australia, and the distribution of plague coincides with the geographical distribution of its natural foci (see Annexure 10). The global distribution of plague (1970 -2004) is illustrated in Figure 2.
According to Tikhomirov (1999, pp.13-14), most plague natural foci are found where there is low annual precipitation, or where dry seasons inhibit the growth of thick woody vegetation and lead to the formation of deserts, semi-deserts and steppes (savannas, prairies, pampas, etc.). By contrast, many areas are free of natural foci of the disease, such as desert areas with few or no rodents and large areas of continuous forest, particularly in the tropics and high glacier-covered mountain ranges. From the above, it can be deduced that primary plague natural foci are connected with particular types of landscapes in which climatic conditions are favourable for a high and stable number of rodent reservoirs and flea vectors of plague. However, plague foci are also dynamic, changing in response to shifts in factors such as climate, landscape and rodent population migration (Tikhomirov, 1999, p.14).

According to Meyer (1963, p.555), seasonal prevalence is a characteristic of plague and depends largely on the influence of the weather and the breeding of rodents and
rodent fleas. In summer, both good rains and sufficient food make the wild rodent population thrive which promotes activity in the natural foci. The incidence of human plague was found to be highest during summer seasons (Stewart, 1985, p.215).

According to Pollitzer (1954, p.47), there are three primary natural foci areas of plague in South Africa, namely the Free State, the Cape Midlands and Port Elizabeth. Plague natural foci still exist in South Africa, although no human case has been reported since the last outbreak in 1982. In terms of the draft *Plague guidelines* (National Department of Health, 2004a, p.5), plague natural foci exist in several parts of South Africa, namely the Eastern and Northern Cape, Free State, Mpumalanga and Gauteng (see Figure 3).

![Figure 3: Distribution of Plague Natural Foci in South Africa](image)

Source: Modified from National Department of Health (2004a) and Segerman (1995)

As mentioned in Section 3.2, countries surrounding South Africa continue to report
human plague. From 1980 to 1997, human plague was reported in 13 countries in Africa, with a total of 19,349 cases and 1,781 deaths. The mean case fatality rate was 9.2 per cent (Tikhomirov, 1999, p. 27). In contrast to the 1990s, during the period 2002 to 2003, human plague was reported in seven African countries (Democratic Republic of the Congo, Madagascar, Malawi, Mozambique, Uganda, Tanzania and Algeria), amounting to a total of 3,913 cases, with 351 deaths. These figures represent 96.65 per cent and 97.75 per cent of the corresponding world totals (World Health Organisation, 2004a, p. 302). It can therefore be deduced that plague still constitutes a threat to the health of South African citizens.

From an effective plague control viewpoint, it is essential to conduct thorough epidemiological surveys within these natural foci areas. The mechanisms of plague transmission are depicted and discussed in the following section.

### 3.4 MECHANISMS OF PLAGUE TRANSMISSION

The ecology of plague is highly variable, since there is a complex interaction between the hosts, the vectors and the plague bacilli that are influenced by a variety of factors. These factors include host susceptibility, season, temperature, humidity, the availability of food and the transmission efficiency of fleas (National Department of Health, 2004a, p. 4).

The basic mechanisms of plague transmission are illustrated in Figure 4 (on the next page). From Figure 4, it can be seen that three ‘cycles’ of plague transmission can occur within wild rodents, commensal rodents and humans. The first transmission cycle shows that plague is primarily a disease of rodents and is transmitted between rodents and to other animals via wild rodent fleas; humans play no role in the long-term survival of *Y. pestis* (Perry & Fetherston, 1997, p. 51). It has been proven that wild plague exists in its natural foci independent of human populations and their
activity (Tikhomirov, 1999, p.18). Furthermore, \( Y. \) pestis is able to live in the dark, moist environment of rodent burrows even after the rodents have been killed by an epizootic. If a new rodent community replaces the old one, the plague chain can be revived (Gottfried, 1983, p.7).

**FIGURE 4:**
**MECHANISMS OF PLAGUE TRANSMISSION**

Source: Adapted from Rooney (2004, p.24)

The transmission cycle amongst wild rodents involves two natural statuses of plague: either 'enzootic' or 'epizootic'. Enzootic means that the pathogen of plague (\( Y. \) pestis) circulates in its animal reservoirs, particularly in wild rodents in their natural environment (Tikhomirov, 1999, p.11). McGovern and Friedlander (1997, p.487) mentioned that an enzootic is the state of a stable rodent-flea infection cycle in a relatively resistant host population, without excessive rodent mortality.
Occasionally, plague bacilli may be introduced into colonies or areas of more susceptible species, and an epizootic may occur. Epizootic denotes a disease attacking large numbers of animals; this is the animal equivalent of human epidemics (National Department of Health, 2004a, p.50). A plague epizootic may go unnoticed unless exceptional rodent mortality or human cases occur. Gratz (1999a, p.63) states that plague penetrated urban rat colonies from its wild nature foci, and a high mortality of rodents can be seen in sylvatic (rural) areas or even in villages or cities. The second transmission cycle amongst the domestic rodents therefore occurs. The said three ‘cycles’ of plague transmission can be illustrated in Figure 5.

![FIGURE 5: PLAGUE TRANSMISSION CYCLES](image)

Source: Adapted from Webber (1996)

According to Pollitzer (1954), plague epizootic (domestic plague) is intimately associated with domestic rodents living with humans and can produce epidemics in humans because the plague-infected fleas may leave the bodies of rats killed by plague seeking a blood meal from another host (including human beings). Humans who contract plague may subsequently become infectious to other people (the third cycle of plague transmission). Humans are accidental hosts in the plague transmission cycle. The pathways of human plague transmission are summarised in Table 3.
### TABLE 3:
**PATHWAYS OF PLAGUE TRANSMISSION TO HUMANS**

<table>
<thead>
<tr>
<th>Plague pathway</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Via vector</td>
<td>The bite of infectious fleas</td>
</tr>
<tr>
<td>Via mucous membrane</td>
<td>Direct contact with infectious body fluids, tissues or animals via the mucous membrane, conjunctiva or damaged skin</td>
</tr>
<tr>
<td>Via the digestive tract</td>
<td>Ingestion of raw or undercooked meat from an infected animal</td>
</tr>
<tr>
<td>Airborne transmission</td>
<td>Inhaling infectious respiratory droplets or other infectious materials</td>
</tr>
</tbody>
</table>

Source: Adapted from Louisiana Office of Public Health. (2004, p.2)

Humans are extremely susceptible to plague and may be infected either directly or indirectly. Indirect transmission through the bite of an infected flea is the most common route of transmission between plague-infected rodents and humans. Humans may also be infected directly from a plague-infected rodent or other animals and their predators while handling, skinning or cutting the meat. The plague bacilli penetrate the human organism through skin lesions or the mucous membranes of the mouth, nose or eyes (Tikhomirov, 1999, pp.11-13; Perry & Fetherston, 1997, pp.51-53). Person to person spread of plague is almost invariably airborne, but flea-borne inter-human plague transmission, usually involving the human flea *Pulex irritans*, can occur (Meyer, 1963, p.573).

From the above it can be deduced that plague is a classic zoonosis and may exist in different transmission cycles, involving the pathogen, the reservoirs and the vectors. The pathogen of the disease, *Y. pestis*, is discussed in the following section.

### 3.4.1 The plague pathogen

The genus *Yersinia*, a member of the family *Enterobacteriaceae*, consists of 11 species, of which three are human pathogens (*Y. pestis*, *Y. pseudotuberculosis*, and ...)
Y. enterocolitica). The image of direct microscopic examination of Y. pestis is shown in Figure 6.

**FIGURE 6:**
THE PLAGUE PATHOGEN: *YERSINIA PESTIS*

*Yersinia pestis*: Giemsa stain of blood smear containing *Yersinia pestis* from a septicemic patient, magnification: original ×1000

Source: Adapted from Chu, Sharp & Saubolle (2002, p.9)

*Y. pestis* is a non-motile, slow-growing, non-acid fast, non-spore-forming, gram-negative *coccobacillus* measuring 1.5 by 0.75 microns that exhibits bipolar staining with Giemsa, Wright’s, or Wayson staining (Chu, Sharp & Saubolle, 2002, p.4; Perry & Fetherston, 1997, p.37). *Y. pestis* belongs to the group of bacilli with low resistance to environmental factors. Sunlight, high temperatures and desiccation have a destructive effect, and ordinary disinfectants such as lysol and preparations containing chlorine destroy the bacilli within one to ten minutes (Tikhomirov, 1999, p.11). The key microbiological characteristics of *Y. pestis* are attached as Annexure 11.

Most research on *Y. pestis* regulatory systems has focused on virulence genes, and the majority of *Y. pestis* strains contain three plasmids of 9.5, 70 to 75, and 100 to 110 kilobase (kb). The life cycle of the *Y. pestis* suggests that virulence may be a determinant necessary for survival in mammals and in fleas (Perry & Fetherston, 1997, p.38). Virulence factors for *Y. pestis* are encoded on the chromosomes and on
the three plasmids. The plasmids are (Center for Infectious Disease Research and Policy, 2005a):

- The pesticin (Pst) plasmid (9.5 kb) encodes plasminogen activator and a bacteriocin;
- the low-calcium-response (Lcr) plasmid (70 to 75 kb) encodes gene products that activate the V antigen and the outer surface proteins (Yops) under low calcium conditions; and
- the pFra plasmid (100 to 110 kb) encodes primarily the fraction 1 (F1) glycoprotein envelope antigen.

The F1 antigen is anti-phagocytic, elicits a humoral response and is a target for immunologic-based diagnostic tests. Most pathogenic Y. pestis strains isolated from humans contain the F1 antigen (Perry & Fetherston, 1997, pp. 49-50). It is necessary to understand the virulence factors and F1 antigen because detection of the F1 antigen in tissues or fluids by direct fluorescent antibody testing or by other standardized antigen detection procedures provide presumptive evidence of plague. In the next section, plague vectors are discussed.

3.4.2 Plague vectors

Wingless, ectoparasitic arthropods belonging to the classes Insecta (insects), including fleas, lice and ticks, are regarded as vectors of plague (Pollitzer, 1954, pp. 391-401). Although it has been shown that both lice and ticks readily become infected with plague, they are seldom able to transmit the disease and are considered to be of limited importance in the plague cycle (South Africa Department of Health and Welfare, 1982, pp. 5-6).

According to Gratz (1999a, p. 64), many more species of the order Siphonaptera
have been implicated in the transmission of sylvatic plague. Broadly speaking, the terms ‘vectors of plague’ and ‘rodents’ fleas’ may be taken as interchangeable (Pollitzer, 1954, p.401). In this study, plague vectors refer to the relevant fleas (see Figure 7).

FIGURE 7:
THE PLAGUE VECTOR: FLEA

Flea (Siphonaptera): Male *Xenopsylla cheopis* (oriental rat flea) engorged with blood. *X. cheopis* is the most important vector of plague. Both male and female fleas can transmit the infection. *X. cheopis* most commonly parasitizes *Rattus* species, but is frequently found on other species in and around houses.

Source: Adapted from Centers for Disease Control and Prevention (2005a, p.1)

According to Rozendaal (1997, p.243), fleas are small, wingless blood-sucking insects with a characteristic jumping movement. They feed mainly on mammals, but also on birds. Over 1 500 species of fleas have been identified, but only a small number of these are proven vectors of plague, although any flea species may be biologically capable of plague transmission under the appropriate conditions (Perry & Fetherston, 1997, pp.52-53).

In order to make flea control effective, plague control personnel must understand the life cycle and behaviour of fleas. The life cycle of fleas has four stages: egg, larva, pupa and adult. Eggs usually hatch within two or three weeks. Ideal conditions for flea egg hatching and larval development are between 18°C and 27°C, with a relative humidity of 70% or greater. If conditions are less than ideal, larval development can take as long as one year. Extremely dry conditions with temperatures over 35°C will usually kill flea larvae. However, flea eggs are very
resistant to and are not easily affected by insecticides (Rozendaal, 1997, pp.243-245; Lane, 1995, p.1). The majority of flea species that transmit the disease are ectoparasites of commensal or peri-domestic rodents (see Table 4).

<table>
<thead>
<tr>
<th>TABLE 4: COSMOPOLITAN PLAGUE VECTORS</th>
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<tbody>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Xenopsylla cheopis</td>
</tr>
<tr>
<td>Xenopsylla astia</td>
</tr>
<tr>
<td>Xenopsylla brasiliensis</td>
</tr>
<tr>
<td>Nosopsyllus fasciatus</td>
</tr>
<tr>
<td>Monopsyllus anisus</td>
</tr>
<tr>
<td>Leptopsylla segnis</td>
</tr>
<tr>
<td>Pulex irritans</td>
</tr>
<tr>
<td>Ctenocephalides felis</td>
</tr>
<tr>
<td>Ctenocephalides canis</td>
</tr>
</tbody>
</table>

Source: Adapted from Gratz (1999a, pp.65-67)

Most of the flea species have a wide distribution, although their percentage in flea population varies from place to place. The commensal rodent fleas are often found on livestock and household animals, which are in close proximity to humans and their dwellings (Gratz, 1999a, pp.65-77).

According to Segerman (1995), the fleas of South Africa are currently classified into eight families, including 32 genera. The taxonomy of fleas in Southern Africa is illustrated in Annexure 12. In Southern Africa, a number of flea species have been isolated with Y. pestis (De Meillon, Davis & Hardy, 1961, p.14). According to Segerman (1995, p.8), the known transmitters of plague are Xenopsylla brasiliensis,
X. cheopis, X. philoxera, X. piriei, Dinopsyllus lypusus and Chiastopsylla rossi. However, in ports and coastal towns, X. cheopis is the dominant flea species on the Rattus species and is the dominant flea vector of plague (Gratz, 1999a, p.68). Important plague reservoirs and their associated fleas in South Africa are summarised in Annexure 13.

The role of flea vectors in the plague transmission cycle can be explained as follows. When a flea sucks blood from an infected rodent, plague bacilli can multiply and eventually block the flea’s proventriculus or foregut. A flea in this condition is known as a ‘blocked’ flea (Pollitzer, 1954, pp.350-352). Those species of fleas most subject to blocking are the most efficient vectors of plague. Although a blocked flea attempts to feed again, blood cannot continue to enter its stomach and instead remains in the oesophagus. When the flea stops sucking, the oesophagus recoils and the accumulated blood is driven into the bite wound, bringing Y. pestis with it. The rodent fleas thus pass the infection onto the next host, whether animal or human (McGovern & Friedlander, 1997, p.486).

Several important premises are needed for the flea to act as an efficient plague vector. Firstly, the flea must be able to ingest the plague organism with its blood meal. Secondly, it must live long enough for the pathogen to multiply sufficiently. Thirdly, it must be able to transfer the pathogen to an animal or human host in sufficient concentrations to cause an infection. Lastly, the fleas must be present in large enough numbers to maintain the infection in the local rodent hosts (Gratz, 1999a, p.65).

In order to understand the epidemiology of plague and the transmission of the infection from rodent reservoirs to human hosts, it is essential to identify the rodent and flea species involved in a given area. Plague reservoirs are therefore described and discussed in the next paragraphs.
3.4.3 Plague reservoirs

Plague is primarily a disease of rodents. According to Perry and Fetherston (1997, p.55), up to 200 species in 73 genera of rodents and other small mammals are susceptible to infection, but most of these species are only occasionally infected and are not necessarily important reservoirs of infection. Mammals that are partially resistant to plague infection serve as continuous reservoirs of plague (McGovern & Friedlander, 1997, p.487). Most carnivores are resistant to plague infection.

Domestic animals such as dogs and cats are most likely to be exposed to *Y. pestis* by contact with an infected rodent or rabbit or by the bite of an infected flea. In the United States of America, between 1977 and 1998, 23 humans (5 died) were reported with identified cat-associated plague (Orloski & Lathrop, 2003, p.445; Gage, Dennis, Orloski, et al., 2000, p.893).

The animal hosts of plague are classified as enzootic (maintenance) hosts and epizootic (amplification) hosts. The enzootic hosts group includes rodents from genera that are relatively resistant to plague. In this group, the mortality rate from plague infection is relatively low, although antibody surveys of field populations may show a positivity rate as high as 100%. Die-off of rodents is rare in this group (Gratz, 1999a, pp.63-64). Epizootic rodent hosts are susceptible to plague and there is a high mortality rate in this group. Wild rodent ‘die-off’ is therefore a characteristic of plague epizootics and a warning sign of a possible spread of plague to commensal rodents and to humans and their pets (Pollitzer, 1954, pp.296-298).

The susceptibility to plague infection of a given rodent species may vary (even within the limits of a natural focus) with variations in the density of the rodent populations and their flea vectors. The virulence of the particular strain of the *Y. pestis* involved in an epizootic may also vary over a period of time (Gratz, 1999a, p.65; Perry &
Fetherston, 1997, pp.49-50). Furthermore, related rodent species living in close association may respond differently to plague infection. For example, *Mastomys coucha* is highly susceptible to plague whilst its morphologically identical sibling species *M. natalensis* is highly resistant in South Africa (National Department of Health, 2004a, p.3).

From the above it can be deduced that it is difficult to group the different species of rodents, lagomorphs and other small mammals involved as common or occasional reservoirs or hosts of plague to fit the classification: enzootic and epizootic hosts (Gratz, 1999a, p.65). The following paragraphs discuss the main plague reservoirs within the natural foci in South Africa.

According to Gratz (1999a, pp.67-68), in the plague foci of South Africa, the main reservoir was thought to be the gerbil *Tatera brantsi*. The passage of plague infection in the Free State has been traced from gerbils as the reservoir, to other wild rodents, *Otomys irroratus* to *Mastomys natalensis* to *Rattus rattus* and then to humans. In an outbreak of plague in Coega in the Eastern Cape Province in 1982, plague antibodies were found in two rodent species: the four-striped mouse, *Rhabdomys pumilo* and the vlei rat, *Otomys irroratus* (Shepherd, Hummitzsch, Leman & Hartwig, 1983, pp.800-801). The gerbils *Tatera brantsi*, *T. leucogastor* and *T. afra* play an important role in the Southern African plague epidemiology. In addition, amongst members of the subfamily *Gerbillinae*, only the distribution of the *Namaqua gerbil*, *Desmodillus auricularis* and the Highveld gerbil, *Tatera brantsii*, has broadly coincided with areas that have historically been affected by plague outbreaks (South African Department of Health and Welfare, 1982, pp.8-9).

*M. natalensis* occurs in the low altitude and high rainfall areas in the eastern coastal region, extending to North-Eastern South Africa, while *M. coucha* keeps to the high altitude and moderate rainfall areas in central and North-Eastern South Africa. The
geographical distribution of human plague in South Africa corresponds closely with the plague-susceptible species *M. coucha*, while the plague-resistant species *M. natalensis* predominates in areas where human plague has not been recorded (Venturi, Chimimba, Van Aarde, et al., 2004, pp.235-244). It can be deduced that *M. coucha* may also play a role in plague outbreaks in South Africa.

For the purpose of this study, South African plague reservoirs can be classified into a number of categories (National Department of Health, 2004a; World Health Organisation, 1999a; South African Department of Health and Welfare, 1982), including:

- Gerbils (*Tatera brantsii, T. leucogaster, T. afra*, and *Desmodillus auricularis*);
- multimammate mouse (*Mastomys natalensis* and *M. coucha*);
- other rodents (*Otomys irroratus, Rhabdomys pumilio, Aethomys namaquensis, A. chrysophilus* and *Pedetes capensis*);
- commensal rodents (*Rattus rattus, R. norvegicus* and *Mus musculus*); and
- carnivores (*Cynictis pencillata* and *Suricata suricatta*).

Additional information on the abovementioned plague reservoirs is attached as Annexure 14. In the next section clinical manifestations of human plague are presented.

### 3.5 CLINICAL MANIFESTATIONS OF HUMAN PLAGUE

*Yersinia pestis* infection in humans may occur in three primary clinical forms, namely bubonic plague, septicaemic plague and pneumonic plague (see Annexure 15). Bubonic plague is the most classical form of human plague. It results from a flea bite or direct contamination of an open skin lesion by plague-infected material. Bubonic plague is characterized by regional lymphadenopathy buboes. It typically involves
initially infected lymph nodes and is most often located in the inguinal, axillary, or cervical regions (Poland & Dennis, 1999a, pp.43-44).

Primary septicaemic plague is a progressive, overwhelming bloodstream infection with *Y. pestis*, with the apparent absence of a primary lymphadenopathy. Primary septicaemic plague is a serious diagnostic consideration in a suspected plague patient without evident lymphadenitis or pneumonia. Septicemic plague can also occur as a secondary condition to bubonic plague (secondary septicaemic plague). Plague septicaemia, whether primary or secondary to bubonic plague, may lead to metastasis infection of other organ systems (Perry & Fetherston, 1997, p.58).

Primary pneumonic plague results from the inhalation of respiratory droplets containing *Y. pestis*. Pneumonic plague is the least common but most dangerous and fatal form of the disease. It can develop as a secondary complication of septicemic plague or bubonic plague (secondary pneumonic plague). Pneumonic plague must be considered highly contagious whenever it occurs; person-to-person transmission is most likely in cold humid environments, coupled with overcrowding conditions (McGovern & Friedlander, 1997, pp.485-488).

In addition to the three aforementioned classic forms, plague can also present in several other forms, such as plague meningitis, plague pharyngitis, pestis minor and subclinical infections. However, they are rare presentations of the disease. Plague meningitis is characterized by fever, headache and a stiff neck, delirium, confusion, or coma. Meningeal plague may be a primary manifestation, but it usually occurs a week or more after the onset of bubonic or septicaemic plague (Poland & Dennis, 1999a, pp.46-47).

Plague pharyngitis results from the contamination of the oropharynx with *Y. pestis*-infected material. Recognized materials of exposure include respiratory droplets expelled during coughing by a patient (or animal) with a respiratory plague
infection, or the ingestion of undercooked or raw tissues of an infected animal (Poland & Dennis, 1999a, p.46). Pestis minor is a milder form of bubonic plague. Patients usually have a febrile illness with localized lymphadenopathy. The nodes drain and patients recover without therapy. Subclinical infections can occur, as evidenced by cross-sectional surveys of serum antibody titres in populations living in endemic areas (Pollitzer, 1954, pp.450-451). The next section deals with the diagnosis and treatment of the disease.

3.6 DIAGNOSIS AND TREATMENT OF PLAGUE

Humans are extremely susceptible to plague. It is therefore important that relevant health workers must be familiar with plague diagnosis and treatment. In this section, diagnosis and treatment of human plague are discussed.

3.6.1 Diagnosis and case definitions of plague

A clinical diagnosis of plague is generally based on patient manifestations and exposure history (Inglesby, Dennis, Henderson, et al., 2000, p.2284). Clinical specimens of suspected cases should be collected immediately for laboratory diagnosis. A definitive laboratory diagnosis of *Y. pestis* infection is based on bacteriological and/or serological evidence: the isolation and identification of the organism from clinical specimens or by demonstrating a diagnostic change in antibody titre in paired serum specimens (Poland & Dennis, 1999a, p.48; Perry & Fetherston, 1997, p.58).

Plague bacilli are often present in large numbers in these specimens and typically show bipolar staining with Giemsa or Wayson’s stain. A number of tests used for the detection of *Y. pestis* include the following (Center for Infectious Disease Research and Policy, 2005a):
• Dipstick for detection of *Y. pestis* antigen;
• Gram and Wayson staining;
• direct fluorescent antibody staining (DFA);
• culture of sample, biochemical identification and confirmation by bacteriophage lysis test;
• enzyme-linked immunosorbent assay (ELISA);
• polymerase chain reaction (PCR); and
• mouse inoculation for recovery of *Y. pestis* (if necessary).

Smears of clinical material can readily be prepared and are useful in the presumptive diagnosis of plague. Blood, bubo aspirates, sputum and cerebrospinal fluid may be stained and cultured to detect the presence of *Y. pestis*. Laboratory diagnostic categories for human plague are summarised in Table 5.

<table>
<thead>
<tr>
<th><strong>TABLE 5:</strong></th>
<th><strong>LABORATORY DIAGNOSTIC CATEGORIES FOR HUMAN PLAGUE</strong></th>
</tr>
</thead>
</table>
| **Suspect plague** | 1. Compatible clinical and epidemiological features; and  
2. Suspicious organisms seen or isolated from clinical specimens, for example, bubo (bubonic plague) or blood (septicaemic plague) or tracheal/lung aspirate (pneumonic plague) |
| **Presumptive plague** | 1. *Y. pestis* F1 antigen detected in clinical materials by direct fluorescent antibody testing, or by some other standardized antigen detection method; or  
2. Isolate from a clinical specimen demonstrates biochemical reactions consistent with *Y. pestis* or PCR (polymerase chain reaction) positivity; or  
3. A single serum specimen is found positive for diagnostic levels of antibodies to *Y. pestis* F1 antigen, not explainable on the basis of prior infection or immunization |
| **Confirmed plague** | 1. Isolate identified as *Y. pestis* by phage lysis of cultures; or  
2. A significant (4-fold) change in antibody titre to the F1 antigen in paired serum specimens |

Source: Adapted from World Health Organisation. (1999a, p.50)
There are no widely available rapid diagnostic tests for plague, although rapid diagnostic tests for detecting the F1 antigen have been developed, produced and evaluated (World Health Organisation, 2006, p.282; Inglesby, et al., 2000, p.2285). It is important to make an early diagnosis when a notifiable disease breaks out. Clinical physicians as well as plague surveillance and control personnel must be familiar with the symptoms of plague and take them into consideration when making a differential diagnosis. The World Health Organisation Regional Office for Africa (2001, pp.29-32) provides clinical case definitions for different levels of the health care services, namely community, health facility and district (see Table 6).

<table>
<thead>
<tr>
<th>Level</th>
<th>Clinical case definition of plague</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>Any person with painful swellings under the arms or in the groin area. In an area known to have plague, any person with cough, chest pain and fever.</td>
</tr>
<tr>
<td>Health facility, and district</td>
<td>Any person with a sudden onset of fever, chills, headache, severe malaise, prostration and very painful swelling of lymph nodes, or cough with blood-stained sputum, chest pain, and difficulty in breathing.</td>
</tr>
</tbody>
</table>

Source: Adapted from World Health Organisation Regional Office for Africa (2001, pp.29-32)

In the case definitions above, a district is defined as the intermediate administrative unit serving a population of between 100 000 and 300 000 people (World Health Organisation Regional Office for Africa, 2001, p.7). From Table 6, it can be deduced that for any person with a cough, chest pain and fever or with painful swellings under the arms in a known plague area, a suspected diagnosis of plague should be made. The World Health Organisation also recommends a standard case definition for the purpose of plague surveillance (see Section 4.3.1). The treatment of plague is discussed in the next section.
3.6.2 Treatment of plague

The treatment of plague mainly involves case management and antibiotic therapy. Important procedures in plague case management are isolation of patients and notification reporting. All patients with plague should be isolated for the first 48 hours after the initiation of treatment (McGovern & Friedlander, 1997, p.497). Suspected plague patients with evidence of pneumonia should be placed in isolation in a single room for 72 hours and managed under respiratory droplet precautions (Health Protection Agency, 2005, p.8). A guideline for plague case management can be summarized as follows (National Department of Health, 2004a):

- Hospitalise patient as soon as possible;
- standard patient care should be applied to the management of all suspected plague patients;
- effective antibiotic treatment is essential;
- bubonic plague cases should be observed for 24 hours under antibiotic therapy to detect incipient pneumonia;
- pneumonic plague patients must be isolated with adequate precautions against airborne spread until 48 hours of antibiotic treatment have been given, with a favourable response; and
- intramuscular streptomycin (30mg/kg per day) for 10 days should be injected. This may be modified when sensitivity results are available.

Standard patient care/hospital precautions should be applied to the management of all suspected plague patients. These include prescribed procedures for hand washing and the wearing of latex gloves, gowns and protective devices to protect the mucous membranes of the eye, nose and mouth during such procedures and patient care activities likely to generate splashes or sprays of blood, body fluids, secretions and excretions (Poland & Dennis, 1999b, pp.57-58). Correct and early
therapy for plague can prevent the complications of the disease. Guidelines for plague treatment with antibiotics are summarised in Table 7.

<table>
<thead>
<tr>
<th>TABLE 7: PLAGUE TREATMENT GUIDELINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug</td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>Streptomycin</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Gentamicin</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Tetracycline</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Chloramphenicol</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Doxycycline</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Oxytetracycline</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

IM= Intramuscular; IV= Intravascular; PO= Orally
Source: Adapted from World Health Organisation. (1999a, p.59) and Inglesby, et al. (2000, p.2287)

According to Poland and Dennis (1999b, p.55), when a diagnosis of human plague is suspected on clinical and epidemiological grounds, appropriate specimens for diagnosis should be obtained immediately and the patient should be started on specific antibiotic therapy without waiting for a definitive answer from the laboratory. Streptomycin is the most effective antibiotic against Y. pestis and the drug of choice for the treatment of plague, particularly the pneumonic form.
In the event of persons exposed to *Y. pestis*, or after contact with pneumonic plague patients, antibiotic prophylaxis should be initiated as soon as possible. People who have had contact with cases of bubonic plague should be assessed for the need for prophylaxis (Health Protection Agency, 2005, p.8). The preferred antimicrobials for preventive or abortive therapy are tetracyclines or one of the effective sulfonamides (see Table 8).

<table>
<thead>
<tr>
<th>TABLE 8: PLAGUE PROPHYLAXIS GUIDELINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Tetracycline</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Doxycycline</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Sulfamethoxazole/trimethoprim</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Source: World Health Organisation (1999a, p.60); Gage, Dennis & Tsai (1996, p.12)

Both antibiotics and vaccines have been used to prevent infections from occurring in the first place (Perry & Fetherston, 1997, p.59). However, according to Poland and Dennis (1999b, p.58), vaccinating communities against epizootic and enzootic exposures is not feasible; vaccination is of little use during human plague outbreaks, since a month or more is required to develop a protective immune response. It is thus recommended that vaccines should be used for persons in the following high-risk groups only (Gage, et al., 1996, p.7):

- Laboratory personnel who routinely perform procedures that involve viable *Y. pestis*; and
persons (e.g., mammalogists, ecologists, and other field workers) who have regular contact with wild rodents or their fleas in areas in which plague is enzootic or epizootic.

The epidemiology of plague has been presented and discussed. A summary of this chapter is presented below.

3.7 SUMMARY

Plague is an ancient disease that originated in the cradle of human civilization in Central Asia. Millions of people died during three major plague pandemics in the 6th, 14th and 20th centuries. Plague was imported into South Africa through harbours during the third pandemic in 1900. Plague-infected rodents carried on the ships from the Far East and South America caused outbreaks in the major South African ports. Plague soon spread inland by the movement of people and materials during the Anglo-Boer War. Currently, plague still occurs widespread with high mortality rates.

Plague exists in its natural foci independent of human populations and their activity. Plague natural foci are found on all continents except Australia, and the distribution of plague coincides with the geographical distribution of its natural foci. Plague foci are dynamic, changing in response to shifts in factors such as climate, landscape, and rodent population migration. Plague natural foci still exist in certain provinces of South Africa, namely the Eastern and Northern Cape, Free State, Mpumalanga and Gauteng. It is therefore necessary to continuously conduct thorough epidemiological surveys within these areas.

Plague is a classic zoonosis disease caused by the bacterium *Y. pestis* and may exist in different transmission cycles, involving the pathogen, the reservoirs and the vector. The transmission cycle amongst wild rodents involves two natural statuses:
either 'enzootic' or 'epizootic'. Enzootic plague means that the pathogen of plague (\textit{Y. pestis}) circulates in its animal reservoirs, particularly in wild rodents. Epizootic plague denotes a disease attacking large numbers of animals; equivalent to human epidemics. Humans are extremely susceptible to plague and may be infected either directly or indirectly. The transmission of plague from animals to humans usually occurs \textit{via} the bite of an infected flea. Humans are thus accidental hosts in the plague cycle.

Plague vectors refer to the relevant fleas. A number of flea species have been isolated with \textit{Y. pestis} in Southern Africa. In Southern Africa the known transmitters of plague are \textit{Xenopsylla brasiliensis, X. cheopis, X. philoxera, X. piriei, Dinopsyllus lypusus} and \textit{Chiastopsylla rossi}. In ports and coastal towns, \textit{X. cheopis} is the dominant flea species on the \textit{Rattus} species and is the dominant flea vector of the disease.

Plague is primarily a disease of rodents. The susceptibility to plague infection of a given rodent species may vary with variations in the density of the rodent populations and their flea vectors. The geographical distribution of human plague in South Africa corresponds closely with the plague-susceptible species \textit{M. coucha}. Besides the commensal rodents, the main plague reservoirs in South Africa were thought to be the gerbils: \textit{Tatera brantsii, T. leucogastor} and \textit{T. afra}.

\textit{Y. pestis} infection in humans may occur in three primary clinical forms, namely bubonic plague, septicaemic plague and pneumonic plague. A clinical diagnosis of plague is generally based on patient manifestations and exposure history. A definitive laboratory diagnosis of \textit{Y. pestis} infection is based on bacteriological and/or serological evidence. Local physicians, plague surveillance and control personnel must be familiar with the symptoms of plague and consider it in the differential diagnosis.
The treatment of plague mainly involves case management and antibiotic therapy. Isolation of patients and notification reporting are important procedures for plague case management. Correct and early therapy for plague victims can prevent the complications of the disease. When a diagnosis of human plague is suspected, the patient should be started on specific antibiotic therapy immediately.

In this chapter, important epidemiological considerations that must be taken into account in any plague surveillance and control strategy, have been identified and discussed. These considerations should form the basis on which plague surveillance and control strategies should be developed. In following this strategy, the next chapter attempts to develop work methods and procedures for the surveillance of plague in South Africa.
4.1 INTRODUCTION

In this chapter work methods and procedures for plague surveillance are presented and discussed. Firstly, since plague surveillance is a component of public health surveillance, the basic principles of plague surveillance are explained from a public health surveillance perspective.

Secondly, work methods and procedures for human case surveillance are discussed in terms of three consecutive activities, namely the notifiable disease reporting, the detection of a plague outbreak and the investigation of a plague outbreak. Human serological surveys for plague infection are also described.

Thirdly, work methods and procedures for rodent surveillance are discussed in terms of rodent trapping and processing, observation of rodent activities, commensal rodent surveys and laboratory-based surveillance of rodents, carnivores and dogs. Safety guidelines for plague surveillance and control personnel are also presented.

Fourthly, work methods and procedures for flea surveillance are discussed. Flea indices are emphasized because they are important and widely used to estimate human and epizootic risks in conjunction with related rodent and flea surveillance data. Work methods and procedures for the collection of fleas and the identification of \( Y.\ pestis \) in fleas are also discussed. The basic principles of plague surveillance are presented in the section that follows.
4.2 BASIC PRINCIPLES OF PLAGUE SURVEILLANCE

As defined in Chapter One, surveillance is the systematic ongoing collection, collation and analysis of data and the timely dissemination of public health information for assessment and action as necessary. The World Health Organisation (1999b, p.9) identified the core activities during the surveillance of any health event as:

- Case detection;
- reporting;
- investigation and confirmation;
- analysis and interpretation; and
- action, including control/response and feedback.

The World Health Organisation recommends an integrated disease surveillance (IDS) strategy for improving priority communicable disease (including plague) surveillance and response in the African region. In terms of the IDS strategy, the surveillance activities for detecting and responding to plague include the following seven steps (World Health Organisation Regional Office for Africa, 2001, pp.2-11):

- **Step 1**: Identify cases;
- **step 2**: Report findings;
- **step 3**: Analyse and interpret the data collected;
- **step 4**: Investigate and confirm suspected cases and outbreaks;
- **step 5**: Respond to the outbreak;
- **step 6**: Provide feedback; and
- **step 7**: Evaluate and improve the system.

From the above it can be deduced that surveillance of human plague cases includes
the following core activities, namely:

- Outbreak/Case detection;
- outbreak investigation and confirmation;
- outbreak reporting; and
- outbreak control and feedback.

Surveillance can be classified as active surveillance and passive surveillance. These are described below:

- **Active surveillance** means that the organisation conducting the surveillance initiates the procedures to obtain reports on a regular basis (usually weekly), rather than waiting for the reports, such as telephone calls or personal visits to the reporting individuals (Jekel, Elmore & Katz, 1996, p.37).

- **Passive surveillance** refers to data supplied to a health department, based on a known set of rules or regulations (Thacker, 1996, p.17). Passive surveillance is defined by the World Health Organisation (1999b, p.152) as reports that are awaited, and no active attempt is made to seek reports from participants.

Usually, both active and passive surveillance are combined within a plague surveillance programme. The process of notifiable disease reporting (passive surveillance) and investigations of a plague outbreak (active surveillance) are discussed later in this chapter (see Section 4.3).

Plague surveillance is a continuous and systematic process of collection, analysis, interpretation and dissemination of descriptive information of plague monitoring activities. Surveillance is also described as the detection of health problems through the appropriate collection of data, followed by its collation, analysis, interpretation and dissemination (Tyler, Jr., 1996, p.14). Surveillance data can be used for
immediate public health action, programme planning and evaluation, and the formulation of research hypotheses (Centers for Disease Control and Prevention, 2001, Section 4). From the above, it can be deduced that surveillance data are of vital importance for any surveillance strategy. According to Gage (1999a, p.135), the systematic collection of plague surveillance data provides information that can be used to:

- Predict areas where future human cases and rodent epizootics may occur;
- identify the most common zoonotic sources of human infection;
- identify the most important rodent and flea species in a given focus of \textit{Y. pestis};
- indicate the hosts and flea species that should be targets for control measures;
- assess the effectiveness of plague prevention and control measures;
- identify local ecological factors or human activities that may result in increased plague exposure risks for humans; and
- detect trends in the epidemiology and epizootiology of plague in a given region.

Effective plague surveillance and control strategies require up-to-date information/data on the incidence and distribution of the disease. Furthermore, the purpose of a disease surveillance system determines the data that should be collected. Based on own research findings during this study, plague surveillance data can be collected by means of the following surveillance strategies:

- Human case surveillance;
- rodent surveillance; and
- flea surveillance.

In the following sections, the abovementioned plague surveillance strategies will be presented.


4.3 HUMAN CASE SURVEILLANCE

For the purpose of this study, human case surveillance for plague can be divided into four distinctive activities, namely:

- Notifiable disease reporting;
- the detection of a plague outbreak;
- the investigation of a plague outbreak; and
- human serological surveys.

Some authors believe that 'disease notification' is an important component of a disease surveillance system because it is a statutory obligation for health workers to notify the health authorities of patients with certain conditions (Katzenellenbogen, Joubert & Karim, 1997, p.197). However, the authors could argue that notification should be seen as an administrative function that could be interpreted as the end of a surveillance strategy and the creation of control strategies. Work methods and procedures to be followed during the notifiable disease reporting process are presented in the section that follows.

4.3.1 Notifiable disease reporting

Governmental health agencies have the authority to designate that certain diseases are notifiable by law and their occurrence must be reported (Buehler, 1998, p.449). A routine reporting system for notifiable medical conditions (including plague) has been established to monitor and control communicable disease trends in South Africa. As discussed in Chapter Two (see Section 2.2.3), the current notification system is based on the *Health Act, 1977* (Act 63 of 1977). Whenever clinical symptoms or laboratory results suggest that a patient is infected with *Y. pestis*, the suspected case should be reported immediately to the relevant Provincial
Department of Health, which then reports it to the National Department of Health. The *International Health Regulations, 1969* (World Health Organisation, 1983) delineates that all confirmed cases of human plague should be investigated and reported through the National Department of Health to the World Health Organisation. The formal procedure for human plague cases reporting is illustrated in Figure 8.

**FIGURE 8:**
**PROCEDURE TO REPORT HUMAN PLAGUE CASES**

<table>
<thead>
<tr>
<th>Diagnosis: Can be any health worker, not necessarily a doctor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill in form GW 17/5 (initial diagnosis form)</td>
</tr>
<tr>
<td>Report immediately</td>
</tr>
<tr>
<td>Local authority / Hospital / Health District</td>
</tr>
<tr>
<td>Whoever is responsible for disease containment</td>
</tr>
<tr>
<td>Fill in form GW17/3 (cases)</td>
</tr>
<tr>
<td>Fill in form GW 17/4 (deaths)</td>
</tr>
<tr>
<td>Report immediately</td>
</tr>
<tr>
<td>Health District surveillance office</td>
</tr>
<tr>
<td>Health Information Unit if data entry is done at health district level – province specific</td>
</tr>
<tr>
<td>Computer disks or e-mail</td>
</tr>
<tr>
<td>Report immediately</td>
</tr>
<tr>
<td>Provincial disease surveillance office</td>
</tr>
<tr>
<td>Health Information Unit if data entry is done at provincial level – province specific</td>
</tr>
<tr>
<td>Computer disks or e-mail</td>
</tr>
<tr>
<td>Report immediately</td>
</tr>
<tr>
<td>National Department of Health</td>
</tr>
<tr>
<td>Directorate: Communicable Disease Control</td>
</tr>
<tr>
<td>Computer disks or e-mail</td>
</tr>
<tr>
<td>Report within 24 hours</td>
</tr>
<tr>
<td>World Health Organisation</td>
</tr>
<tr>
<td>Prevention and Control of Diseases</td>
</tr>
</tbody>
</table>

If a patient's symptoms suggest human plague, samples (specimens) should immediately be collected for diagnostic confirmation at an officially accredited microbiological laboratory. As discussed in Section 2.2.5, the revised *International Health Regulations, 2005*, determines that pneumonic plague is a potential international public health concern that will always lead to the utilisation of the World Health Organisation’s algorithm. The occurrence of a suspected case of plague in an area not known to be endemic for plague should also be notified to the World Health Organisation.

A disease reporting form provides important information of the notifiable disease reporting process. Reports of human plague cases should be standardized so that, whenever possible, the same information is recorded for each case (World Health Organisation Regional Office for Africa, 2001, pp.56-57). According to Gage (1999a, pp.137-138), a plague reporting form should include:

- Core patient information: Age, gender, occupation, residence (including country), place of exposure (if known), source of exposure (if known) and the date of onset of the disease;
- a case definition: A preliminary classification of the case (suspected, presumptive or confirmed);
- the clinical observations: Clinical presentation (bubonic, septicaemic or pneumonic);
- the process of treatment (including recovered or fatal);
- the laboratory results; and
- the results from epidemiological and environmental investigations: Possible exposure of others that came into contact with the patient, rodent and vector surveillance data.

The currently used initial diagnosis form (i.e. GW 17/5 form) for notifiable disease
reporting is attached as Annexure 16. The initial diagnosis form mentioned above does not include a clear case definition or details of epidemiological and environmental investigation. From a plague surveillance perspective, a notifiable disease reporting form is presented in Annexure 17.

The case definition is a key component of a standard reporting form. According to Teutsch and Thacker (1995, p.3), a public health surveillance system is dependent on a clear case definition for the health-related event under surveillance. A case definition is a standard set of criteria used to decide if a person has a particular disease, or if the case can be considered for reporting and investigation (World Health Organisation Regional Office for Africa, 2001, p.22). Case definitions can make use of both clinical and surveillance criteria. It is important that physicians and other health care workers be familiar with both clinical and surveillance case definitions of plague and to consider them during diagnosis. The clinical case definitions of plague were discussed in Chapter Three (see Table 6). A standard case definition for plague surveillance provided by the World Health Organisation is illustrated in Table 9.

<table>
<thead>
<tr>
<th>TABLE 9: STANDARD CASE DEFINITION FOR PLAGUE SURVEILLANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Clinical description</strong></td>
</tr>
<tr>
<td>Disease characterised by rapid onset of fever, chills, headache, severe malaise, prostration, with:</td>
</tr>
<tr>
<td>• bubonic form: extreme painful swelling of lymph nodes (buboes);</td>
</tr>
<tr>
<td>• pneumonic form: cough with blood-stained sputum, chest pain, difficult breathing.</td>
</tr>
<tr>
<td><strong>Note:</strong> Both forms can progress to a septicaemic form with toxemia: sepsis without evident buboes rarely occurs.</td>
</tr>
<tr>
<td><strong>2. Laboratory criteria for diagnosis</strong></td>
</tr>
<tr>
<td>• Isolation of <em>Y. pestis</em> in cultures from buboes, blood, CSF (cerebrospinal fluid) or sputum;</td>
</tr>
</tbody>
</table>
or

- Passive haemagglutination (PHA) test, demonstrating at least a fourfold change in antibody titre, specific for F1 antigen of *Y. pestis*, as determined by the haemagglutination inhibition test (HI) in paired sera.

### 3. Case classification

#### 3.1. Suspected

A case compatible with the clinical description may or may not be supported by a laboratory finding of Gram stain negative bipolar coccobaccili in clinical material (bubo aspirate, sputum, tissue, blood).

#### 3.2. Probable

A suspected case with:

- Positive direct fluorescent antibody (FA) test for *Y. pestis* in clinical specimen; or
- PHA test, with an antibody titre of at least 1:10, specific for the F1 antigen of *Y. pestis* as determined by the HI test; or
- Epidemiological link with a confirmed case.

#### 3.3. Confirmed

A suspected or probable case that is laboratory-confirmed.

Source: Adapted from World Health Organisation (1999b, pp.95-96).

Notifiable disease reporting is an important method for early detection of a plague outbreak. A standard case definition will ensure uniformity in early detection of an outbreak. The detection of a plague outbreak is discussed in the next section.

### 4.3.2 Detection of a plague outbreak

As defined in Chapter One, an outbreak is the occurrence of a disease at an unusual or unexpected frequency. Even a single confirmed human plague case should be regarded as an outbreak (see Section 1.10.2). Outbreak detection is a core activity during plague surveillance. The aim of outbreak detection is to control the spread of
the disease among the population at risk as early as possible (Connolly, 2005, pp.114-115). The ability of a surveillance system to detect an outbreak at the earliest possible stage depends on three factors, namely timeliness, validity and system experience. Early detection of a plague outbreak can therefore be achieved (Centers for Disease Control and Prevention, 2004, pp.2-3):

- By the timely and complete receipt and analysis of plague case reports;
- by improving the ability to recognise patterns indicative of a possible outbreak, such as through improving the early predictive value of data, or by lowering the threshold of an outbreak; and
- through the receipt of new types of data that can signify a plague outbreak early in its course.

From the above it can be deduced that the early detection of a plague outbreak is based on the effective capturing and processing of different types of plague surveillance data. Outbreaks typically have been detected based either on accumulated case reports of medical notifiable diseases or by astute clinicians and laboratory personnel who alert public health officials about clusters of diseases (Centers for Disease Control and Prevention, 2004, p.2; Giesecke, 2002, p.151). However, outbreaks cannot usually be predicted early due to the characteristics of the disease; it is therefore necessary to have formal guidelines for plague outbreak responses to facilitate interventions related to prevention and control (National Department of Health, 2000, Section 9).

When a plague outbreak occurs, the response must be immediate. An outbreak control team should be set up immediately by the Health District to implement investigation as well as control measures with the collaboration of relevant staff from the provincial and national governments. The strategy on how to establish a Plague Outbreak Control Team is discussed in Chapter Five (see Section 5.3.1). An
important function of the said team is to conduct field investigation of the outbreak, which is discussed in the next section.

### 4.3.3 Investigation of a plague outbreak

An investigation is a method used for identifying and evaluating people who have been exposed to an infectious disease or affected by an unusual health event (World Health Organisation Regional Office for Africa, 2001, p.97). The investigation of a disease outbreak is a primary function of public health agencies. Once a plague outbreak has been identified, routine passive surveillance should be replaced by active surveillance (Giesecke, 2002, p.151). This implies that the investigation of the outbreak must be carried out immediately. From the above work procedures to be followed in response to a plague outbreak can be illustrated, as shown in Figure 9.

**FIGURE 9: RESPONSE PROCEDURES DURING A PLAGUE OUTBREAK**

- **Routine surveillance system**
  - A pending outbreak
  - Outbreak detection
  - Outbreak investigation
  - Outbreak confirmed
  - Control measures
  - Evaluation and conclusion

- **Notifiable disease reporting**
- **Laboratory-based surveillance**
- **Confirm an outbreak of plague**
- **Search for additional cases**
- **Determine the source and routes of transmission**
- **Identify areas of potential risk to humans**
- **Write an investigation report**

- **Human case treatment and management**
- **Flea control**
- **Rodent control**
- **Education**

Tyler (1996, p.14) states that an epidemic investigation is often triggered by effective epidemiological surveillance at various levels of reporting. From a plague surveillance perspective, one or more suspected plague cases require an immediate outbreak investigation. From Figure 9, it can be deduced that once a suspected plague case is reported, the first procedure of the investigation is to confirm whether the outbreak exists. Confirming an outbreak is based on a clear case definition, standardized reports and laboratory analysis. Following confirmation of a plague outbreak, surveillance personnel should immediately conduct an investigation to obtain an exposure history from the patient in order to make an assessment of likely sources of infection and potential risks to others in the area.

The aim of an outbreak investigation is to verify the outbreak and control strategies introduced so that any future outbreak can be better controlled and managed. Based on own research findings of this study, the procedures to be followed during a plague outbreak should include:

- Confirming an outbreak of plague;
- searching for additional cases;
- determining the source and routes of transmission;
- identifying areas of potential risk to humans; and
- writing an investigation report.

An investigation for each human case should be conducted to determine the source of infection and the risk of additional human cases. Comprehensive knowledge of the ecology of the outbreak area will be helpful for detecting future epizootics and to identify areas of high risk. The process of a plague outbreak investigation should include (National Department of Health, 2004a; World Health Organisation Regional Office for Africa, 2001, p.104; Gage, 1999a, pp.137-139):
• Reviewing local hospital and clinical records;
• identifying other potential cases from interviews with local health care providers;
• collecting blood samples from potential cases for analysis;
• recording a complete history of a patient’s activities and travels during the incubation period of the infection;
• collecting information on possible exposure to the infection;
• ascertaining probable contacts from interviews with the patient, family and friends of a plague pneumonia case;
• determining which animal and flea species are the likely sources of infection or pose a continuing threat to humans;
• identifying proximity of infected rodents and fleas to human dwellings or work places;
• identifying predominant vegetation types in the outbreak area;
• identifying land use patterns (such as agricultural, residential, industrial); and
• collecting information on types of dwellings present and whether these dwellings provide food and harbourage for rodents.

Finally, an investigation report should be compiled by the outbreak control team. The investigation report should explain why the outbreak occurred and identify weaknesses in existing surveillance and control measures. This will enable recommendations to be made on specific prevention and control strategies (Katzenellenbogen, et al., 1997, p.203). When an outbreak of plague occurs, all efforts and resources should be aimed at controlling the outbreak. It should thus be noted that the process of a plague outbreak investigation may be conducted simultaneously or consecutively with plague control measures (see Section 5.3.2). A human plague case may be detected by laboratory analysis. Human serological surveys are introduced below.
4.3.4 Human serological surveys

As discussed earlier (see Section 3.6.1), a definitive laboratory diagnosis of \textit{Y. pestis} infection is based on the isolation and identification of the organism from clinical specimens, or by demonstrating a diagnostic change in antibody titre in serum specimens. The detection of the F1 antigen in human tissues or body fluids by direct fluorescent antibody (DFA) testing (or other standardized antigen detection procedures) provides presumptive evidence of plague. Gage (1999a, p.137) states that human serological surveys play an important role in active surveillance following the identification of a suspect case of human plague. In South Africa serological studies on human plague have been conducted ever since the plague epidemic of 1967. The passive haemagglutination (PHA) technique was employed during these studies. Eighteen people (14.3 \%) had titres of 1:16 or higher (the highest titre was 1:128) in a total of 126 people. All patients showed a rising titre to a maximum of 1:512 (Isaacson & Hallett, 1975, pp.1165-1166).

Rodent surveillance is an active approach to monitoring activity among plague susceptible hosts in order to effectively detect a plague outbreak. Equipment required during rodent surveillance is listed in Annexure 18. Equipment required for flea collection is listed in Annexure 19. Work methods and procedures for rodent surveillance are presented and discussed in the next section.

4.4 RODENT SURVEILLANCE

As discussed in Chapter Three (see Section 3.4.3), rodents are the primary reservoirs of plague and nearly all human cases are associated with rodent epizootics. The results of rodent surveillance provide reference data on changes in the rodent and flea populations that may indicate the occurrence of a plague epizootic (Harrison, 1995, pp.31-32). In the following sections rodent surveillance is
discussed as follows:

- Rodent trapping and processing;
- observations of rodent activities;
- commensal rodent surveys; and
- laboratory-based surveillance of rodents, carnivores and dogs.

The next section focuses on work methods and procedures for rodent trapping and processing.

4.4.1 Rodent trapping and processing

The systematic trapping and processing of rodents is important because the basic rodent population data, including population densities, ecological data (such as age structures, reproductive status), rodent habitat preference and local distributions can be obtained by the trapping and processing of rodents (Gage, 1999a, p.145). Trapping and processing of rodents also provide sera, tissue samples and ectoparasites of rodents for laboratory analysis. As discussed in Chapter One, it is important that work methods and procedures for rodent trapping be carried out in a standardized way in order to obtain valid data. In terms of own research findings of the study, and confirmed by Leirs (2004, pp.40-41) and Harrison (1995, pp.50-53), work methods and procedures for rodent trapping include:

- Rodent habitat assessment;
- establishment of traplins; and
- baiting and trap setting.

According to Harrison (1995, p.50), a habitat is defined as an area that has similar plant life and physical features in which an animal or group of animals normally live.
The following section discusses the procedure to be followed during rodent habitat assessment.

**4.4.1.1 Rodent habitat assessment**

Information of a rodent habitat provides important baseline data for a plague surveillance programme. Rodent habitat data should include information on predominant vegetation types, roads, railways, airports, seaports and land use patterns (i.e. agricultural, residential or industrial). Rodent habitat data should also include the types of dwellings present as well as whether these dwellings or other man-made structures provide food and harbourage for rodents (National Department of Health, 2004a, p.25; Harrison, 1995, p.51). In addition, rodent habitat assessment must identify plant life and physical features where the trap site is located. A rodent habitat assessment form is presented in Annexure 20.

Within each trap site, sub-habitats should be identified. For example, houses can be divided into a number of sub-habitats, including gardens, outside sheds, basements, attics and storage rooms (Leirs, 2004, p.40). After identification of the trap site and rodent habitat assessment, traplines should be established within each identified habitat. The establishment of traplines is discussed below.

**4.4.1.2 Establishment of traplines**

Harrison (1995, p.50) states that the basic trapline should transect those areas most representative of the rodent habitat. In open areas, traps should be placed in one or more traplines at 10 metre intervals. Gage (1999a, p.147) believes that traps should be set where there are burrows, nests or runways, or along transects with 10 to 20 traps (or more) spaced at approximately 20 metre intervals along each transect. Trapping grids can be established, with the trap spacing intervals based on local
conditions (see Figure 10). Each grid can be laid out in a square grid of 10 x 10 trapping stations (ten metres between each). The size of each study site should therefore be approximately one hectare (100 m x 100 m). Two trapping grids sites should be established in each target area. Half of the trapping grid should be fallow; the other half should be peri-domestic (near a house) or a field close to human habitation (Vibe-Petersen & Leirs, 2004, pp.57-58).

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**FIGURE 10: TRAPPING GRID FOR THE STUDY OF RODENT POPULATION DYNAMICS**

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Source: Adapted from Vibe-Petersen & Leirs (2004, p.58)

Trapping grids should be located away from fields where rodenticides are applied. Each trapping station should be marked with a tag (such as a painted brick). Once all the tags (bricks) are in place, a Sherman trap must be set at each tag (brick) (Vibe-Petersen & Leirs, 2004, p.58). In the next section baiting and trap setting are discussed.
4.4.1.3 Baiting and trap setting

In each habitat type different types of traps should be used because different traps may yield different species of small mammals. The proportion of different trap types depends on different species and the local conditions. Live traps are preferable to snap or dead-fall traps for capturing rodents for flea collection, because fleas tend to leave a dead host's body as soon as the host's body temperature drops. Live traps can also be used to capture rodents for tissue and blood samples. Live traps are typically rectangular box-shaped devices with hinged doors with spring mechanisms for shutting the door once an animal has entered the trap (Gage, 1999a, p.145; Harrison, 1995, p.36).

A mixture of peanut butter and maize bran or rolled oats can be used as bait. When trapping in urban areas, it is useful to add some dried fish or sardine oil. When trapping for *Cricetomys* (giant pouched rats), fresh fruit or green maize should be used. Traps should be carefully checked while setting. The baits are placed in the rigid live trap through the trap doors (see Annexure 21). Traps are usually placed in the afternoon and collected the next morning. Work methods and procedures for processing of trapped rodents and their fleas are presented in the following section.

4.4.1.4 Processing of trapped rodents and associated fleas

Each trap containing a rodent should be placed in a plastic bag which should be securely closed. At the field station each bag should be carefully opened and each rodent emptied into a separate plastic bag (Leirs, 2004, p.43). Work procedures for rodent processing are summarised as follows (Leirs, 2004, p.42; Mills, et al., 1995, pp.17-29):

- Recording the trap site of each captured rodent;
- removing rodents from traps;
- anaesthetizing rodents;
- weighing each rodent;
- taking of blood samples;
- combing rodents and collecting fleas;
- rodent measurements;
- dissecting and taking of tissue samples;
- sewing up rodents and preserving them in formalin;
- labelling rodent and each specimen (blood, organs and fleas) vial;
- filling in data forms; and
- shipping specimens.

A rodent should be kept alive as long as possible for blood sample collection. Following dissection, rodents should be preserved in formalin and each specimen taken from the body should be shipped to the relevant laboratory. If carcasses are not saved for laboratory tests, they should be sprayed with disinfectant, placed in a double biohazard bag and incinerated (Mills, et al., 1995, p.28). Details of work methods and procedures for rodent trapping and processing are presented in Annexure 21. The next section will discuss the observation of rodent activity during rodent surveillance.

### 4.4.2 Observation of rodent activities

Observation of rodent activities is a useful method during rodent surveillance. The simplest method for monitoring plague in rodent populations is to collect dead rodents and to forward the carcasses to the laboratory for examination for evidence of Y. pestis infection. According to Harrison (1995, pp.35-36), observations of rodent activities for unusual conditions (e.g. sick, sluggish, dead animals or other inactivity not attributable to seasonal changes) every two weeks will provide useful data of
potential plague epizootics. Gage (1999a, p.144) states that mapping and periodically checking the target area for visible signs of activity among plague-susceptible rodents is an important surveillance technique.

Plague surveillance personnel should be alert to signs of rodent die-offs and the public should be encouraged to report sick or dead rodents observed near their homes or work places. A total lack of rodents in areas where they used to thrive may be a signal for a plague epizootic. Carrion-feeding flies at the entrances of rodent burrows, bad odours from burrows and poorly-maintained burrows are also signs of rodent die-offs. If it is suspected that a plague epizootic has occurred, carcasses of rodents and other plague susceptible animals, such as lagomorphs (hares and rabbits) and domestic cats should be collected for laboratory analysis (National Department of Health, 2004a).

The data mentioned above should be plotted on maps for the purpose of orientation and for the identification of suitable surveillance locations. Work methods and procedures for commensal rodent surveys are discussed in the section that follows.

4.4.3 Commensal rodent surveys

The purpose of commensal rodent surveys is to determine the approximate density of the rodent population and its distribution within the habitats or infested areas (World Health Organisation, 1998, p.2). Commensal rodents may be found almost everywhere that humans live and work. Rodents are rarely seen when infestation is low. Rodents that can be seen during the daytime indicate a sizable infestation. Rodents leave a variety of signs within an infested area. The most frequent indoor rodent sign is droppings. The most frequent outdoor rodent signs include burrows and gnawed material. During a commensal rodent survey the following signs of rodents should be noticed (Koren & Bisesi, 2003, p.324; United States Army
Environmental Hygiene Agency, 1991, pp.14-15), including:

- **Sound**: Sounds of gnawing, scratching, squeaking and running on walls and across ceilings can be heard in buildings infested by rodents;
- **Droppings**: Droppings (faeces) are found in places rats and mice frequent. Only fresh droppings are soft;
- **Norway rat droppings** are capsule shaped (0.6 to 1.9 cm long);
- **House mouse droppings** are rod shaped (0.3 to 0.6 cm long);
- **Roof rat droppings** are spindle shaped;
- **Urine**: Rodent urine is not visible under natural light. Under ultraviolet light it fluoresces bluish white to yellowish white (other materials such as lubricating oils and the optical bleaches in detergents also fluoresce);
- **Rub marks**: Dirt and oil on rodent fur leave rub marks where they rub against pipes, beams, and openings in their travels. Rat rub marks are much more conspicuous than those left by mice;
- **Runways**: Runways occur in sheltered areas where rodents feel secure as they move. The runways are smooth and relatively free of dust from the constant movement of the rodents. Like smudge marks, rat runways are more conspicuous than those made by mice;
- **Tracks**: Footprints and tail marks may be found in dust and mud. Tracking patches made with flour or talc can be used to determine rodent presence in buildings. Dry soil dust can be used outdoors if it is protected from weather and disturbance;
- **Burrows**: Holes and enlarged openings in walls are often burrow entrances. Norway rat burrows may be found around shrubbery and sidewalks, under foundations and along stream banks;
- **Gnawing**: Rodent gnawing results in small piles of wood chips around doors, baseboards and windows; damage to stored goods and food product containers; and enlarged openings where pipes and wires penetrate walls. Freshly gnawed
areas are lighter in colour than the un-gnawed material, and tooth marks may be apparent;

- Nests and food caches: Mouse and rat nests, usually in the form of a loose ball of shredded cloth, insulation, paper, or dry vegetation may be found when cleaning garages, attics and other storage areas. Nests are often built in furniture, inside large electrical appliances and in vehicles that have been parked for more than a few days;
- Odour: Mice produce a musky odour that an experienced observer can differentiate from rat odour. Odour is probably not detectable when the rodent population is low and ventilation good; and
- Pet reactions: Most cats and dogs show strong interest in wall or floor areas where rats or mice are present, especially if it is a recent invasion.

Criteria to be used to determine the severity of a rodent infestation during rodent surveys are presented in Annexure 22. Commensal rodent surveys that specify the severity and scope of an infestation will contribute to formulating a strategy for commensal rodent control (see Section 5.5.2). In the following section, the laboratory-based surveillance during plague surveillance will be discussed.

### 4.4.4 Laboratory-based surveillance for rodents

According to Buehler (1998, p.449), the utilisation of laboratory analysis is highly effective for the identification of plague infection. As mentioned above (see Section 4.4.2), rodent specimens should be sent to the plague laboratory for analysis if a plague epizootic has occurred. The identification of *Y. pestis* in rodent tissue is firstly discussed.

#### 4.4.4.1 The identification of *Y. pestis* in rodent tissue

In conducting rodent surveillance, *Y. pestis* can be detected in the tissue (such as
the liver, spleen, kidney and heart) of rodents by direct immunofluorescent assays (DFA), enzyme-linked immunosorbent assays (ELISA), or by isolating the organism in pure culture. According to Gage (1999a, p.143), *Y. pestis* can also be identified by means of detecting the plague antigen in moist marrow samples taken from long bones (such as the femur), even when the rodent has been dead for several months. Work procedures for isolating the *Y. pestis* in pure culture are described by Chu, et al. (2002) in *Basic protocols for level A laboratories: The presumptive identification of Yersinia pestis*. Relevant laboratory personnel have full access to the said protocols.

4.4.4.2 Rodent serological surveys

Serological survey for antibodies against the plague bacillus is a useful tool for detecting plague foci and for monitoring the efficacy of plague control strategies (Gordon, Isaacson & Taylor, 1979, p.767). The South African experience has demonstrated that the method of isolating *Y. pestis* in rodent tissues rarely yields positive results, except during plague epizootics (National Department of Health, 2004a, p.26). Serological surveys have at least two important advantages over attempts to isolate *Y. pestis* from tissues of captured rodents (Gage, 1999a, p.148):

- The likelihood of detecting plague antibodies in rodent sera is many times higher than recovering an isolate of *Y. pestis* from tissues; and
- the results of rodent serological surveys are much less likely to be affected by seasonal factors than are attempts to isolate *Y. pestis* from rodent tissues.

The isolation of *Y. pestis* from rodent tissues is much more time consuming than rodent serological surveys. Hence, the isolation of *Y. pestis* from rodent tissues may not be necessary in situations where a reliable serological survey is available. According to Gage (1999a, p.148), rodent sera can be analysed by various techniques, including filter complement fixation, passive haemagglutination, latex
agglutination and enzyme immunoassays.

Blood samples for a serological survey can be collected from rodents by a number of techniques, including cardiac puncture and retro-orbital bleeding from the eye (see Annexure 21). Whole blood for serological analysis can also be collected on filter paper strips which are especially useful during field studies (Gill, Shepherd, Leman and Erasmus, 1987, p.159). The following section deals with rodent carnivores and dogs serological surveys.

4.4.5 Laboratory-based surveillance for carnivores and dogs

Rodent carnivore serological surveys are more sensitive/effective than rodent serological surveys or the isolation of *Y. pestis* from rodent tissue. Laboratory-based surveillance for carnivores is discussed firstly.

4.4.5.1 Rodent carnivore serological surveys

When a plague epizootic occurs among susceptible rodents, dead and dying rodents may be consumed by carnivores. The carnivores (such as *Cynictis pencillata* and *Suricata suricatta*) may then become infected, either by rodent fleas or by direct contact with rodent tissue. Carnivores do not usually die from plague; they produce plague antibodies that are detectable through serological techniques (Harrison, 1995, p.32). Some carnivore species (including domestic dogs) may survive plague infection and develop antibodies that can be detected for as long as six months (Gage, 1999a, p.150).

An advantage of carnivore serological surveys is that sampling sera from just a few of these carnivores is roughly equivalent to sampling hundreds of rodents for plague infection over a wide area (Gage, 1999a, p.150; Govere & Durrheim, 1999, p.570).
Serological surveys of carnivores can therefore be used as a powerful technique for detecting evidence of plague activity. According to Gage (1999a, p.150), carnivore serological surveys are especially recommended when:

- Vast areas must be sampled;
- plague has not previously been detected in local rodent populations;
- epizootics have not occurred in local rodent populations for many years; and
- it is suspected that plague may have disappeared from an area.

Wild rodent carnivores can be collected by trapping or shooting. Harrison (1995, p.65) suggests that a minimum of two small carnivores should be trapped alive in each sampling area of 0.5 square miles (1.3 km²) or less. In areas larger than 0.5 square miles, an additional carnivore should be trapped for each additional 0.5 square miles. In addition, reasonable trapping success would be one small carnivore per 20 to 40 trap nights (one trap night means one trap set overnight). Blood samples can be obtained by cardiac puncture of recently killed or anaesthetized animals, bleeding from large veins, or opening the body cavity to gain access to blood in the heart (Gage, 1999a, p.151).

Gage (1999a, p.150) states that a sudden increase in the percentage of antibody-positive carnivores indicates that there is an ongoing or a recent epizootic activity in the rodent population. High antibody levels combined with a high proportion of serologically positive carnivores indicate more recent and widespread plague activity. Harrison (1995, p.64) argues that only one antibody-positive serum does not indicate an epizootic, regardless of how high the titre is, although it does demonstrate plague activity at one time or another and in the location where the animal has been.

A moderately large percentage (25-30%) of positive sera with relatively high titres
(1:256 or greater) should be cause for concern. The geometric mean of positive titres (GMPT) in excess of 1:100 with a normal distribution of titres and sufficient sample size (25 or more) probably indicates recent and perhaps current plague activity (Harrison, 1995, pp.64-65). Furthermore, plague surveillance personnel should perform extensive investigations within a suspected area, whenever the results of the rodent carnivore (including domestic dogs) serological surveys suggest plague activity. Serological surveys of domestic dogs are discussed in the next section.

4.4.5.2 Serological surveys of domestic dogs

Domestic dogs are most likely to be exposed to plague bacilli by contact with an infected rodent or rabbit or by the bite of an infected flea (Orloski & Lathrop, 2003, p.445). Govere and Durrheim (1999, p.570) state that serological surveys of domestic dogs have a number of advantages when conducting plague surveillance:

- They range over a relatively wide area and tend to scavenge on dead and dying rodents;
- they do not easily succumb to plague;
- they are relatively easy to sample;
- they are long-lived, compared to rodents; and
- plague antibodies persist in them for a few months.

As mentioned in Section 4.6.5, dogs may produce a specific Y. pestis antibody that can be detected for as long as six months. Domestic dogs serve as excellent sentinel animals for plague surveillance. Dog serological surveys are particularly useful in detecting plague in the absence of overt rodent plague and to obtain data in areas where plague infection is widespread or quiescent (National Department of Health, 2004a, p.32). Domestic dogs can be bled from veins in the forelegs or
hindlegs, without adverse effect. According to Gage (1999a, p.151), dogs should be properly restrained, muzzled or anaesthetised prior to bleeding, to prevent them from biting handlers. Fleas should also be collected from these dogs. Field data sheets for dogs (see Annexure 23) should be completed after sampling. Relevant information (gender, age and type) of the dog can be obtained from the owner. The sample date and the sample site must be carefully noted. A Global Position System (GPS) must be used for locating the sample site.

Rodent surveillance requires plague surveillance personnel to handle live rodents and carcasses. Plague surveillance and control personnel must therefore be trained to execute their tasks in a safe manner. In the section that follows, safety concerns for plague surveillance and control personnel will be addressed.

### 4.4.6 Safety concerns for plague surveillance and control personnel

Plague surveillance and control personnel must be taught how to protect themselves from being infected. Based on own research findings and confirmed by Gage (1999a, pp.141-142), fundamental precautions include the following:

- Minimizing exposure to rodent excreta;
- avoiding infection *via* aerosols from a plague pneumonia case;
- always wearing proper protective clothing and equipment;
- properly anaesthetizing animals before handling them; and
- carefully disinfecting contaminated working spaces, equipment and clothing.

During rodent handling and dissection, personnel should wear protective clothing and equipment, including a proper respirator. A correctly fitted respirator is essential to prevent unfiltered air from entering the mask without passing through the filters. Protective clothing and equipment include (Mills, et al., 1995, p.8):
• A disposable surgeon’s gown that ties at the back, or disposable coveralls;
• disposable shoe covers;
• latex gloves;
• a powered air-purifying respirator (PAPR) or a half-face respirator with safety glasses.

Respirators should be equipped with high-efficiency particulate air (HEPA) filters. The disposable clothing (gowns or coveralls, shoecovers, and gloves) should be removed and placed in biohazard bags for safe disposal after completion of processing and clean-up (World Health Organisation, 2000, p.6). Safety guidelines for plague surveillance and control personnel are summarised in Annexure 24. Work methods and procedures for flea surveillance are discussed in the next section.

4.5 FLEA SURVEILLANCE

Fleas are the primary vectors of plague (see Section 3.4.2). Knowledge of local flea species and their hosts is essential for estimating risks of human plague infection and designing of specific control measures. Surveillance data from fleas also provide clues about which hosts are involved in local plague epizootics (Harrison, 1995, p.30). Flea indices are important indicators during plague surveillance. In the next section flea indices are discussed.

4.5.1 Flea indices

According to Gage (1999a, p.155), the most basic information obtained during flea and rodent surveillance is the number of fleas of different species found on various species of hosts. The raw data can be used to calculate various types of flea indices, including:
A burrow (or house) flea index can be similarly calculated as the specific rodent nest flea index. The specific flea index is the most widely used of these indices. When using flea indices, it is important to estimate human and epizootic risks in conjunction with other rodent and vector surveillance data. For example, it has been reported that a specific flea index of greater than 1 for *X. cheopis*, represents a potentially dangerous situation with respect to increased plague risk for humans (Gage, 1999a, p.155). On the other hand, it is quite possible that the specific flea index below 1 for *X. cheopis* represents a hazard in an endemic area at the beginning of the normal plague season for that area, while the same index in excess of 1 may not indicate an overly dangerous situation when the seasonal decline in plague has just commenced (National Department of Health, 2004a, p.34).

Many factors affect the reliability of flea indices, including host species, host age, trapping techniques, seasonal variations, trapping sites selected and the natural tendency of fleas to have different hosts. Monthly or weekly flea indices may demonstrate seasonal trends (National Department of Health, 2004a, p.35). It was found that the examination of 20 host animals was sufficient to establish a reliable specific flea index through the sequential sampling method (Gage, 1999a, p.155). In order to obtain reliable flea indices, standardized work methods and procedures for
rodent trapping and flea collection should be followed. In addition, flea indices should be calculated only when the rodents have been trapped in the same area and at the same time.

The determination of the total flea index (the number of fleas per host) is also important. When the number of *X. cheopis* fleas on the *Rattus* species increases above a certain level, it may be necessary to initiate control measures to decrease the risk of human cases and plague epizootics (Gage, 1999a, p.152). Plague surveillance and control personnel should determine and monitor the flea indices within a target area. To determine the flea indices, the fleas must be collected before serological investigations commence. Work methods and procedures for flea collection are described in the following section.

### 4.5.2 Flea collection

Flea collection can be carried out simultaneously with an existing rodent surveillance programme. Fleas can be collected from different sources, namely the captured rodents, rodent burrows, rodent nests and human dwellings. Collecting fleas from captured rodents is presented first.

#### 4.5.2.1 Collecting fleas from captured rodents

Fleas should be killed by freezing, anaesthetization or insecticides before they can be collected. Fleas can be euthanatized by filling a plastic bag with carbon dioxide or with a cotton ball containing anaesthetic (Gage, 1999a, p.154; Harrison, 1995, p.56). The most common method for collecting fleas is to remove them from captured host animals. The anaesthetized rodents are brushed from the tail end forwards with a stiff toothbrush. Fleas can then be removed with a suction device or a wet applicator stick (Leirs, 2004, p.40). Annexure 21 contains a detailed description of work methods and procedures for collecting and processing fleas from captured rodents.
4.5.2.2 Collecting fleas from rodent burrows

When a rodent die-off has occurred, fleas remaining in the rodent burrows may be the only indicator for determining whether plague was the cause and the extent of plague activity in the epizootic area. Fleas can be collected from rodent burrows by means of swabbing/flagging. A typical burrow swab consists of a long, flexible rubber rod (or wire), covered with a piece of white flannel cloth. The rubber rod (or wire) is used to insert the cloth deep into the burrow; fleas mistake it for normal hosts and cling to the cloth. The cloth is then removed slowly from the burrow and placed in a plastic bag for examination (Gage, 1999a, p.154). Fleas in burrows can also be collected from a sentinel animal (such as a laboratory mouse) introduced into the rodent burrows (Harrison, 1995, p.56).

4.5.2.3 Collecting fleas from rodent nests

Gage (1999a, p.154) states that many fleas spend more time in the nests of their hosts than on the hosts themselves. Rodent nest fleas can be collected by sorting the nest material in a white enamel pan, as described in Annexure 21. Rodent nests should be dug carefully to obtain the nest material. The soil below a nest, as well as the interior of the gallery walls must be scraped off and deposited in a cloth bag for examination. Materials from different nests must be kept separate. Fleas collected from the nests must also be kept separate from those found in the burrows and carefully labelled as to their locality (Harrison, 1995, p.56; De Meillon, et al., 1961, p.24). Specific rodent nest flea index can be calculated by the collecting of fleas from rodent nests. A rodent nest fleas field data form is presented in Annexure 25.

4.5.2.4 Collecting fleas from human dwellings

There are several techniques for the collection of wandering (without host) fleas in
human dwellings. These techniques (National Department of Health, 2004a, p.37; United States Army Center for Health Promotion and Preventive Medicine, 1992, pp.3-7) include:

- Sentinel guinea pigs can be released in human dwellings to wander around overnight. Fleas are then collected from the captured guinea pigs the next morning;
- Flea water traps can also be used. A white enameled tray (5 cm deep), half-filled with water is placed on the floor of the room. A piece of brick is placed in the middle of the tray, and a lighted candle is set on it. The room is then closed for the night and fleas are collected from the tray the next day; and
- Flea sticky-paper is another effective technique for the collection of wandering fleas.

Determining which flea species are infected with *Y. pestis* is critical for identifying the specific plague vectors in a target area. The next section introduces the identification of *Y. pestis* in fleas.

**4.5.3 The identification of *Y. pestis* in fleas**

*Y. pestis* has been detected in fleas using immunological techniques and polymerase chain reactions (PCR). PCR has been demonstrated to be more sensitive and reliable for the identification of plague bacilli in fleas (Engelthaler, Gage, Montenieri et al., 1999, p.1980). Care must be taken to avoid false positives due to possible contamination during the PCR assays. Another method for determining whether fleas are infected with plague is to inoculate susceptible laboratory animals (such as mice) with ground fleas suspended in physiological saline (0.85%). The mice are then monitored over 21 days, and those that die are necropsied to obtain tissues for bacterial isolation (Gage, 1999a, p.156).
4.6 SUMMARY

Plague surveillance is a continuous and systematic process of collection, analysis, interpretation and dissemination of descriptive information of plague monitoring activities. For the purpose of this study, the core activities of plague surveillance include:

- Outbreak/case detection;
- outbreak investigation and confirmation;
- reporting; and
- outbreak response and feedback.

In this chapter plague surveillance was discussed in terms of the following strategies:

- Human case surveillance;
- rodent surveillance; and
- flea surveillance.

Surveillance is classified into two types, namely active surveillance and passive surveillance. Both are usually combined within a plague surveillance programme. In South Africa, the current notification system is based on the *Health Act, 1977* (Act 63 of 1977). Each plague case must be reported to the relevant Provincial Department of Health, who then report to the National Department of Health.

A public health surveillance system is dependent on a clear case definition of the health-related event under surveillance. A plague case reporting form should be standardized so that whenever possible, the same information is recorded for each case.
The early detection of a plague outbreak is dependent on an effective plague surveillance system. Even a single confirmed case is the epidemic threshold for a plague outbreak investigation. Once a plague outbreak has been identified, routine passive surveillance should be replaced by active surveillance. This implies that the outbreak must be investigated immediately.

Trapping and processing of rodents can provide rodent population data, serum, tissue samples and fleas. Observation of rodent activities is a useful method during rodent surveillance. Rodents that disappear (wipe out) completely may be the signal for a plague epizootic. Commensal rodent surveys that define the severity and scope of rodent infestation will contribute to formulating a strategy for commensal rodent control.

The collection of fleas should be carried out simultaneously with rodent surveillance. The most common method for flea collection is to remove them from captured rodents. Flea indices are used as indicators for determining the importance of local flea species as plague vectors.

Human serological surveys play an important role during active surveillance, following the identification of a suspected human plague case. Serological surveys from carnivores have more advantages than rodent serosurveys and attempts to isolate *Y. pestis* from rodents. Domestic dogs serve as excellent sentinel animals during plague surveillance. Dog serological surveying is particularly useful in detecting plague in the absence of overt rodent plague and to obtain data in areas where plague infection is widespread or quiescent.

Effective plague surveillance is the premise for successful plague prevention and control. Work methods and procedures for plague control are presented and discussed in the next chapter.
CHAPTER FIVE
WORK METHODS AND PROCEDURES FOR THE CONTROL OF PLAGUE

5.1 INTRODUCTION

Plague control has been defined as the actions and programmes directed towards reducing plague incidences and prevalence by suppressing the conditions that encourage rodent reservoirs and flea vectors of the disease. In this study, work methods and procedures for plague control are discussed from four perspectives, namely:

- Plague control strategies;
- the control of a plague outbreak;
- the use of insecticides to control flea vectors; and
- the use of rodenticides to control rodent reservoirs.

Firstly, basic strategies for the control of plague are discussed. These control strategies include legislative measures, health education, environmental management, chemical control, biological control, mechanical control and medical control. An Integrated Vector Management (IVM) strategy is also presented.

Secondly, work methods and procedures for the control of a plague outbreak are discussed. This section will focus on the establishment of a Plague Outbreak Control Team and the implementation of the outbreak control strategies. The establishment of a Plague Outbreak Control Team is discussed from national, provincial and health district perspectives.

Thirdly, the nature and characteristics of insecticides and rodenticides are introduced with emphasis on their application. Work methods and procedures for the
use of insecticides/rodenticides in flea vector/rodent reservoir control are identified and discussed. The basic strategies for the control of plague are introduced in the section that follows.

5.2 BASIC STRATEGIES FOR THE CONTROL OF PLAGUE

In general, communicable disease control can be directed at the chain of infection, namely the agent, the transmission route, the host and/or the environment (Webber, 1996, p.35). According to Kim-Farley (1997, p.1563), control measures of communicable diseases are multiple and mainly include: immunisation, isolation, environmental methods and vector control. Plague is a vector-borne disease, which is primarily a disease of wild rodents, transmitted through fleas (World Health Organisation Regional Office for Africa, 2003, p.1). From the above, it can be deduced that measures of plague control should be directed at the rodent reservoirs and flea vectors of the disease.

Most documentary sources highlight different strategies for controlling plague, including: legislative measures, health education, environmental management, chemical control, biological control, mechanical control and medical control (Bio-integral Resource Center, 2005, pp.11-16; National Department of Health, 2004a, pp.11-12; Gratz, 1999b, pp.97-99; Kim-Farley, 1997, pp.1570-1571). These control strategies are discussed in the following sections.

5.2.1 Legislative measures

Plague control can only be carried out and maintained effectively by legislative measures. Legislative measures in this context refer to the development, promotion, and enforcement of regulatory codes, regulations and laws that relate to plague control (Bio-integral Resource Center, 2005, p.11). In South Africa, a number of
legislative measures regarding the control of the disease exist. These include the:

- *International Health Regulations, 1969/2005*;
- *Health Act, 1977* (Act 63 of 1977);
- *International Health Regulations Act, 1974* (Act 28 of 1974);
- *Regulations Relating to Communicable Diseases and the Notification of Notifiable Medical Conditions* (Regulation 2438 of 1987);
- *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947* (Act 36 of 1947); and
- *Regulations Regarding the Prevention of Rodent Infestation and the Storage of Grain, Forage, etc. in Urban and Rural Areas of the Republic of South Africa* (Regulation 1411 of 1966).

The abovementioned legislations were discussed in Chapter Two (see Section 2.2). Any plague control activities must be conducted under the said legislative measures. In analysing the abovementioned legislations it becomes noticeable that no provision is made for work methods and procedures on how to execute the legislative requirements. This situation contributed to the need for this study and is supported by the United Nations Division for Sustainable Development (United Nations, 1992). Health education for plague control is discussed in the next section.

### 5.2.2 Health education

According to Connolly (2005, p.88), health education and community participation in intervention play a key role in plague prevention and control. In areas where plague affects animals, community education is the cornerstone for plague prevention. Educational programmes directed at the general public about how to avoid exposure to disease-bearing animals and their flea vectors should include sufficient information about the following (Heiberg, 2006, p.9; Centers for Disease Control and

- Routes of plague infection;
- the importance of avoiding flea bites by using insecticides and repellants;
- wearing protective clothing when handling potentially infected animals;
- the general public should be encouraged to monitor the die-offs of rodents and to report the die-offs to local authorities for further investigation;
- the importance of rodent-proof buildings;
- the importance of appropriate storage and disposal of food and garbage to prevent access and shelter for rodents (remove rock piles, rubbish, cluttered firewood and potential food supplies such as pet and wild animal food);
- garbage around houses should be removed and deposited at central garbage stations (established by local government);
- rodent control (inexpensive rodent traps and safety aspects of poisoning);
- pet management: domestic dogs and cats should be treated periodically with appropriate insecticides and not be allowed to roam freely; and
- building capacity amongst the local community health workers and traditional leaders in the signs, symptoms, diagnosis and treatment of the disease.

From the above it can be deduced that health education is a strategy to change human behavior to coincide with the principles of plague control. In the next section, environmental management for plague control is discussed.

5.2.3 Environmental management

From a communicable disease control perspective, environmental management is defined as the planning, organisation, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with
man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact (World Health Organisation, 1980, p.9). Environmental management is naturalistic and involves an attempt to extend and intensify natural factors which limit vector breeding, survival and contact with humans. It should be carried out prudently and skillfully. Environmental management techniques for the control of plague are generally grouped into three categories, namely (World Health Organisation, 1980, pp.9-10):

- **Environmental modification**: A form of environmental management consisting of any physical transformation that is permanent or long-lasting of land, water and vegetation, aimed at preventing, eliminating or reducing the habitats of vectors without causing unduly adverse effects on the quality of the human environment. Environmental modification includes drainage, filling, land leveling and transformation of impoundment margins;

- **Environmental manipulation**: A form of environmental management consisting of any planned recurrent activity aimed at producing temporary conditions unfavourable to the breeding of vectors in their habitats. Environmental manipulation includes a number of activities, for example water salinity changes, stream flushing, regulation of the water level in reservoirs, vegetation removal, shading and exposure to sunlight; and

- **Modification of human habitations and behaviours**: A form of environmental management that reduces man-vector-pathogen contact. Examples of this approach include the siting of settlements away from vector sources, rodent-proofing of houses, personal protection and hygiene measures against vectors.

Effective environmental management reduces the risk of persons being bitten by infectious rodent fleas and other host animals in places where people live, work and recreate. Environmental management for plague control should include at least the
following (National Department of Health, 2004a, pp.30-31; Gage, 1999b, pp.169-170):

- The reduction of habitats suitable for the harbourage and nesting of rodents (improved sanitation and housing conditions, proper storage of grain and foodstuffs, proper waste disposal);
- structures should be made rodent proof by sealing or removing any unused piping;
- drain covers should be tight-fitting and well maintained to prevent access to rodents;
- doors and windows should fit tightly, any openings to the exterior should be plugged or be less than 6mm;
- care should be taken to prevent rodents entering buildings via lift shafts, garbage shafts or air-conditioning ducts;
- garbage should be kept in rodent-proof bins and periodically removed from the property or buried;
- food residues and stocks must be managed appropriately in order to prevent rodent access; and
- yards/airports/ports should be kept free of accumulations of rubbish, construction debris and discarded equipment.

Environmental management should be seen as an important continued control measure after an outbreak of plague. Plague control personnel should work closely with other health workers to regulate and modify activities and practices that are likely to lead to increased food and harbourage for rodent reservoirs. In the following section, chemical control of plague is introduced.
5.2.4 Chemical control

Chemical control of rodents and their fleas is an efficient means of controlling urban plague outbreaks and extensions. Chemical control implies the application of substances or mixtures of substances to prevent, destroy, repel, or mitigate a vector/pest (Kim-Farley, 1997, p.1570). From a plague control perspective, chemical control is discussed in terms of three types of application, namely:

- Insecticides for the control of fleas (see Section 5.4);
- rodenticides for the control of rodents (see Section 5.5); and
- fumigants for the control of rodents and fleas.

Fumigants can be used to kill rodents and their ectoparasites living in inaccessible areas in buildings, ships and in burrows in the soil. Before the discovery of DDT (dichloro-diphenyl-trichloroethane), flea and rodent control were carried out by fumigating burrows with hydrogen cyanide gas (HCN) through the insufflation of HCN dusts or granules. Some commonly used fumigants include calcium cyanide (Ca CN), carbon monoxide (CO), sulfur dioxide (SO$_2$) and hydrogen phosphide. The use of fumigants has several shortcomings, namely the fumigants (Gratz, 1999b, pp.100-126):

- are often not dense enough to reach all parts of the rodent burrow system;
- have no persistence of action; and
- have considerable toxicity.

Fumigants are generally fast-acting and can be quite dangerous to both humans and other non-target animals. Fumigants should only be applied by persons well trained and experienced. Fumigation is generally not recommended for use in plague control programmes. The biological control of plague is introduced in the next
section.

### 5.2.5 Biological control

Biological control is defined as the utilisation of predators, parasites, or pathogens to help control a vector/pest species (Bio-integral Resource Center, 2005, p.14). The Southern African rodent predators include the smaller cats and genets, some mongooses, the black-shouldered kite, the long-crested eagle, the rock kestrel, the forest buzzard, owls, moles and house snakes (Willan, 1992, p.49). The utilisation of insect growth regulators (IGR) is an example of a biological technique for vector control (Kim-Farley, 1997, p.1571). Detailed information about biological control is beyond the scope of this study. In the next section mechanical control of rodent reservoirs will be discussed.

### 5.2.6 Mechanical control

Mechanical control can be defined as devices that a target species enters, or walks onto, and/or that release a trigger mechanism that results in the animal being captured dead or alive. Mechanical control of rodents includes the use of glue boards and rodent traps (Bio-integral Resource Center, 2005, p.14; United States Army Environmental Hygiene Agency, 1991, pp.21-23).

Glue boards are placed in runways without bait and rodents attempting to cross them are caught on the sticky surface. Glue boards will lose their effectiveness in dusty areas, extreme temperatures and in areas with moisture. The use of glue boards is quasi-lethal, inhumane and less useful for rats. Glue boards should not be used where children, pets or desirable wildlife are accessible (Bio-integral Resource Center, 2005, p.15). From the above it can be deduced that glue boards are generally not recommended.
Traps consist of two types: live traps and killing traps (Pollitzer, 1954, p.525). Work methods and procedures for live trapping of rodents have been discussed in Chapter Four (see Section 4.4.2). From a commensal rodent control perspective, killing traps (commonly called snap traps) are generally used. In contrast with the use of rodenticides, trapping has several advantages, namely (Willan, 1992, p.56):

- It does not rely on inherently hazardous rodenticides (it is environmental safe);
- it permits users to evaluate their success; and
- it allows for disposal of the rodent carcasses, thereby eliminating odour problems from decomposing carcasses when poisoning is done within buildings.

Trapping is regarded as an effective method for controlling house mice, but not large rats (United States Army Environmental Hygiene Agency, 1991, p.22; Pollitzer, 1954, p.530). Gratz (1999b, p.129) is of the opinion that trapping can be very effective in situations where rodenticides cannot be used and where rodent infestations are not excessive, especially in areas subject to repeated invasion. The preferred method is to try trapping first in homes, garages and other small structures where only a few rodents may be present.

The procedures for snap trapping of commensal rodents may be summarised as follows (Bio-integral Resource Center, 2005, pp.14-15; Willan, 1992, pp.64-65; United States Army Environmental Hygiene Agency, 1991, pp.21-23):

- The best trapping locations are against walls, behind or under objects, in dark corners and in other places where rodent activity is seen;
- attention should be paid to latrines, kitchens, food stores, nearby undergrowth and rubbish piles;
- traps should be used in adequate numbers (a large number of traps for a short period is more effective than a few traps over a longer time);
• snap traps can be set parallel to a wall, back to back with their triggers facing away from each other;
• two or three traps in a row (or trap groups) make trapping more effective;
• expanded triggers can make trapping more effective;
• traps should be maintained in good operating condition (the trigger mechanism must be sensitive enough so that rodents cannot remove the bait without springing the trap);
• only fresh bait must be used;
• the most convenient and effective bait is peanut butter. Different baits may be more effective in some areas due to local food preferences; and
• bait must be securely fastened to the trigger. Baits that don’t stick to the trigger can be tied on with string, dental floss or very thin wire.

It may be necessary to ‘prebait’ traps for a few days to enhance trapping success for rodents. Prebait is a technique used to encourage rats to eat lethal doses of fast-acting rodenticides. Prebait seeks to persuade individual rats to eat larger and larger quantities at each visit, as well as attracting increasing numbers of rats away from their usual food source (Central Science Laboratory, 2005, p.63). Based on own research findings, the procedures for prebaiting are conducted as follows:

• Place traps out with bait, but do not set the triggers;
• check daily to see if bait is taken or removed; and
• when the take of bait is steady, add a very small amount of fresh bait to the trap and then set the trigger.

Since medical intervention is important for the control of plague, it is discussed below.
5.2.7 Medical intervention

In Chapter Three (see Section 3.6.2), medical intervention (the treatment of plague) which involves case management and antibiotic therapy was presented. Basic antibiotic therapy includes streptomycin, tetracyclines and sulfonamides. Both antibiotics and vaccines have been used to prevent infections from occurring in the first place. Vaccines should only be used for persons in high-risk groups.

Detailed information on medical intervention will be further discussed in Section 5.3.2 (Plague outbreak control measures). The control of rodents and fleas should be conducted under an Integrated Vector Management strategy, which is introduced in the following section.

5.2.8 Integrated Vector Management for plague control

The major burden of disease in the African region is attributable to vector-borne diseases, such as malaria, trypanosomiasis, onchocerciasis, plague and leishmaniasis (World Health Organisation Regional Office for Africa, 2003, p.1). The burden of vector-borne diseases and the need to reduce the reliance on pesticides during vector control are two compelling reasons for the promotion of an Integrated Vector Management strategy. Integrated vector management (IVM) is a term used to refer to the public health equivalent of Integrated Pest Management (IPM) in agriculture (Hirsch, Gallegos, Knausenberger & Arata, 2002, p.40).

Integrated Vector Management is defined by the World Health Organisation (2004c, p.24) as a process of evidence-based, decision-making intended to plan, deliver, monitor and evaluate targeted, cost-effective and sustainable combinations of regulatory and operational vector control measures. According to the World Health Organisation (2004c, p.5), the characteristic features of an IVM strategy include:
• The selection of methods based on knowledge of factors influencing local vector biology, disease transmission and morbidity;
• the use of a range of evidence-based interventions, often in combination and synergistically;
• collaboration within the health sector, outside the health sector and with other public/private sectors whose works impact on vectors;
• engagement with local communities and stakeholders; and
• a public health regulatory and legislative framework, including incorporating health safeguards in development.

From the above it can be deduced that IVM strategy does not constitute individual programmes, but is the component of integrated disease control programmes. An IVM strategy should thus be a sub-component of the national health care delivery system. The IVM strategy builds on the concept of selective vector control with the targeted use of different vector control methods, alone or in combination, to prevent or reduce human-vector contact. The IVM strategy utilises a range of interventions, including (World Health Organisation Regional Office for Africa, 2003, p.2):

• Environmental management (see Section 5.2.3); and
• the safe and judicious use of insecticides (see Section 5.4 and 5.5).

The World Health Organisation Regional Office for Africa is promoting the use of IVM strategy for the control of vector-borne diseases amongst Member States in the African region. Work methods and procedures for the control of a plague outbreak are discussed in the following sections.

5.3 PLAGUE OUTBREAK CONTROL

As discussed in Chapter Four (see Section 4.3.2), when a plague outbreak occurs,
an Outbreak Control Team must be established immediately to conduct and orchestrate the response. The effective control of a plague outbreak consists of two activities, namely:

- The establishment of a Plague Outbreak Control Team; and
- the implementation of outbreak control measures.

A Plague Outbreak Control Team should include relevant members from different spheres of government. The strategy on how to establish a Plague Outbreak Control Team is discussed in the following section.

5.3.1 Establishing a Plague Outbreak Control Team

Since outbreak investigation and the control of a disease is a team effort, the World Health Organisation recommended that a specialised National Plague Team should be established and equipped with adequate personnel, equipment and laboratory facilities for its activities in each member country. In some countries, a National Epidemic Response Committee exists to conduct the management of disease outbreaks. Once the disease surveillance system detects an outbreak, the committee must set up an outbreak control team immediately (World Health Organisation Regional Office for Africa, 2001, p.124).

In practice, an Outbreak Control Team should be established before an outbreak occurs. Members of the said team are normally performing their usual roles, but in the event of an outbreak of plague, they come together to undertake the special functions of an outbreak response. Gage (1999b, p.158) recommends that the National Department of Health should maintain at least one Plague Outbreak Control Team composed of experts in plague surveillance and control. Members of this team should at least include an epidemiologist, a serologist and a zoologist.
In South Africa, a National Plague Outbreak Control Team has been established by the National Department of Health. This team is led by a National Plague Outbreak Control Coordinator who is appointed by the Minister of Health (National Department of Health, 2000, pp.3-5). According to the National Department of Health (2004a, p.19), the National Plague Outbreak Control Team should involve role-players from all relevant sectors, including representatives from the:

- Directorate: Communicable Disease Control;
- Directorate: National Institute for Communicable Diseases;
- Directorate: Emergency medical services;
- Directorate: Environmental health; and the
- Directorate: Health promotion.

These role-players have already been introduced in Chapter Two (see Section 2.3). The National Plague Outbreak Control Team should provide expertise and support to the provinces and work in close coordination with the municipal health staff in the event of an outbreak. The said team should also be responsible for the management and coordination of outbreak control activities as well as associated epidemiological investigations (see Section 4.3.3). The names, addresses and telephone numbers of the members of the National Plague Outbreak Control Team should be kept by all Health Districts as well as the Provincial Outbreak Control Teams at all times, so that the said members can be contacted immediately in the event of an outbreak (see Annexure 26).

At the provincial level, a Provincial Outbreak Control Coordinator has been appointed for each of the nine provinces in South Africa (Tshabalala-Msimang, 2004). The coordinator has the responsibility to establish a Provincial Outbreak Control Team and to prevent and control disease outbreaks in his/her province (National Department of Health, 2000, pp.5-7). The organisational structure of a
Provincial Outbreak Control Team is the same as the National Outbreak Control Team but from a provincial perspective.

A Provincial Outbreak Control Coordinator has the responsibility to identify and coordinate appropriate resources required for outbreak investigations. The provincial coordinator will communicate with the National Outbreak Control Coordinator and ensure submission of a final outbreak investigation report to the National Outbreak Control Coordinator and other organisations involved in an outbreak investigation (National Department of Health, 2000, p.7). A Provincial Outbreak Control Team should provide support to Health Districts within its province during the initial investigation of an outbreak, and determine whether or not to apply for support from the National Outbreak Control Team.

At the Health District level, health services should maintain adequately trained staff to promote plague awareness, prevention and control (Gage, 1999b, p.158). According to the World Health Organisation Regional Office for Africa (2001, pp.13-14), plague outbreak control is a function of the Integrated Disease Surveillance (IDS) system. The Health District is the focus of integrating surveillance in the IDS system (see Section 4.2.3). Health Districts thus have the overall responsibility for investigating plague outbreaks. Each Health District should appoint a Plague Outbreak Control Coordinator. This coordinator, as in the case of each province, should establish a Health District Plague Outbreak Control Team which should include representatives from (National Department of Health, 2004a, p.18):

- Communicable diseases control;
- Epidemiology and health information (from the Provincial Health Department);
- Primary health care and emergency services;
- Laboratory services (from the National Health Laboratory Service);
- Environmental health; and
• Health promotion.

As illustrated in Figure 9 (see Section 4.3.3), when a pending plague outbreak occurs, an Outbreak Control Team should be set up immediately by the Outbreak Control Coordinator of the Health District to implement investigation and control measures with the coordination of relevant staff from the provincial and national health departments. Work methods and procedures for the surveillance of a plague outbreak were discussed in Chapter Four (see Section 4.3.3). The results of outbreak surveillance should provide recommendations on specific prevention and control strategies. In the next section, control measures for a plague outbreak are discussed.

5.3.2 Plague outbreak control measures

In order to ensure preparedness for plague outbreaks, known endemic foci should be identified and essential information collected and analysed. Such information includes at least the following (Gratz, 1999b, p.97):

• The insecticide susceptibility status of the important flea vectors and rodent reservoirs; and
• seasonal variations in flea and rodent population densities and flea indices.

From the above it can be deduced that establishing and maintaining an effective surveillance system to detect unusual plague activity in a focus area is an imperative control measure. A plague outbreak may be controlled by eliminating or reducing the source of infection, interrupting the transmission route of infection and protecting persons at risk. Wisner and Adams (2002, p.173) state that the two main strategies for controlling an outbreak of plague are:
To reduce the number of cases through preventive activities; and
to reduce mortality due to the disease through early case detection and effective
treatment.

As discussed in Section 4.3.3, when an outbreak of plague occurs, all efforts and
resources should be aimed at controlling the outbreak. Plague control measures
should not be delayed while waiting for laboratory confirmation of the disease in
question. General control measures may be employed after beginning the
investigation of an outbreak. According to Connolly (2005, p.125), plague outbreak
control measures involve the following:

- Prevention of exposure: the source of infection is reduced to prevent the disease
  spreading to other members of the community (this may involve prompt diagnosis
  and treatment of cases using standard protocols, isolation of cases, health
  education, modification of the environment and vector and reservoir control);
- prevention of infection: susceptible people should be protected by vaccination;
- prevention of disease: prophylaxis treatment for high-risk people; and
- prevention of death: through effective health care services delivery.

According to Jekel, et al. (1996, p.51), the control of a plague outbreak mainly
includes four common strategies, namely sanitation, prophylaxis, diagnosis and
treatment and vector control. From the above it can be deduced that an effective
plague control strategy should include at least the following (National Department of
Health, 2004a; World Health Organisation, 1999a):

- Isolation of patients (quarantine);
- effective treatment of patient/s;
- preventive measures (vaccine and antibiotic prophylaxis);
- rodent control;
• flea control;
• health education; and
• continued control measures after an outbreak.

Surveillance and control measures should be continued in a 5km radius of the outbreak area. When the outbreak has been controlled and stabilized the quarantine measures can be lifted (see Section 3.6.2). Continued control measures after a plague outbreak should include (National Department of Health, 2004a, p.35; Gage, 1999b, pp.169-170):

• Active surveillance of possible new cases and routine plague case reporting should be continued once weekly for one month;
• Flea control: Dwellings must be treated with insecticides for flea control twice weekly during quarantine and afterwards once a month for one year;
• Rodent control: Active rodent control must continue for six months. All farm owners within the infected area should be involved;
• Serological surveillance: Serum samples must be taken from dogs and rodents every three months and seropositive dogs must be re-bled every three months;
• Epidemiological report: A complete epidemiological report (including each case) must be completed and forwarded to the National Department of Health; and
• Health education must continue, especially to improve environmental conditions and to prevent future outbreaks.

As discussed in Section 5.2.4, the use of insecticides/rodenticides is the most common method for the control of flea vectors/rodent reservoirs. Work methods and procedures for the use of insecticides to control flea vectors are discussed in the next section.
5.4 THE USE OF INSECTICIDES TO CONTROL FLEA VECTORS

The purpose of flea control is to interrupt the plague transmission route. The first step for controlling a plague outbreak is flea vector control because the death of a large number of plague-infected rodents is likely to introduce large numbers of fleas into the environment (Gratz, 1999b, p.98). These fleas (particularly blocked fleas) will seek other hosts, including humans, thereby increasing the potential for human infection. Insecticides used for the control of flea vectors are discussed below.

5.4.1 Insecticides used for the control of fleas

In the past, the most common and effective method for the control of rodent fleas was DDT (dichloro-diphenyl-trichloroethane) dust. Alternative insecticides are increasingly being used because of the insecticide resistance of fleas in many areas to DDT and also because of environmental contamination concerns (Rozendaal, 1997, p.249). When locally safe, effective and affordable alternatives are not available, the continued use of DDT for disease vector control is conditionally approved in accordance with the World Health Organisation recommendations and guidelines (World Health Organisation, 2004b, pp.1-2).

Most alternative insecticides are effective against both adult and larval fleas. These alternative insecticides include organic phosphorus (OG), carbamate, pyrethroid and insect growth regulator (IGR) (Gratz, 1999b, p.102). In South Africa, only products that are registered under the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947), may be used for the control of fleas (Vermeulen, J.B., Krause, M., Nel, A., Hollings, N. and Greyling, J., 1992, p.iii). Insecticides registered in South Africa and recommended by the World Health Organisation for the control of fleas are listed in Table 10.
### Table 10: Insecticides Registered for Use in South Africa and Recommended by the World Health Organisation for the Control of Fleas

<table>
<thead>
<tr>
<th>Insecticides</th>
<th>Class</th>
<th>Formulation type</th>
<th>Grams per active ingredient</th>
<th>Dosage</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltamethrin</td>
<td>Pyrethroid</td>
<td>Emulsifiable concentrate</td>
<td>15g/l</td>
<td>100ml/5L water/100m²</td>
<td>Coarse spray onto surfaces frequented by fleas</td>
</tr>
<tr>
<td>Permethrin</td>
<td>Pyrethroid</td>
<td>Liquid</td>
<td>2.5g/l</td>
<td>Undiluted</td>
<td>Coarse spray onto surfaces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dusting powder</td>
<td>5g/kg</td>
<td>-</td>
<td>Dust lightly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smoke tin</td>
<td>135g/kg</td>
<td>1tin/120-1000m²</td>
<td>Ignite and let smoulder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wettatable powder</td>
<td>250g/kg</td>
<td>50-70g/10L water</td>
<td>Coarse spray onto surfaces</td>
</tr>
<tr>
<td>Propoxur</td>
<td>Carbamate</td>
<td>Dusting powder</td>
<td>10g/kg</td>
<td>-</td>
<td>Dust freely</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Emulsifiable concentrate</td>
<td>200g/l</td>
<td>250-500ml/10L water</td>
<td>Coarse spray or brush onto surfaces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wettatable powder</td>
<td>500g/kg</td>
<td>200g/10L water</td>
<td>Coarse spray or brush onto surfaces</td>
</tr>
<tr>
<td>Gamma-BHC (Lindane)</td>
<td>Organic chlorine</td>
<td>Dusting powder</td>
<td>6g/kg</td>
<td>-</td>
<td>Dust freely</td>
</tr>
</tbody>
</table>

Source: Adapted from Gratz (1999b, pp.102-103) and Vermeulen et al., (1992, pp.201-202)

Insecticides are rarely applied in their pure form; they are available as special formulations that are adapted to the requirements of the various application methods (Rozendaal, 1997, p.360). As mentioned in Section 5.3.2, the insecticide susceptibility status of flea vectors in an endemic focus must be identified in order to ensure preparedness for plague outbreaks. The next section deals with flea resistance to insecticides.

#### 5.4.1.1 Flea resistance to insecticides

Insecticide resistance is defined by the World Health Organisation (1957) as the developed ability in a strain of insects to tolerate doses of toxicant which would
prove lethal to the majority of individuals in a normal population of the same species. Insecticide resistance is therefore defined as an inherited characteristic that allows an insect to survive a dose of a pesticide that would normally prove fatal.

Insecticide resistance has spread widely in flea vectors since DDT resistance was first confirmed in *X. cheopis* in the 1960s. Resistance to insecticides is a serious impediment to flea control. When resistance becomes apparent, the choice of a replacement insecticide depends on the mechanism of resistance, namely susceptibility, cost-effectiveness and availability (Rozendaal, 1997, p.360). It is therefore necessary that the susceptibility of target flea vectors to insecticides should be determined periodically (Gratz, 1999b, p.103).

The method of insecticide sensitivity surveys in flea vectors can be carried out on adult fleas using a WHO Susceptibility test kit which is available through the World Health Organisation Regional Office (Gratz, 1999b, pp.101-103). In some cases, field trials should be done to determine the efficacy of candidate insecticides against flea populations under local conditions. According to Harrison (1995, p.47), insecticide sensitivity surveys may be performed one to seven days before and two to seven days after insecticide application to determine insecticide effectiveness. A rodent burrow flea index of 0.3 or less indicates effective flea control. Flea control on commensal rodents is described and discussed in the following section.

5.4.2 Flea control on commensal rodents

It was found that in most urban plague endemic areas, the flea vectors were *X. cheopis*, *X. astia* or *X. brasiliensis*. Their rodent hosts, often the *Rattus* species, usually nest in dwellings and buildings, or nest in burrows around houses, warehouses and other structures. Work procedures for the control of fleas on commensal rodents are described below (Gratz, 1999b, p.99; Rozendaal, 1997,
Identify rodent runways and burrows (see Section 5.5.2);

blow the insecticidal dust into the mouth of a rodent burrow with an insecticidal duster (see Figure 11);

place patches of insecticidal dust approximately 1cm thick around the rodent burrow;

place patches of dust next to indoor rat runways (usually found along walls);

place patches of dust 15-30cm wide at several points along each runway;

a hand shaker (see Figure 11) can be used to reach runways along rafters or the wall-roof junction;

when flea control is urgent a liquid insecticide spray can be used to control indoor fleas; and

record the date, place and the type of insecticide used.

When following the abovementioned procedures, based on own research findings and confirmed by Gratz (1999b, pp.99-100) and Rozendaal (1997, pp.249-250), a number of key issues should be taken into account, namely:

Insecticidal dusting should begin immediately after the verification of human cases or plague positive rodents;

the extent of an area to be dusted is determined by the location of plague cases and the size of the area to be protected;

dust patches should be placed where they will not be swept away or disturbed by human activity;

care must be taken not to contaminate foodstuffs or cooking utensils;

special care should be taken to avoid contaminating stored food when dusting food warehouses or storage rooms; and

dusting operations should be announced on the radio and in the local press to
ensure that plague control staff carrying out the work are allowed free access to all structures and that dust deposits are not swept up but left undisturbed as long as possible.

Source: Adapted from Rozendaal (1997, p.250)

A plunger-type duster can apply fine, dry layers of a powdery mixture containing a small amount of pesticide. A hand shaker may be used for applying tracking powders and patches for rodents in runs along the base of walls or foundations or on beams.

Epsom salts can be used to control fleas in emergencies when no insecticide is available. An alternative for flea control on commensal rodents is to use bait boxes which will be discussed in the next section that deals with flea control on wild rodents.

5.4.3 Flea control on wild rodents

Wild rodent fleas are more difficult to control than commensal rodent fleas because it is difficult to determine the limits of the area to be treated due to the wide population dispersion of wild rodents. When conducting flea control on wild rodents, three
common methods may be considered, namely (California Department of Health Services, 2006, p.11; World Health Organisation, 1998, p.2):

- The use of fumigants;
- the application of insecticidal dusts into rodent burrows; and
- the application of insecticides via rodent bait boxes.

The use of fumigants for the control of rodents and their fleas was discussed in Section 5.2.4. Wild rodent fleas have been controlled by a variety of different methods of insecticide application, including being broadcast from aircraft and application in and around burrows with power (electrically-driven) and hand dusters (Gratz, 1999b, p.101). The shortcomings of insecticidal dusts used in and around wild rodents' burrows are time and labour intensive. Due to the increase in insecticide resistance of fleas in many areas and the growing concern about the introduction of insecticides into the environment, bait boxes are used widely for rodent and flea control (see Figure 12).

![FIGURE 12: TWO TYPES OF RODENT BAIT BOXES](image)

Bait box A: has a lockable lid and high internal baffles to prevent interference.

Bait box B: has a low baffle but is probably more ‘rat-friendly’.

Source: Adapted from Central Science Laboratory. (2005, p. 21)

Bait boxes can be quickly and cheaply made of bamboo tubes (40cm long and 7-10cm in diameter) or of floorboard (30 × 20cm) covered by a metal roof (Rozendaal, 1997, p.251). Bait boxes contain both a slow-acting rodenticide in an
attractive bait in the interior and insecticidal dusts at the box entrances. Rodents entering the boxes cross the dust, picking up insecticide on their fur and carrying it back to their nests, killing the fleas on their bodies and those in the nests (California Department of Health Services, 2006, p.11; Gratz, 1999b, p.101).

Bait boxes are effective to reduce flea populations over a considerable radius from the boxes because the rodents carry the insecticide back to their nests. Bait boxes may also be used for the control of commensal rodents. Rozendaal (1997, p.250) is of the opinion that bait boxes are safe to use where food is stored and in crowded areas, such as markets. Bait boxes can be placed along rodent runways at intervals of 60 metres. Suitable bait consists of 100 grams of rolled oats mixed with rodenticides (see Section 5.5.2.3).

The use of bait boxes is labour-intensive and requires rebaiting and replenishment of the dusts until the threat of plague abates (see Section 5.3.2). Another limitation of bait boxes is that they will not be effective if a plague epizootic has killed most or all rodents in the area (Harrison, 1995, p.48). Work methods and procedures for the use of rodenticides to control rodent reservoirs are discussed in the next section.

5.5 THE USE OF RODENTICIDES TO CONTROL RODENT RESERVOIRS

As discussed previously (see Section 5.4), after flea control which is the first step of controlling a plague outbreak, the control of rodent reservoirs can be undertaken. In areas where plague is not endemic, rodent control measures can be carried out independently of flea control. Active rodent control must be conducted using an integrated vector management (IVM) strategy that includes both chemical and non-chemical methods (see Section 5.3). The most common and effective method for rodent control is the use of rodenticides. In the next section, rodenticides are introduced.
5.5.1 Rodenticides

Rodenticides refer to chemical agents that are lethal to rodents. They are generally incorporated in either food baits, dusts or water. Rodenticides can be divided into two categories, namely (Gratz, 1999b, pp.110-114; World Health Organisation, 1998, p.1):

- Acute rodenticides (single dose, quick-acting); and
- chronic rodenticides (multiple doses, slow-acting).

Acute rodenticides are firstly introduced.

5.5.1.1 Acute rodenticides

Acute rodenticides are highly toxic to many non-target animals and humans and few of them have effective antidotes. They are mixed at high concentrations into food baits. Their main advantage is a rapid effect with a minimum amount of bait (World Health Organisation, 1998, p.1). Acute rodenticides are principally and most effectively employed in situations demanding a rapid reduction of high-density populations, particularly during emergencies (Gratz, 1999b, pp.108-115).

Acute rodenticides can cause ‘bait shyness’, which is a disadvantage due to their rapid action. Bait shyness means that if the rodents recover from an illness after exposure to acute rodenticides, any future encounters are likely to be avoided with the same rodenticides. This condition is also called a ‘learned aversion’ (Central Science Laboratory, 2005, p.9).

As discussed before (see Section 5.2.6), prebait may increase bait consumption and consequently the effectiveness of acute rodenticides. Prebait can encourage
rodents to eat lethal doses of acute rodenticides. Prebait involves applying plain (un-poisoned) bait for several days (four to eight days normally) until the rodents become accustomed to the bait. The baits used during prebait should be the same as that used later in the poison treatment (Central Science Laboratory, 2005, p.63). Small amounts of prebait, about 50-100g for rats and 10g for mice, should be placed wherever traces of rodents are found. Acute rodenticide is then put out, typically for one or two nights (Gratz, 1999b, p.125; World Health Organisation, 1998, p.2).

From the above, it can be deduced that prebait reduces the main advantage (rapid action) of acute rodenticides. In a plague control programme, if an effective flea vector control strategy has been carried out, sufficient time may be available for prebait. If immediate rodent control is essential, prebait may be omitted, although efficacy is inevitably reduced. Anticoagulants can be used to supplement such a programme, but a different bait base must be used (Gratz, 1999b, p.125; World Health Organisation, 1998, p.2).

Currently, only two acute rodenticides (calciferol and zinc phosphide) are used for rodent control programmes. These two rodenticides are introduced below (Gratz, 1999b, pp.121-122):

- **Calciferol:** Calciferol (Vitamin D₂, activated ergosterol) is a white crystalline compound, slightly soluble in vegetable oil and soluble in organic solvents such as acetone, chloroform and ether. When taken in toxic amounts, it promotes the absorption of calcium from the gut and from bone tissue. This results in a high level of calcium in the blood which is deposited in the lungs, cardiovascular system and kidneys. Death occurs in rats in four to eight days following feeding. Calciferol is palatable to both rats and mice at a 0.1% concentration. Calciferol is toxic to many animals and humans, but antidotal measures (including cortisone and procaine calcitonin) are available.
- **Zinc phosphide:** Zinc phosphide is a fine-greyish black powder with a definite garlic-like odour and strong taste. It is moderately quick-acting: death may occur in less than one hour. Most rats die from heart failure accompanied by liver and kidney damage/failure. It is generally used at 1-2.5% in cereal, fish, meat, vegetable or fruit baits. Baits should be used as fresh as possible because zinc phosphide's toxicity may be greatly reduced due to extreme heat and humidity. Zinc phosphide may also be considered for large scale use as an acute poison against commensal rodents.

According to the World Health Organisation (1998, p.1), chronic rodenticides are regarded as anticoagulants that induce chronic and eventually fatal internal bleeding. In this study, chronic rodenticides refer to anticoagulants which are introduced and discussed in the next section.

### 5.5.1.2 Anticoagulants

Anticoagulants can disrupt the mechanism that controls blood clotting and cause fatal internal haemorrhages (Gratz, 1999b, p.108). All anticoagulant compounds are insoluble in water, although the sodium or calcium salts of most are water-soluble and available for the preparation of liquid baits. In general, anticoagulants are divided into two categories, namely (Central Science Laboratory, 2005, p.57 and p.64):

- **First generation anticoagulants**, which is a term used to describe the many compounds that were introduced before 1970, of which only warfarin, coumatetralyl and diphacinone currently remain registered for use in South Africa; and
- **Second generation anticoagulants**, which are introduced to counter rodent resistance to first-generation anticoagulants. They retain the same mode of
action as the previous compounds and are considerably more toxic - not only to rats, but also to other species.

In South Africa, only products that are registered under the *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947* (Act No. 36 of 1947), may be used for the control of rodents (see Table 11).

**TABLE 11: RODENTICIDES REGISTERED FOR USE IN SOUTH AFRICA AND RECOMMENDED BY THE WORLD HEALTH ORGANISATION**

<table>
<thead>
<tr>
<th>Rodenticides</th>
<th>Formulation type</th>
<th>Grams per active ingredient</th>
<th>Effective against species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First generation anticoagulants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coumatetrayl</td>
<td>Bait block</td>
<td>0.375 g/kg</td>
<td>Commensal rodents</td>
</tr>
<tr>
<td>Diphacinone</td>
<td>Bait concentrate</td>
<td>7.5 g/kg</td>
<td></td>
</tr>
<tr>
<td>Warfarin</td>
<td>Bait ready for use</td>
<td>0.05 g/kg</td>
<td>Rats, mice</td>
</tr>
<tr>
<td><strong>Second generation anticoagulants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brodifacoum</td>
<td>Bait block</td>
<td>0.05 g/kg</td>
<td>Wild and commensal rodents</td>
</tr>
<tr>
<td>Bromadiolone</td>
<td>Dusting powder</td>
<td>1.5 g/kg</td>
<td>Rats, mice</td>
</tr>
<tr>
<td></td>
<td>Bait ready for use</td>
<td>0.05 g/kg</td>
<td></td>
</tr>
<tr>
<td>Difenacoum</td>
<td>Bait block</td>
<td>0.1 g/kg</td>
<td>Commensal rodents</td>
</tr>
<tr>
<td>Flocoumafen</td>
<td>Bait block</td>
<td>0.05 g/kg</td>
<td>Commensal rodents</td>
</tr>
</tbody>
</table>

Source: Adapted from Gratz (1999b, pp.110-114) and Vermeulen, et al. (1992, p.206)

According to Gratz (1999b, pp.108-109), anticoagulants have three main advantages over acute rodenticides, namely:

- They do not cause bait shyness (prebait is not required);
- poisoning hazards to non-target species are generally low; and
- an effective antidote (Vitamin K) is available.
Anticoagulants for the control of rodents should be targeted for either or both commensal and wild/village rodents. Work methods and procedures for the control of commensal rodents with anticoagulants are discussed firstly.

5.5.2 Targeting commensal rodents

As mentioned in Chapter Three (see Section 3.4.3), commensal rodents refer to the Norway rat (*R. norvegicus*), the roof rat (*R. rattus*) and the house mouse (*M. musculus*). Underestimating the extent of an infestation of rodents may lead to the failure of a rodent control programme. Before rodenticides are used, it is essential to first survey the target infested areas in order to define the severity and scope of the infestation. According to the Central Science Laboratory (2005, pp.12-33), work methods and procedures for rodent control with rodenticides should be conducted systematically, which are illustrated in Figure 13.

![Figure 13: Work Procedures for Rodent Control with Rodenticides](source)

Commensal rodent surveys in an infested area were discussed in Section 4.4.3. The baiting stations to be used must be recorded during the surveys (World Health Organisation, 1998, pp.2-3). From Figure 13, it can be deduced that a strategy for the application of rodenticides should be formulated after the infested area has been
surveyed. The first step of the said strategy is to select the right rodenticides. These are discussed below.

5.5.2.1 Selecting the right rodenticides

The choice of which anticoagulant to use depends on the likelihood of rodent resistance to the rodenticides. The purpose of selecting the right rodenticide is to achieve the right balance between efficacy and safety (Central Science Laboratory, 2005, p.14). The full extent of anticoagulant resistance in South Africa is not available. Hence, it is difficult to recommend a particular anticoagulant, unless a sample of the rodent population is tested firstly. However, if resistance is anticipated, the second generation anticoagulants should be selected.

If anticoagulants are not available or cannot be used, or significant resistance is known to be present, then rodenticide formulations based on acute rodenticides (e.g. calciferol) are an alternative option (Central Science Laboratory, 2005, p.15; World Health Organisation, 1998, p.3). The next section discusses how to select the best bait to use.

5.5.2.2 Selecting the best bait to use

Rodenticide baits may have different formulations, such as loose-grain, pellets, wax blocks or place-packs (sachets). Whether rodents will eat baits or not, depends on what they are used to eating as well as their individual preferences (Central Science Laboratory, 2005, p.16). Rodenticides should be mixed with food that the rodents are currently eating but food that does not contain large amounts of vitamin K₁. A processed cereal is normally used as the base material in food baits. A coloured dye is incorporated to alert against accidental human consumption or feeding to livestock or non-target animals. A variety of attractants, additives and preservatives
may be added to make preparation easier or to improve efficacy (World Health Organisation, 1998, p.1).

Within a wild rodent population, baits highly palatable to some rodents may not appeal to other rodents. Rodents have the nature to remove any kind of food to a ‘safe place’ from any location where they do not want to stay. Thus, wax blocks and place-packs are particularly prone to being carried away (Central Science Laboratory, 2005, p.18). The next section discusses the procedure on how to decide on the number of bait stations.

5.5.2.3 Deciding on the number of bait stations

Bait stations should be sited close to fresh rodent signs, such as on the side of a track or on runways and tracks (especially the entrances adjacent to a wall), near active burrows or gaps in vegetation. Suitable places for baits should be where rodents might nest, such as rubbish piles and beneath discarded machinery (Central Science Laboratory, 2005, p.23). As a guide, an average density of two bait stations per 100 m$^2$ or one station every five metres should be sufficient to treat most infestations. In places where rodent infestation is dense, bait stations can be placed closer together (e.g. as close as one metre apart).

At one inspection visit, if more than one quarter of the stations that baits have been eaten by rodents, more bait stations should be added (Central Science Laboratory, 2005, pp.24-25). The procedure to follow in deciding on the amount of bait per station is discussed below.

5.5.2.4 Deciding on the amount of bait per station

The amount of bait per station depends on three factors, namely replenishment
schedule, the toxicity of the rodenticide and the infestation size (Central Science Laboratory, 2005, p.25). A typical treatment against rodents involves surveying the infested areas and leaving enough of the anticoagulant bait (25-50g for mice and 200g or more for rats) at each baiting station (Gratz, 1999b, pp.123-124).

It is important to maintain surplus anticoagulant bait throughout the entire treatment process. When inspecting the baits, the quantity of bait should be doubled where complete takes occur. Bait stations with partial takes should be added to, to maintain a surplus. When rodents start to die, replenishments should become less frequent. Simultaneously, the amount of bait per station can be reduced (Central Science Laboratory, 2005, pp.25-26).

For the second generation anticoagulants, a ‘pulsed baiting’ strategy should be applied to ensure effective control of rodents. This baiting strategy (minimal baiting) seeks to use minimum amounts of bait to achieve satisfactory control, instead of the saturation amounts (200-500g) laid when using the first generation anticoagulants (National Department of Health, 2004a, p.31). The said strategy is to use a large number of small baits (5-15g) in a once every 5-7 days baiting schedule, placing the small baits at all baiting stations. After baiting, three rodent dead ‘pulses’ will be presented in the next 1-2 days, 7 days and 14 days (Gratz, 1999b, p.124). The next section discusses the frequency of bait inspections.

5.5.2.5 Deciding on the frequency of bait inspections

As mentioned in the section above, it is important to maintain surplus anticoagulant bait throughout the entire treatment process. Hence, bait inspection is necessary to confirm that the baits are still fresh and to collect dead rodents. The frequency of bait inspections largely depends on the rodents’ response and the likelihood of non-target animals taking the bait (Central Science Laboratory, 2005, p.28).
Each baiting station should be revisited on the second, fourth and seventh days in
each seven-day cycle. If the rate of bait uptake is slow and control is not urgently
required, a visit once a week may be sufficient. If the infestation is large, the baits
should be checked every 1-2 days, at least during the early stages of baiting and
more baits added if necessary. When no more bait is being consumed, generally
after about two or three weeks, the excess bait should be removed (Central Science

5.5.2.6 Evaluating the bait

Anticoagulant treatment can take as little as 2-3 weeks to be effective, but those
lasting five weeks should not be regarded as abnormally long, particularly if the
infestation is heavy. As a general rule, if no bait has been taken for two weeks and
there are no fresh indications of infestation, the application was probably successful
(World Health Organisation, 1998, p.2). The signs of an effective treatment are
presented below (Central Science Laboratory, 2005, pp.33-34):

- More than 50% of baiting points have a take within the first two weeks of the
treatment;
- There are no ‘complete’ takes at each inspection visit;
- Each bait station has a take of more than 50g over 2-3 days during the first two
weeks;
- Most fresh rodent droppings are coloured by the warning dye (blue or red usually)
that is incorporated into the products; and
- Dead rodents appear and fresh rodent signs diminish.

When evaluating a poisoning strategy for an acute rodenticide (such as calciferol),
the following successful signs should be taken into account:
• Most of the bait has been eaten at all points on the first or second night (baits may be eaten over another 2-3 nights);
• Dead rodents appear within one week; and
• Fresh rodent signs are difficult to find after two weeks.

The use of rodenticides to control wild and village rodents is discussed in the next section.

5.5.3 Targeting wild and village rodents

As mentioned before (see Section 5.4.3), wild rodents and their fleas are more difficult to control than commensal rodents. It is a difficult and time-intensive task to eliminate wild rodents. If wild rodents are localized and close to human habitation, it might be feasible to alter the environment by cultivation to discourage rodents (Webber, 1996, p.293). Environmental management (see Section 5.2.3) is thus an effective control measure for wild rodent populations. As discussed previously (see Section 5.4.3), wild rodents and their fleas can be controlled by the use of pesticides, fumigants and bait boxes.

When attempts are made to control village rodents, potential immigrant rodents must be considered after large-scale reduction of local rodents occurs. Control strategy for village rodents should take into account cropping and harvesting practices. A number of factors should be considered to control village rodents, including (Gratz, 1999b, pp.128-129):

• It is essential to survey the entire village area for signs of rodents;
• The control of village rodents should focus on rodent populations in and around structures;
• Villagers should be encouraged to implement rodent-proof measures to prevent
or reduce re-entry of rodents;

- It is important to provide rodent-proof containers for stored foods; and
- In addition to poisoning, traps can be used to control small infestations.

### 5.6 SUMMARY

Control of plague transmission is directed at controlling the rodent reservoirs and flea vectors of the disease. In this chapter, basic strategies for plague control were discussed, including legislative measures; health education; environmental management; chemical control; biological control; mechanical control and medical intervention. An integrated vector management (IVM) strategy should be adopted and implemented by the environmental health practitioners to control flea vectors and rodent reservoirs.

Work methods and procedures for a plague outbreak response, as well as control measures were presented and discussed from two perspectives, namely the establishment of a Plague Outbreak Control Team and the implementation of outbreak control measures. A plague outbreak investigation and its control is a team effort and needs close cooperation within the different spheres of government. When a pending plague outbreak occurs, a Plague Outbreak Control Team should be set up immediately by the Outbreak Control Coordinator of the Health District. The said team should implement outbreak investigations and control measures with the coordination of relevant staff from the provincial and national health departments.

Basic strategies for the control of a plague outbreak were identified and discussed in terms of the following:

- The isolation of patients (quarantine);
• effective treatment of patients;
• preventive measures (vaccine and antibiotic prophylaxis);
• the control of rodents and fleas;
• health education; and
• continued control measures after an outbreak of the disease.

The first step for controlling a plague outbreak is flea vector control in order to prevent large numbers of fleas entering the environment. Once flea indices have been reduced, control of rodent reservoirs can commence.

Pesticides registered for use in South Africa and recommended by the World Health Organisation for the control of rodents and fleas have been discussed. Rodenticides were divided into two categories, namely acute rodenticides and chronic rodenticides. Flea/rodent resistance to pesticides is a serious impediment to flea/rodent control. It is therefore important that the susceptibility of target fleas/rodents to pesticides should be determined periodically.

When conducting the control of wild rodents and their fleas, three common methods may be considered, namely the use of fumigants, insecticides and bait boxes. Environmental management is an effective control measure for wild rodent populations. Work methods and procedures that have been developed during the use of rodenticides to control commensal rodents include:

• Surveying the infested area;
• selecting the right rodenticides;
• selecting the best bait to use;
• deciding on the number of bait stations;
• deciding on the amount of bait per station;
• deciding on the frequency of bait inspections; and
• evaluating the bait.

In the next chapter, a conclusion with emphasis on the findings of the study will be presented. Relevant recommendations will also be made.
CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

The purpose, significance and research objectives of this study were presented in Chapter One. The primary objective of the study was to develop formal work methods and procedures for plague surveillance and control in South Africa. Two secondary objectives of this study were:

- To analyse the national health system of South Africa with specific reference to the organisational structure of plague surveillance and control; and
- to analyse and describe the epidemiology of plague, focusing on the distribution and characteristics of the disease in South Africa.

The researcher followed a qualitative, explorative, descriptive, inductive and deductive research design. A documentary research approach was employed as the primary method of data collection for the study. In order to obtain additional information, both semi-structured personal interviews and physical observations during plague surveys at the Nelson Mandela Metropolitan Municipality were conducted by the researcher.

In Chapter One, a review of related literature on work methods and procedures, the national health system in South Africa, the epidemiology of plague, and plague surveillance and control were presented. From the literature review, the researcher attempted to identify some gaps in previous research and to provide a framework for establishing the importance of the study as well as a benchmark for comparing the results of this study with other findings.

Chapter One defined important concepts used in the study. Plague surveillance was defined as a continuous and systematic process of collection, analysis, interpretation and dissemination of descriptive information on plague monitoring
activities. Plague control was defined as the actions and programmes directed towards reducing plague incidences and prevalence by suppressing the conditions that encourage rodent reservoirs and flea vectors of the disease.

In **Chapter Two** the organisational structure of the national health system in South Africa was explained and discussed from national, provincial and municipal perspectives. These discussions focused on the relevant health services and important decision-makers related to plague surveillance and control in South Africa.

The **Constitution of the Republic of South Africa, 1996** (Act 108 of 1996) is the supreme law and the foundation of the health care system in South Africa. It gives conspicuous expression to the fundamental right to health care for all; and also rules that the delivery of health care services is a concurrent function amongst the three spheres of government within a framework of cooperative governance.

The **National Health Act, 2003** (Act 61 of 2003) is important legislation for the implementation of the constitutional rights on health. This Act was promulgated to provide a framework for a structured uniform national health system. It delineates the health services in three spheres of government, namely national, provincial and municipal. From the said Act, it can be deduced that plague surveillance and control are functions of environmental health practitioners in the municipal sphere of government (‘surveillance and prevention of communicable diseases’ and ‘vector control’).

A number of legislative documents related to plague surveillance and control were also presented. These included the:

- **Health Act, 1977** (Act 63 of 1977);
- **International Health Regulations Act, 1974** (Act 28 of 1974);
• *International Health Regulations*, 1969/2005;
• *Regulations relating to communicable diseases and the notification of notifiable medical conditions*, 1987 (Regulation 2438 of 1987);
• *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act*, 1947 (Act 36 of 1947); and
• *Regulations Regarding the Prevention of Rodent Infestation and the Storage of Grain, Forage, etc. in Urban and Rural Areas of the Republic of South Africa* (Regulation 1411 of 1966).

Decision-makers of the national sphere of government that may have a direct or an indirect influence on plague surveillance and control have been identified and discussed. These decision-makers include:

• The Minister of Health;
• the National Health Council;
• the Director-General of Health;
• the Directorate: Communicable Diseases Control; and
• the Directorate: Environmental Health.

The National Health Laboratory Service (NHLS) was also discussed, since the NHLS is responsible for the identification of plague pathogens and plays an important role in the national plague surveillance and control strategy.

There are nine provinces within the provincial sphere of government in South Africa, namely the provinces of the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Mpumalanga, Northern Cape, Limpopo, North West and Western Cape. A Provincial Department of Health takes full responsibility for the effective rendering of health care services throughout its province. The generic organisational structure of a Provincial Department of Health is similar to that of the national sphere of
government, but from a provincial perspective.

The District Health System (DHS) is a fundamental organisational framework of the health care system in South Africa. The Constitution of the Republic of South Africa, 1996 (Act 108 of 1996), prescribed three categories of municipalities, namely Category A (metropolitan municipalities), Category B (local municipalities) and Category C (district municipalities). The six metropolitan municipalities (Category A), together with 46 district (Category C) municipalities constitute the health districts (a total of 52) in South Africa.

In the municipal sphere of government, health care services delivery can be divided into three tiers, namely health districts, health subdistricts and local municipalities. The responsibility for environmental health services is transferred from provinces to the Category A and C municipalities. Environmental health practitioners play an important role in plague surveillance and control within municipal health services.

In Chapter Three, the epidemiology of plague was presented and discussed from the following perspectives:

- The historical background of plague;
- the geographic distribution of plague;
- the mechanisms of plague transmission;
- the clinical manifestations of human plague; and
- the diagnosis and treatment of plague.

Plague was imported into South Africa through harbours during the third pandemic in 1900. The most recently reported outbreak of plague in South Africa was in the Coega area in the Eastern Cape Province in 1982, during which 18 cases with one death were reported.
Plague foci are dynamic, changing in response to shifts in factors such as climate, landscape and rodent population migration. In South Africa, plague natural foci exist in several areas, namely Eastern and Northern Cape, Free State, Mpumalanga and Gauteng.

Plague is a classic zoonosis and exists in different transmission cycles involving the pathogen (\textit{Y. pestis}), the rodent reservoirs and flea vectors. In South Africa the fleas most frequently found on the rodent reservoirs of plague are \textit{X. philoxera}, \textit{X. brasiliensis} and \textit{Dinopsyllus ellobius}. In Chapter Three, South African plague reservoirs were identified and classified as:

- Gerbils (\textit{Tatera brantsii}, \textit{T. leucogaster}, \textit{T. afra}, and \textit{Desmodillus auricularis});
- multimammate mouse (\textit{Mastomys natalensis} and \textit{M. coucha});
- other rodents (\textit{Otomys irroratus}, \textit{Rhabdomys pumilio}, \textit{Aethomys namaquensis}, \textit{A. chrysophilus} and \textit{Pedetes capensis});
- commensal rodents (\textit{Rattus rattus}, \textit{R. norvegicus} and \textit{Mus musculus}); and
- carnivores (\textit{Cynictis pencillata} and \textit{Suricata suricatta}).

Chapter Three discussed the primary clinical forms of the disease, namely bubonic plague, septicaemic plague and pneumonic plague. Bubonic plague is the classical form of human plague. It results from a flea bite or direct contamination of an open skin lesion by plague-infected material. Primary septicaemic plague is a progressive, overwhelming bloodstream infection with \textit{Y. pestis}, with the apparent absence of a primary lymphadenopathy. Pneumonic plague must be considered highly contagious because person-to-person transmission most likely occurs from the inhalation of respiratory droplets containing the plague pathogen.

A clinical diagnosis of plague is generally based on the patient’s manifestations. A definitive laboratory diagnosis of \textit{Y. pestis} infection is based on bacteriological
and/or serological evidence: the isolation and identification of the organism from clinical specimens or by demonstrating a diagnostic change in antibody titre in paired serum specimens. Clinical case definitions of plague were discussed.

In Chapter Three, treatment measures for plague were also presented. The treatment of plague mainly involves case management and antibiotic therapy. A guideline for plague case management was developed. Effective antibiotics for the treatment of plague are streptomycin, tetracyclines and sulfonamides. Both antibiotics and vaccines have been used to prevent infections of the disease. The preferred antimicrobials for preventive or abortive therapy are tetracyclines or one of the sulfonamides.

Work methods and procedures for plague surveillance were developed in Chapter Four. Basic principles of plague surveillance were discussed. Surveillance was classified as active surveillance and passive surveillance; both of them can be combined within a plague surveillance programme. The plague surveillance activities for which work methods and procedures have been developed in Chapter Four include the following:

- **Human case surveillance:**
  - Notifiable disease reporting;
  - the detection of a plague outbreak;
  - the investigation of a plague outbreak;
  - human serological surveys.
- **Rodent surveillance:**
  - Rodent trapping and processing;
  - observation of rodent activities;
  - commensal rodent surveys;
  - laboratory-based surveillance of rodents and their carnivores; and
Flea surveillance:

- Flea indices;
- flea collection;
- the identification of *Y. pestis* in fleas.

According to the *International Health Regulations, 1969*, all confirmed cases of human plague should be investigated and reported through appropriate authorities to the World Health Organisation. In South Africa, a routine reporting system of notifiable medical conditions (including plague) has been established to monitor and control communicable disease trends. A procedure for plague human case reporting was presented in Chapter Four.

A plague outbreak was defined as a sudden occurrence of one or more confirmed human cases within a specific geographical area. The early detection of a plague outbreak is based on the effective capture and processing of data from plague surveillance. Routine passive surveillance should be replaced by an active surveillance approach if a plague outbreak has been confirmed. Response procedures during a plague outbreak were presented in Chapter Four. Human serological surveys play an important role in active surveillance following the identification of a suspect case of human plague.

Rodent surveillance can provide reference data on rodent and flea populations, which may indicate the occurrence of a plague epizootic. Trapping rodents is an important plague surveillance method, because it provides basic population data, sera, tissue samples and fleas. Work methods and procedures for rodent trapping and processing were developed and discussed, namely:

- Rodent habitat assessment;
- trapline establishment;
baiting and trap setting; and
the processing of trapped rodents and associated fleas.

Rodent habitat assessment refers to trap site identification and description. Information of a rodent habitat provides important baseline data for a plague surveillance programme. A rodent habitat assessment form was presented in Chapter Four. A basic trapline for rodents should transect those areas most representative of the rodent habitat. Chapter Four also outlined the work methods and procedures to be followed for the processing of trapped rodents and their fleas. These methods and procedures include:

- Recording the trap site of each captured rodent;
- removing rodents from traps;
- anaesthetizing rodents;
- weighing each rodent;
- taking of blood samples;
- combing rodents and collecting fleas;
- rodent measurements;
- dissecting and taking of tissue samples;
- sewing up rodents and preserving them in formalin;
- labelling rodents and each specimen (blood, tissues and fleas) vial;
- filling in data forms; and
- shipping specimens.

Safety guidelines for plague surveillance and control personnel were developed in Chapter Four. Observation of rodent activity was discussed since it is a useful method for obtaining important data on potential plague epizootics. Commensal rodent surveys were presented to define the severity and scope of a rodent infestation. These surveys help in formulating a strategy for commensal rodent
control. A sample form to be used to identify rodent infestation during rodent surveys was presented.

Techniques of laboratory-based surveillance of rodents and their carnivores were discussed. These laboratorial techniques include:

- The identification of *Y. pestis* in rodent tissue;
- rodent serological surveys;
- rodent carnivore serological surveys; and
- serological surveys of domestic dogs.

Rodent serological surveys have an advantage over other attempts to isolate *Y. pestis* from rodent tissues. Rodent carnivore serological surveys are more sensitive in plague diagnosis than both rodent serological surveys and the isolation of *Y. pestis* from rodents. Domestic dogs serve as excellent sentinel animals during plague surveillance. Serological surveys of domestic dogs are particularly useful in detecting plague in the absence of overt rodent plague, or to obtain data in areas where plague infection is widespread or quiescent.

Flea surveillance data may provide clues about which hosts are involved in local epizootics. Flea indices are essential information for determining the importance of local flea species as plague vectors. When using flea indices, it is important to estimate human and epizootic risks in conjunction with other rodent and vector surveillance data. When flea indices increase above a certain level, it may be necessary to initiate control measures to decrease the risk of human infection and plague epizootics.

In Chapter Four, work methods and procedures for the collection of fleas were discussed in terms of the following activities:
• The collection of fleas from captured rodents;
• the collection of fleas from rodent burrows;
• the collection of fleas from rodent nests; and
• the collection of fleas from human dwellings.

It was found that *Y. pestis* can be detected in fleas by using immunologic techniques and polymerase chain reactions (PCR) which are useful laboratorial techniques for identifying the specific plague vectors in a target area.

Work methods and procedures for the different control strategies of plague were presented and discussed in **Chapter Five**. These control strategies include:

• Legislative measures;
• health education;
• environmental management;
• chemical control;
• biological control;
• mechanical control;
• medical intervention; and
• integrated vector management for plague control.

Work methods and procedures for plague control were presented and discussed from the following perspectives:

• Plague outbreak control;
• the use of insecticides to control flea vectors; and
• the use of rodenticides to control rodent reservoirs;

When a plague outbreak occurs, a Plague Outbreak Control Team should be set up
immediately by the relevant Health District officer. The said team must implement epidemiological investigations and control strategies with the coordination by relevant staff from the Provincial and National Departments of Health. The establishment of a Plague Outbreak Control Team was discussed from national, provincial and health district perspectives. This team should compile investigation reports which will enable recommendations to be made for future prevention and control strategies.

Plague control strategies may be employed during the epidemiological investigation simply on the basis of common sense. The first step for controlling a plague outbreak is the control of flea vectors in order to prevent large numbers of fleas entering the environment. The purpose of flea control is to interrupt the plague transmission route. Insecticide dusting should begin as soon as possible after the verification of human cases and/or positive rodents.

Resistance to insecticides was discussed in Chapter Five because it is a serious impediment to flea control. In order to achieve effective flea control, plague control personnel must know the insecticide susceptibility status of the target fleas. The susceptibility of target flea vectors to insecticides should be determined periodically. Work methods and procedures for the control of fleas on commensal and wild rodents were developed in Chapter Five.

When a human plague outbreak occurs, or rodent surveillance data indicate a potentially dangerous situation with respect to increased plague risk for humans, rodent control programmes must be carried out. Active rodent control must be conducted using an Integrated Vector Management (IVM) strategy that includes both chemical and non-chemical methods. The most common and effective method for rodent control is the use of rodenticides.
Rodenticides refer to agents that are lethal to rodents. They are generally incorporated in either food baits, dusts or water. Rodenticides can be divided into two categories, namely:

- Acute rodenticides (single dose, quick-acting); and
- chronic rodenticides (multiple doses, slow-acting).

Acute rodenticides are highly toxic to many non-target animals and humans; and few of them have effective antidotes. Acute rodenticides are principally and most effectively employed in situations demanding a rapid reduction of high-density populations, particularly during emergencies. Currently, only two acute rodenticides (calciferol and zinc phosphide) are used during rodent control programmes.

Chronic rodenticides are regarded as anticoagulants that induce chronic and eventually fatal internal bleeding. Anticoagulants are divided into two categories, namely: first generation anticoagulants and second generation anticoagulants. Anticoagulants have a number of advantages over acute rodenticides. In Chapter Five, work methods and procedures for the use of rodenticides during rodent control strategies were presented and discussed. These methods and procedures include the following:

- Surveying an infested area;
- Formulating a strategy for the use of rodenticides:
  - Selecting the right rodenticides;
  - selecting the best bait to use;
  - deciding on the number of baiting stations;
  - deciding on the amount of bait per station;
  - deciding on the frequency of baiting inspections.
- Applying the bait; and
Evaluating the bait.

Before rodenticides are used, it is essential to first survey the target area and to record the baiting sites to be used. The purpose of such a survey is to determine the approximate density of the rodent population and its distribution within the rodent habitat or infested area. Commensal rodents may be found almost everywhere where humans live and work. Normally, rodents are rarely seen when infestation is low. Rodents that can be seen during the daytime indicate a sizeable infestation.

The purpose of selecting the right rodenticide is to achieve the right balance between efficacy and safety. If resistance is anticipated, the second generation anticoagulants should be selected. Rodenticides should be mixed with the food that the rodents are currently eating which does not contain large amounts of vitamin K$_1$. A processed cereal is normally used as the base material in food baits.

The control of wild rodents and their fleas was discussed in Chapter Five. If wild rodents are localized and close to human habitation, it might be feasible to alter the environment by cultivation to discourage rodents. Environmental management is thus an effective control measure for the wild rodent populations. Pesticides can also be used to control wild rodents and their fleas.

**RECOMMENDATIONS**

Work methods and procedures for plague surveillance and control as developed in this study provide numerous opportunities for further research, namely:

- To establish an effective plague surveillance and control system within a comprehensive national health care system in South Africa;
- to enhance the communication and cooperation of plague surveillance and
control personnel in the different spheres of government (including public and private sectors);

- to identify plague natural foci in South Africa;
- to identify rodent reservoirs and flea vectors in each plague natural focus in South Africa; and
- to improve data management for plague surveillance and control.


South African Department of Health and Welfare. (1982). Plague transmission and


INTERVIEWS

Dr E. Hoosain, Manager: Public Health Surveillance, Health Business Unit, Nelson Mandela Metropolitan Municipality, October 12, 2005.


Mr M. Adams, Senior EHP: Pest Control and Plague Surveillance Section, Environmental Health Business Unit, Nelson Mandela Metropolitan Municipality, September 22, 2005.


Ms K. Green, Manager: Information System, Department of Health, Province of the Eastern Cape, September 30, 2005.

Ms M.D. Manuel, Manager: Community Services, Department of Health, Province of the Eastern Cape, October 3, 2005.

ANNEXURE 1:
LETTER: REQUEST FOR PERMISSION TO CONDUCT RESEARCH:
NELSON MANDELA METROPOLITAN MUNICIPALITY

Department of Environmental Health
P.O. Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth
6031

Mr. N.J. Oliphant
Manager: Environmental Health Business Unit
Nelson Mandela Metropolitan Municipality
Port Elizabeth

Dear Mr. Oliphant

RESEARCH: MTECH: ENVIRONMENTAL HEALTH - REQUEST TO VISIT PEST CONTROL PERSONNEL

I am currently registered with the Nelson Mandela Metropolitan University (NMMU) for a Master's Degree in Environmental Health. My dissertation is entitled ‘Work methods and procedures for plague surveillance and control in South Africa’.

To enable me to effectively execute this study I will need to visit the plague surveillance and control personnel within your department (Pest Control Unit / Division) to conduct work studies on existing work methods and procedures and to test alternative ones. Dr. H.J. Maarschalk, the Head of the Department of Environmental Health of the NMMU will be supervising the study and may be contacted at telephone 041/5043273 should you have any questions.

Your favourable consideration of this request would be appreciated.
Yours sincerely,

Hongxing Zhou
E-mail: zhou_hongxing@hotmail.com
Mr H. Heinemann
Manager: Environmental Health Department
Eastern Cape Province
Port Elizabeth

Dear Mr. Heinemann

RESEARCH: MTECH: ENVIRONMENTAL HEALTH - REQUEST FOR PERMISSION TO CONDUCT INTERVIEWS IN THE EASTERN CAPE PROVINCIAL ENVIRONMENTAL HEALTH DEPARTMENT

I am currently registered with the Nelson Mandela Metropolitan University (NMMU) for a Master’s Degree in Environmental Health. My dissertation is entitled ‘Work methods and procedures for plague surveillance and control in South Africa’.

To enable me to effectively execute this study I will need to conduct personnel interviews with relevant officers at your department. Dr. H.J. Maarschalk, the Head of the Department of Environmental Health of the NMMU will be supervising the study and may be contacted at telephone 041/5043273 should you have any questions.

Your favourable consideration of this request would be appreciated.

Yours sincerely,

Hongxing Zhou
E-mail: zhou_hongxing@hotmail.com
ANNEXURE 3:
INTERVIEW SCHEDULE FOR THE STUDY

In order to obtain additional information, semi-structured personal interviews with relevant role-players in the Eastern Cape Provincial Environmental Health Department and the Nelson Mandela Metropolitan Municipality (NMMM) were conducted. Questions on the interview schedule included:

• What is the current organisational structure for health care service delivery in the Eastern Cape Provincial Health Department?
• What is the current organisational structure for environmental health service delivery in the NMMM/in the Eastern Cape Provincial Health Department?
• What is the relationship between the Environmental Health Business Unit and the Health Business Unit at the NMMM?
• Which unit/section is responsible for plague surveillance and control in the NMMM/in the Eastern Cape Provincial Health Department?
• What are the current organisational arrangements in response to plague outbreaks in the NMMM/Eastern Cape Province?
• What legal documents/guidelines are being used by the plague outbreak response teams of the NMMM/Eastern Cape Provincial Health Department?
• What do you think can be done to improve the effectiveness/efficiency of plague surveillance and control in the NMMM/Eastern Cape Provincial Health Department?
INFORMATION AND INFORMED CONSENT FORM

TITLE OF THE RESEARCH PROJECT

WORK METHODS AND PROCEDURES FOR
PLAGUE SURVEILLANCE AND CONTROL IN SOUTH AFRICA

Principle investigator: Hongxing Zhou

Supervisor: Dr H.J. Maarschalk

Address: Department of Environmental Health
P.O. Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth
6031

Contact Telephone: 0721185856

DECLARATION BY PARTICIPANT

I, the undersigned, __________________________________(name) (I.D. No:_____________________), the participant of _______________________
____________________________________________________________
______________________________________________________ (address).

A. HEREBY CONFIRM AS FOLLOWS:

1. I was invited to participate in the abovementioned research project which is being undertaken by Hongxing Zhou of the Department of Environmental Health in the Faculty of Health Science at the Nelson Mandela Metropolitan University.
2. This research project aims to develop formal work methods and procedures for plague surveillance and control in South Africa. The information will be used as the requirements for a Master’s Degree in Environmental Health.

3. Procedures: I understand that I will be asked to answer some questions concerning the topic above.

4. Risks: None

5. Confidentiality: My identity will not be revealed in any discussion, description or scientific publications by the researcher.

6. My participation is voluntary. My decision whether or not to participate will in no way affect my present or future employment.

7. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalization.

8. Participation in this study will not result in any additional cost to myself.

B. I HEREBY CONSENT VOLUNTARILY TO PARTICIPATE IN THE ABOVEMENTIONED PROJECT

Signed / confirmed at __________________________________________

____________________________________    on_______________2005.

Signature of participant______________________
## ANNEXURE 5:

<table>
<thead>
<tr>
<th>Level</th>
<th>Section</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Section 92 (2)</td>
<td>Members of the Cabinet (e.g. the Minister of Health) are accountable to Parliament for the exercise of their powers and the performance of their functions.</td>
</tr>
<tr>
<td></td>
<td>Section 125 (2) and Part A of Schedule 4</td>
<td>The Premier of a province exercises the executive authority by implementing all national and provincial legislation on health services; developing and implementing provincial policy on health services.</td>
</tr>
<tr>
<td>Provincial</td>
<td>Section 133 (1), (2)</td>
<td>The members of the Executive Council of a province are responsible for the functions of the executive assigned to them by the Premier; are accountable collectively and individually to the legislature for the exercise of their powers and the performance of their functions.</td>
</tr>
<tr>
<td></td>
<td>Section 155 (6)</td>
<td>Each provincial government must provide for the monitoring and support of local government in the province.</td>
</tr>
<tr>
<td></td>
<td>Section 152 (1d)</td>
<td>One of the objects of local government is to promote a safe and healthy environment.</td>
</tr>
<tr>
<td>Municipal</td>
<td>Section 155 (1)</td>
<td>There are the following categories of municipality: Category A: A municipality that has exclusive municipal executive and legislative authority in its area. Category B: A municipality that shares municipal executive and legislative authority in its area with a Category C municipality within whose area it falls. Category C: A municipality that has municipal executive and legislative authority in an area that includes more than one municipality.</td>
</tr>
<tr>
<td></td>
<td>156 (1a) and Part B of Schedule 4</td>
<td>A municipality has the right to administer municipal health services.</td>
</tr>
</tbody>
</table>

ANNEXURE 6:
DECISION-MAKING INSTRUMENT FOR THE ASSESSMENT AND
NOTIFICATION OF EVENTS THAT MAY CONSTITUTE A PUBLIC HEALTH
EMERGENCY OF INTERNATIONAL CONCERN

Events detected by national surveillance system

- A case of the following diseases is unusual or unexpected and may have serious public health impact, and thus shall be notified:
  - Smallpox
  - Poliomyelitis due to wild-type poliovirus
  - Human influenza caused by a new subtype
  - Severe acute respiratory syndrome (SARS).

- Any event of potential international public health concern, including those of unknown causes or sources and those involving other events or diseases than those listed in the box on the left and the box on the right shall lead to utilization of the algorithm.

- An event involving the following diseases shall always lead to utilization of the algorithm, because they have demonstrated the ability to cause serious public health impact and to spread rapidly and internationally:
  - Cholera
  - Pneumonic plague
  - Yellow fever
  - Viral haemorrhagic fevers (Ebola, Lassa, Marburg)
  - West Nile fever
  - Other diseases that are of special national or regional concern, e.g. dengue fever, Rift Valley fever, and meningococcal disease.

Is the event unusual or unexpected?

Is the public health impact of the event serious?

Is there a significant risk of international spread?

Is there a significant risk of international travel or trade restrictions?

Event shall be notified to the WHO under the International Health Regulations, 2005

Source: Adapted from the International Health Regulations, 2005 (World Health Organisation, 2005c, p.45)
ANNEXURE 7:
ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE AND CONTROL
IN THE NATIONAL DEPARTMENT OF HEALTH

ANNEXURE 8: GENERIC ORGANISATIONAL STRUCTURE OF A PROVINCIAL DEPARTMENT OF HEALTH

Source: Adapted from Hall, et al. (2002) and Eastern Cape Department of Health. (2005).
ANNEXURE 9:
ORGANISATIONAL STRUCTURE FOR PLAGUE SURVEILLANCE AND
CONTROL IN THE NELSON MANDELA METROPOLITAN HEALTH DISTRICT

## ANNEXURE 10:
### THE DISTRIBUTION OF PLAGUE NATURAL FOCI

<table>
<thead>
<tr>
<th>Continent</th>
<th>Recorded natural foci of plague</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>None</td>
</tr>
<tr>
<td>Europe</td>
<td>The fringe areas of the Caspian depression</td>
</tr>
<tr>
<td></td>
<td>The eastern slopes of the Caucasus</td>
</tr>
<tr>
<td>Americas</td>
<td>United States</td>
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<tr>
<td></td>
<td>Canada</td>
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<td></td>
<td>Mexico</td>
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<td></td>
<td>Argentina</td>
</tr>
<tr>
<td></td>
<td>Bolivia</td>
</tr>
<tr>
<td>Asia</td>
<td>The foothills of the Caucasus</td>
</tr>
<tr>
<td></td>
<td>Mongolia</td>
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<tr>
<td></td>
<td>China</td>
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<tr>
<td></td>
<td>India</td>
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<td></td>
<td>Cambodia</td>
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<td></td>
<td>Indonesia</td>
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<td></td>
<td>Myanmar</td>
</tr>
<tr>
<td>Africa</td>
<td>Democratic Republic of the Congo</td>
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<td></td>
<td>Madagascar</td>
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<tr>
<td></td>
<td>Malawi</td>
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<tr>
<td></td>
<td>South Africa</td>
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<tr>
<td></td>
<td>Senegal</td>
</tr>
<tr>
<td></td>
<td>Mauritania</td>
</tr>
<tr>
<td></td>
<td>Mozambique</td>
</tr>
<tr>
<td></td>
<td>Namibia</td>
</tr>
</tbody>
</table>

ANNEXURE 11:
KEY MICROBIOLOGICAL CHARACTERISTICS OF YERSINIA PESTIS

The microbiologic characteristics of *Yersinia. pestis* are summarized as follows (Center for Infectious Disease Research and Policy, 2005a):

- Pleomorphic gram-negative bacillus (1.0 to 2.0 µm x 0.5 µm); single cells or short chains in direct smears;
- Bipolar (‘closed safety pin’) staining with Giemsa, Wright's, or Wayson stains (may not be visible on Gram stain);
- Facultative anaerobe;
- Nonmotile, nonsporulating;
- Non–lactose fermenter;
- Slow-growing in culture: colonies are pinpoint after 24 hours on sheep blood agar (SBA) and much smaller than other *Enterobacteriaceae* growing for 24 hours on SBA; colonies may not be visible on MacConkey or eosin methylene blue agar at 24 hours;
- Catalase-positive, oxidase- and urease-negative (rarely, strains may be urease-positive);
- Optimal growth at 28 °C;
- ‘Stalactite pattern’ in broth culture with clumps of cells from the side of the tube settling to the bottom if disturbed;
- At 48 to 72 hours of incubation on solid media, colonies have a raised, irregular, ‘fried egg’ appearance under 4x enlargement, which becomes more pronounced as the culture ages; colonies also have been described as having a ‘hammered copper’ shiny surface;
- Alkaline slant/acid butt (K/A) on triple sugar iron agar (TSI) without gas or H₂S;
- Data banks for many commercial identification systems do not include *Y. pestis*;
- Relatively inert in biochemical test media; and
- Generally susceptible to tetracyclines, chloramphenicol, aminoglycosides, sulfonamides (with or without trimethoprim), and fluoroquinolone antibiotics.
## Annexure 12:
### Taxonomy of Fleas in Southern Africa

<table>
<thead>
<tr>
<th>Suborder (3)</th>
<th>Superfamily (4)</th>
<th>Family (8)</th>
<th>Subfamily (15)</th>
<th>Genus (32)</th>
<th>Species (isolation of Yersinia. pestis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulicomorpha</td>
<td>Pulicoidea</td>
<td>Pulicidae</td>
<td>Pulicinae</td>
<td>5</td>
<td>Echidnophaga gallinacean, pulex irritans</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Archaeopsyllinae</td>
<td>1</td>
<td>Ctenocephalides felis strongylus</td>
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<td></td>
<td></td>
<td></td>
<td>Xenopsyllinae</td>
<td>4</td>
<td>Xenopsylla brasiliensis, X. cheopis, X. philoxera</td>
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<tr>
<td></td>
<td></td>
<td>Tungidae</td>
<td>Tunginae</td>
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<tr>
<td>Malacopsyloidea</td>
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<td>Rhopalopsyllidae</td>
<td>Parapsyllinae</td>
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<td>Ceratophilomorpha</td>
<td>Ceratophylloidea</td>
<td>Ceratophyllidae</td>
<td>Ceratophyllinae</td>
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<td>Nosopsyllus fasciatus</td>
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<td>Leptopsyllidae</td>
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<td>Leptopsylla segnis</td>
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<td>Ischnopsyllidae</td>
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<td>Ischnopsyllinae</td>
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<td>Hystrichopsyllomorpha</td>
<td>Hystrichopsyllidae</td>
<td>Hystrichopsyllidae</td>
<td>Listropsyllinae</td>
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<td>Listropsylla dorippae</td>
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<td></td>
<td></td>
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<td>Dinopsyllinae</td>
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<td>Dinopsyllus ellobius</td>
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<tr>
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<td>Ctenophthalminae</td>
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<td>Ctenophthalmus calceatus</td>
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<td></td>
<td></td>
<td>Chimaeropsyllidae</td>
<td>Chiastopsyllinae</td>
<td>3</td>
<td>Chiastopysylla numae</td>
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Source: Adapted from Segerman (1995); De Meillon, Davis & Hardy (1961, p.14).
## ANNEXURE 13:
**IMPORTANT HOSTS AND VECTORS OF PLAGUE IN SOUTH AFRICA**

<table>
<thead>
<tr>
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<th>Flea species</th>
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Source: Adapted from South African Department of Health and Welfare. (1982, p.39)
ANNEXURE 14:
PROBABLE PLAGUE RESERVOIRS IN SOUTH AFRICA

The information in this annexure originated from various sources, namely:

- *Plague transmission and prevention* (South African Department of Health and Welfare, 1982);
- *The complete book of southern African mammals* (Mills & Hes, 1997);
- *The rodents of southern Africa: Notes on their identification, distribution, ecology and taxonomy* (De Graaff, 1981); and

Both the photos and the distribution maps of plague reservoirs are adapted from *The complete book of southern African mammals* (Mills & Hes, 1997). In this study, the South African plague reservoirs can be classified into several categories, namely:

- Gerbils (*Tatera brantsii, T. leucogaster, T. afra*, and *Desmodillus auricularis*);
- multimammate mouse (*Mastomys natalensis* and *M. coucha*);
- other rodents (*Otomys irroratus, Rhabdomys pumilio, Aethomys namaquensis, A. chrysophilus* and *Pedetes capensis*);
- commensal rodents (*Rattus rattus, R. norvegicus* and *Mus musculus*); and
- carnivores (*Cynictis pencillata* and *Suricata suricatta*).

Besides the animals mentioned above, other species of mammals may also be partially resistant to plague infection, such as domestic dogs and cats, which may serve as continuous reservoirs of plague. Plague surveillance and control personnel should be familiar with the local species of reservoirs.
1. *Tatera brantsii* (Highveld gerbil)

*Tatera brantsii* is a colonial burrowing rodent, making its burrows in sandy soils and sandy loam soil. It is nocturnal and feeds on roots, seeds and inserts, but its staple diet consist of the corms of certain sedges. The highveld gerbil is one of the primary hosts of plague in Southern Africa.

The highveld gerbil is generally widely distributed in the highveld and Kalahari in South Africa. It has a dull brownish-buff colour dorsally, with a white belly. The hairy tail is long with a pale or white tip without a dense fringe.

2. *Tatera leucogaster* (Bushveld gerbil)

*Tatera leucogaster* is very similar to *T. brantsii*, except that it is brighter in colour and has a dark tip to its tail and a marked tuft of hairs. Its habits are like those of *T. brantsii* and in an area where their distribution overlaps they can often be found in the same burrow. *T. leucogaster* is another primary host of plague.

The bushveld gerbil is widely distributed in the northern parts of Southern Africa, including South Africa (in the bushveld of the North-West, the Northern Province and Mpumalanga).
3. *Tatera afra* (Cape gerbil)

The cape gerbil is endemic to the Cape biotic zone, in an area of the Western Cape. It is reddish-orange to a pale buff infused with dark brown. It has a pure white belly, and the line of demarcation with the upperparts is clearly defined.


4. *Desmodillus auricularis* (Short-tailed gerbil, Namaqua gerbil)

The short-tailed gerbil is endemic to southern Africa. It is found in the Northern and Western Cape, the Southwestern Free State and Gauteng. It is smaller than the *Tatera* species and has a tan brown colour with a white belly. It has a white spot behind each ear.

The hairy tail is shorter than the head and body length. It eats seeds of grasses and annuals and is fond of the *dubbeltjie*, the husks of which are frequently found outside burrow entrances. It is a nocturnal, burrowing rodent living in colonies. This gerbil has been found to be more resistant to plague than the *Tatera* and could possibly maintain plague between epizootics.
5. *Mastomys natalensis* (Natal multimammate mouse)

All species of the multimammate mouse have soft, grey-based fur, the colouration of the upperparts ranging from shades of grey through yellowish to brown. The underparts are white to off-white. The female mouse has 12 pairs of mammae. *M. natalensis* is plague-resistant.

*Mastomys natalensis* is found in the Northern Province, Mpumalanga, KwaZulu-Natal and the Eastern Cape (the South-Eastern coastal region).

6. *Mastomys coucha* (Multimammate mouse)

*M. coucha* ranges from the Eastern Cape northwards through the Free State into Gauteng, the North-West, the Northern Province and Mpumalanga. *M. coucha* is very similar to *M. natalensis*, but different in its 2n chromosome number (36 diploid chromosomes per nucleus as opposed to 32).

*Mastomys coucha* makes its nest under any available cover such as fallen logs, piles of debris and in deserted burrows. It is frequently found in storerooms, outbuildings and grain-stacks. *M. coucha* is susceptible to plague and is important in carrying plague from gerbils to domestic rodents and man.
7. *Otomys irroratus* (Vlei rat)

The vlei rat is widely distributed, and in South Africa is absent only from the more arid western and northwestern regions. It has a thick-set head and body and is dark grey to black in colour with long fluffy fur. The upper and lower incisors are grooved.

*Otomys irroratus* lives in moist areas where there is dense grass cover, and feeds on grass stems and the leaves of grasses, herbs and shrubs. It is active mainly during the night and at dawn and dusk. The vlei rat is susceptible to plague and becomes secondarily infected when an epizootic is in progress.

8. *Rhabdomys pumilio* (Striped mouse)

The striped mouse is widespread through most of Southern Africa. It has a yellow-brown colour with four black strips on its back and a grey-white belly. It is generally diurnal and eats seeds, fruit, vegetable matter and insects. It forms runs in dense grass and nests in holes or builds nests of sticks and grass.

*R. pumilio* can become secondarily infected from other gerbils and as it can live close to human habitation, it may infect domestic rodents.
9. *Aethomys namaquensis* (Namaqua rock mouse)

The Namaqua rock mouse is widely distributed in Southern Africa. It is a common species with a high breeding potential. It is reddish-yellowish-brown; in some parts of its range it has black-tipped hair showing through. Its chest and flanks are greyish with a white belly.

*Aethomys namaquensis* species is well-adapted to life in hot, arid environments. It is not particularly fussy about its habitat requirements, but prefers crevices and does not burrow. *A. namaquensis* is extremely plague-sensitive, much more so than *A. chrysophilus*, and they may play different roles in the plague cycle.

10. *Aethomys chrysophilus* (Red veld rat)

The red veld rat is distributed in the northern regions of South Africa, excluding the drier areas of the Karoo. The species is larger than the Namaqua rock mouse. Some individuals of the species can be quite reddish in colour. Its feet are pure white.

*Aethomys chrysophilus* is a predominantly terrestrial and nocturnal. It is known to enter houses - sometimes in order to feed. *A. chrysophilus* plays a role in the transmission of plague.
11. *Pedetes capensis* (Springhare)

*Pedetes capensis* is nocturnal and feeds on rhizomes and stems of grasses and also on bulbs and green shoots of various plants. The springhare can travel long distances to forage. It is susceptible to plague but less so than the *Tateras* and may be able to disseminate plague to rodents that are not in direct contact with gerbils.

The springhare is common and widespread over much of eastern and southern Africa in relatively flat arid and semi-arid areas. It is fawny-brown in colour with a white belly and has long hind legs, short front legs, large ears and a long hairy tail with a black tip.

12. *Rattus rattus* (House rat, Black rat)

*Rattus rattus* rarely digs its own burrows but nests wherever there is suitable undisturbed cover. It becomes infected from the wild rodent, although it does not maintain the plague organism itself. *R. rattus* is one of the main sources of human bubonic plague.

The house rat is commensal with man and is found all over South Africa in and near human dwelling. Colour varies from pure black to grey and grey with a cream belly. The tail is longer than the head and body length, and is naked or sparsely covered with hair. It is omnivorous and needs to drink water regularly.

The Norway rat originated in the northern temperate regions of Asia and spread westwards through human activities and movement. In Southern Africa it is confined to ports and the larger coastal towns and cities. The brown rat is very different in character and appearance from the house rat. *Rattus norvegicus* attains a larger size and can be distinguished by its narrower braincase, stouter body, shortness of the ears, length of tail (shorter than length of head and body) and coarser fur. Like the house rat, the brown rat is a cosmopolitan species. It is chiefly nocturnal and suspicious of strange objects, making it more difficult to capture than the house rat. *R. norvegicus* can be infected by plague.

14. *Mus musculus* (House mouse)

*Mus musculus* is widely distributed in Southern Africa. The upperparts are buffy-brown, the flanks the same colour, flowing into a light brownish belly. Its tail is brown and longer than the length of head and body. *Mus musculus* is predominantly nocturnal. It lives in close proximity to man, often in cracks in walls and floors, constructs its nest of any household debris, and is omnivorous. It is susceptible to plague.
15. *Cynictis pencillata* (Yellow mongoose)

Apart from a marginal spread into southern Angola, *Cynictis pencillata* is a Southern Africa endemic. It is found in the Eastern Cape, KwaZulu-Natal, Mpumalanga and Northern Province. It has an amazing habitat tolerance. It feeds mainly on insects but also eats dead or sick rodents.

A large amount of rodent fur in its faeces gives an indication of rodent mortality occurring in a certain area. It does not die from plague, but produces antibodies to the disease if infected. This makes it a useful indicator of where plague has recently occurred. In addition, it is the most important transmitter of rabies.

16. *Suricata suricatta* (Suricate)

Suricate ranges throughout the semi-arid regions in Southern Africa. It is locally common from southern Angola, through Namibia and Botswana to South Africa’s North-West Province, Free State, Eastern and Western Cape but does not reach Cape Town.

*Suricata suricatta* is fawn to silvery-grey with darker, irregular transverse bars. Hindquarters are stockier than the forequarters. Front claws are very long. It has a round, broad head with short, sharp-pointed muzzle. Dark circles around the eyes. Suricate is a carnivore, and can transmit plague.
**ANNEXURE 15:**

**CLINICAL PRESENTATION OF CLASSIC HUMAN PLAGUE**

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<th>Bubonic plague</th>
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</tbody>
</table>
| **Presenting features** | 1. Sudden onset of fever, chills, weakness  
2. Usually within 1 day, painful swollen lymph node or group of nodes (bubo) occurs in groin, axilla, or cervical region  
3. Skin lesions may occur at the site of flea bite but are present in <10% of cases  
4. Associated lymphangitis occurs  
5. Presenting symptoms may include fever, chills, bubo, headache, prostration, altered mental status, anorexia, abdominal pain, cough, chest pain, skin rash |
| **Complications** | 1. Secondary septicaemia: can lead to DIC (disseminated intravascular coagulation), shock, multisystem involvement;  
2. Secondary pneumonic plague  
3. Meningitis |
| **Case-fatality rate** | Over 50% without antibiotic treatment |
| **Laboratory features** | Laboratory features for 40 patients:  
1. Mean WBC (white blood cell) count: 21,500/mm³  
2. PMNs (polymorphonuclear neutrophils) showed cytoplasmic vacuolation in 24 patients, Dohle bodies in 20 patients, toxic granules in 8 patients  
3. Mean platelet count: 210,000/mm³ (18 patients had platelet counts <150,000/mm³)  
4. SGOT (Serum glutamic-oxaloacetic transaminase) elevated in 13 patients (20-92 M-IU)  
5. LDH (lactate dehydrogenase) elevated in 7 patients (308-900 units)  
6. Alkaline phosphatase elevated in 9 patients (33-116 units)  
7. PTT (partial thromboplastin time) >10 seconds over control in 6 patients |

<table>
<thead>
<tr>
<th>Septicaemic plague</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incubation period</strong></td>
</tr>
</tbody>
</table>
| **Presenting features** | 1. May present with primary septicaemic plague  
2. Presenting symptoms may including: fever, chills, headache, gastrointestinal symptom (nausea, vomiting, diarrhea, abdominal pain)  
3. Mental status changes commonly occur (delirium, coma) |
| **Complications** | 1. Illness rapidly progresses to sepsis syndrome often with DIC, |
shock, and multisystem involvement
2. Skin lesions reflect DIC
3. Meningitis
4. Secondary plague pneumonia
5. Endophthalmitis
6. Hepatic or splenic abscesses

<table>
<thead>
<tr>
<th>Case-fatality rate</th>
<th>Overall 30%-50%</th>
</tr>
</thead>
</table>
| **Laboratory features** | 1. Laboratory features consistent with severe bacterial infection and sepsis syndrome  
2. Leukocytosis, leukopenia, or normal WBC count may be seen  
3. CXR (chest x-ray) shows patchy alveolar infiltrates (usually bilateral), often with consolidation  
4. Mean WBC count: 18,950/mm$^3$ all had marked left shifts  
5. Bacteria seen on peripheral blood smear (17.6%) |

### Pneumonic plague

<table>
<thead>
<tr>
<th>Incubation period</th>
<th>1-4 days</th>
</tr>
</thead>
</table>
| **Presenting features** | 1. Symptoms of primary plague pneumonia: fever, chest pain, dyspnea, productive cough, hemoptysis, tachypnea, cyanosis, bubo not present  
2. Gastrointestinal symptoms (nausea, vomiting, abdominal pain, diarrhea) |
| **Complications** | 1. Septicaemia with sepsis syndrome  
2. Meningitis |
| **Case-fatality rate** | Close to 100% |
| **Laboratory features** | 1. Findings consistent with severe bacterial infection and sepsis syndrome  
2. CXR findings in series of 9 cases of secondary pneumonic plague: Alveolar infiltrates (100%); pleural effusion (55%); one patient developed cavitary lesion 3 weeks after illness onset  
3. Consolidation common on CXR; massive mediastinal adenopathy occurs rarely  
4. Organisms usually seen on sputum Gram stain |

Source: Adapted from Center for Infectious Disease Research and Policy. (2005a).
# ANNEXURE 16:

## INITIAL DIAGNOSIS FORM FOR NOTIFIABLE DISEASES

**Notification of medical condition**  
(Sections 32, 47 of Act 63 of 1977)  
**Department of National Health**

Please print:  
- Where appropriate, mark the correct box with a tick (√).
- Complete in duplicate. Original to be sent to local authority where patient was diagnosed: copy to remain in book.

## DETAILS OF PATIENT

<table>
<thead>
<tr>
<th>Surname</th>
<th>First names</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Ethnic group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Asian</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>Black</td>
</tr>
</tbody>
</table>

Residential address:

District

Tel. no.

Name and address of employer, school, crèche or other institution where patient spends much of the day:

Tel. no.

## DETAILS OF MEDICAL CONDITION

<table>
<thead>
<tr>
<th>Medical condition</th>
<th>Date of onset</th>
<th>Date of death (if applicable)</th>
</tr>
</thead>
</table>

Possible place of infection

Diagnosis was based on  
- Clinical history and examination only
- Clinical and other investigations

## RESULTS OF INVESTIGATIONS

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## REFERRED TO

Name of hospital or clinic:

<table>
<thead>
<tr>
<th>Patient registration No:</th>
<th>Date of admission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## NOTIFIED BY

Name:

Address:

Tel. no.

Profession  
- Medical practitioner
- Nurse
- Other

Signature | Date
-----------|-------

Source: Adapted from Health Systems Trust. (1998).
ANNEXURE 17:
PLAGUE SURVEILLANCE REPORTING FORM (CASE-BASED)

Where appropriate, mark the correct box with a tick (√).

<table>
<thead>
<tr>
<th>Name of Reporting Health Facility:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Health District:</td>
<td>Province:</td>
</tr>
<tr>
<td>Address of the Health Facility:</td>
<td></td>
</tr>
<tr>
<td>Telephone:</td>
<td>Fax:</td>
</tr>
<tr>
<td>Confirmed clinically by:</td>
<td></td>
</tr>
<tr>
<td>(Name of medical doctor, telephone number if different from above)</td>
<td></td>
</tr>
<tr>
<td>Confirmed Laboratory:</td>
<td></td>
</tr>
<tr>
<td>Name of contact person:</td>
<td>Telephone:</td>
</tr>
</tbody>
</table>

**DETAILS OF PATIENT**

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date of birth: _____ _____ _____ years months days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender:</td>
<td>Male [ ] Female [ ]</td>
</tr>
<tr>
<td>Ethnic group:</td>
<td>Asian [ ] Black [ ] Coloured [ ] White [ ]</td>
</tr>
<tr>
<td>Residence:</td>
<td></td>
</tr>
</tbody>
</table>

**DETAILS OF MEDICAL CONDITION**

<table>
<thead>
<tr>
<th>Date seen at Health Facility:</th>
<th>Dates of onset:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory results:</td>
<td></td>
</tr>
<tr>
<td>Clinical presentation:</td>
<td>Bubonic [ ] Septicaemic [ ] Pneumonic [ ]</td>
</tr>
<tr>
<td>Final Classification:</td>
<td>Suspected [ ] Presumptive [ ] Confirmed [ ]</td>
</tr>
<tr>
<td>Process of treatment (including recovered or fatal):</td>
<td></td>
</tr>
</tbody>
</table>

**DETAILS OF EPIDEMIOLOGICAL INVESTIGATION**

(place and source of exposure, possible exposure of others that came into contact with the patient, rodent and vector surveillance data):

<table>
<thead>
<tr>
<th>Signature:</th>
<th>Date: DD / MM / YY</th>
</tr>
</thead>
</table>

Source: Own structured.
ANNEXURE 18:
EQUIPMENT REQUIRED FOR RODENT SURVEILLANCE

The following materials are required in order to effectively perform rodent and flea surveillance. The quantity will depend on the number of habitats to be sampled (Leirs, 2004, p.47; Harrison, 1995, pp.61-62; Mills et al., 1995, p.19):

- Reliable transport;
- local maps or aerial pictures;
- Global Positioning System (GPS) and computer;
- note pads, pencils, watch, identification literature for small mammals;
- rodent field data form (see Annexure 27), habitat assessment data form (see Annexure 20);
- personal protection equipment (PPE): boots, rubber gloves, overalls, masks, goggles, flea repellant;
- traps, bait, masking tape, tape measure, trap bag;
- anaesthetising jars (or bags), Metofane or halothane;
- equipment for flea collection (see Annexure 19);
- at least six dissection kits;
- sharps container;
- scissors, knife, forceps, magnifying lens;
- scale or balance (50g - 2000g), ruler (mm);
- syringes and needles, blood tubes, cotton wool, tube ranks, filter paper, vials (9mm);
- labels: blood/spleen/kidney/liver/lung and heart/stomach/ectoparasite (see Annexure 21);
- fixatives such as methanol, ethanol (absolute 96%), formalin;
- jars (or bags) for rodent carcasses; and
- soap, bleach solution for disinfection.
ANNEXURE 19:
EQUIPMENT REQUIRED FOR FLEA COLLECTION

Equipment required for collection of ectoparasites (fleas) from nest, burrow or body of small mammals is listed below (Segerman, 1995, p.8):

- Calico mouse bags 25cm×20cm;
- airtight tin or jar;
- chloroform or cyanogas;
- two large white enamel basins at least 20cm deep and 37.5cm in diameter;
- flea bucket consisting of an inner bucket with a 5mm mesh bottom 25cm deep, 23cm diameter at the top, 20cm at the bottom, and an outer bucket 38cm×23cm with mosquito gauze bottom soldered firmly about 5cm from the bottom of the bucket;
- a burrow scraper made of a piece of hoop iron 38cm×2.5cm, with one end bent at right angles with a half-moon shaped piece of iron 4cm wide, riveted on;
- a small dustpan of about 20cm×10cm;
- a small carpet brush or toothbrush;
- collection tube with suction bulb;
- dissecting needle;
- specimen tubes or bottles;
- 70% alcohol;
- pieces of white card to fit into tubes or bottles; and
- a soft lead pencil for labelling.
## ANNEXURE 20:
### RODENT HABITAT ASSESSMENT DATA FORM

<table>
<thead>
<tr>
<th>Trap site code:</th>
<th>Trapline number(s):</th>
<th>Form number:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Province:</th>
<th>Health district:</th>
<th>Municipality:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Locality:</th>
<th>Date: DD / MM / YY</th>
<th>GPS reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observer/s:</th>
<th>Telephone:</th>
<th>GPS reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>S</td>
</tr>
</tbody>
</table>

### Habitat factors

<table>
<thead>
<tr>
<th>Weather</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunny</td>
<td>Partly sunny</td>
<td>Cloudy</td>
</tr>
<tr>
<td>Rainy</td>
<td>Temperature: °C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General topography</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain</td>
<td>Rolling hills</td>
</tr>
<tr>
<td>Valley</td>
<td>Terrace</td>
</tr>
</tbody>
</table>

### Predominant vegetation types

<table>
<thead>
<tr>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barren</td>
<td>Desert</td>
</tr>
<tr>
<td>Desert</td>
<td>Scratch</td>
</tr>
<tr>
<td>Scrub</td>
<td>Forest</td>
</tr>
<tr>
<td>Grassland</td>
<td>Meadow</td>
</tr>
<tr>
<td>Meadow</td>
<td>Wetland</td>
</tr>
<tr>
<td>Wetland</td>
<td>Riparian</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Land use patterns</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>Residential</td>
</tr>
<tr>
<td>Residential</td>
<td>Industrial</td>
</tr>
<tr>
<td>Industrial</td>
<td>Roads</td>
</tr>
<tr>
<td>Railways</td>
<td>Airports</td>
</tr>
<tr>
<td>Airports</td>
<td>Seaports</td>
</tr>
<tr>
<td>Seaports</td>
<td>Other</td>
</tr>
<tr>
<td>Sand</td>
<td>Gravel</td>
</tr>
<tr>
<td>Gravel</td>
<td>Rock</td>
</tr>
<tr>
<td>Rock</td>
<td>Clay</td>
</tr>
<tr>
<td>Soil</td>
<td>Loam</td>
</tr>
<tr>
<td>Loam</td>
<td>Wet</td>
</tr>
<tr>
<td>Wet</td>
<td>Dry</td>
</tr>
<tr>
<td>Dry</td>
<td>Other</td>
</tr>
<tr>
<td>Water available</td>
<td>Remarks</td>
</tr>
<tr>
<td>River/stream</td>
<td>Marsh</td>
</tr>
<tr>
<td>Marsh</td>
<td>Spring</td>
</tr>
<tr>
<td>Lake/pond</td>
<td>Other</td>
</tr>
<tr>
<td>Lake/pond</td>
<td>Marsh</td>
</tr>
<tr>
<td>Marsh</td>
<td>Other</td>
</tr>
<tr>
<td>Permanent</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Intermittent</td>
<td>Temporary</td>
</tr>
<tr>
<td>Temporary</td>
<td>No water</td>
</tr>
</tbody>
</table>

### Shrub

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Few</td>
</tr>
<tr>
<td>Few</td>
<td>Scattered</td>
</tr>
<tr>
<td>Scattered</td>
<td>Clumped</td>
</tr>
<tr>
<td>Shrub</td>
<td>Remarks</td>
</tr>
<tr>
<td>Height</td>
<td>Remarks</td>
</tr>
<tr>
<td>Low (&lt;1m)</td>
<td>Medium(1-2m)</td>
</tr>
<tr>
<td>Medium(1-2m)</td>
<td>Tall (&gt;2m)</td>
</tr>
</tbody>
</table>

### Human structure types

<table>
<thead>
<tr>
<th>Market areas</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain stores</td>
<td>Slaughterhouse</td>
</tr>
<tr>
<td>Slaughterhouse</td>
<td>Other</td>
</tr>
<tr>
<td>Rural houses</td>
<td>Remarks</td>
</tr>
<tr>
<td>Urban Houses</td>
<td>Remarks</td>
</tr>
<tr>
<td>Urban Houses</td>
<td>Remarks</td>
</tr>
<tr>
<td>Storied building</td>
<td>Other</td>
</tr>
<tr>
<td>Gardens</td>
<td>Remarks</td>
</tr>
<tr>
<td>Rubbish station</td>
<td>Remarks</td>
</tr>
<tr>
<td>Other</td>
<td>Remarks</td>
</tr>
</tbody>
</table>

### Species diversity

<table>
<thead>
<tr>
<th>Mammals</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Birds</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>High</td>
</tr>
</tbody>
</table>

### Human activity influence

| Low | Moderate | High |

### Remarks:

ANNEXURE 21:
WORK METHODS AND PROCEDURES FOR
RODENT TRAPPING AND PROCESSING

A number of documents were studied in order to develop the work methods and procedures for rodent trapping and processing. These documents include the following: *Plague manual: Epidemiology, distribution, surveillance and control* (World Health Organisation, 1999a), *Prevention and control of plague: Technical guide 103* (Harrison, 1995), *Guidelines for collecting small mammals* (Leirs, 2004), *Methods for trapping and sampling small mammals for virologic testing* (Mills, et al., 1995) and *Guidelines for the collection of clinical specimens during field investigation of outbreaks* (World Health Organisation, 2000).

Before any of the following procedures are performed, protective personnel clothing must be used (see Annexure 24). Work methods and procedures for rodent trapping and processing are presented below.

1 **Identification of trap site**

   - Trap sites should represent different habitats.
   - Within each site, sub-habitats should be identified.
   - Two or more trap sites should be established in each habitat type.

2 **Trap site description**

   - The trap site description should include plant life and physical features where the trap line is located.
   - Use maps, aerial pictures or satellite images to locate the trap sites.
   - Fill in a habitat assessment data form (see Annexure 20) and draw a map of the situation. If possible, take some pictures and label them accordingly.

3 **Establishing traplines**

   - Establish a trapline within each habitat to be sampled.
• Place traplines in areas that are out of sight of roads, sidewalks, paths or other areas of human activity. Avoid areas frequented by livestock to prevent destruction.
• The basic trapline should transect those areas most representative of the habitat (areas with rocks, grass, shrubs, trees, etc., should be included). Follow a straight line if possible.
• The basic unit for a trapline consists of a straight line of 10 trap stations at 10 meters intervals.
• Traps should be set at specific sites where there are burrows, nests, runways or they can be set along transects with 10-20 traps (or more) spaced at approximately 20 meters intervals along each transect.
• If necessary, trapping grids can be established, with the intervals for trap spacing based on local conditions.
• In areas likely to contain a species that has specialized habitat requirements, set traps especially for those species. Set these traps at random in specific areas most likely to catch the target species.
• Assign an alphanumeric code to each trapline.
• Mark the individual trap sites with brightly coloured bricks or streamers, engineer survey tape or flags on wire stakes.
• Number the streamers according to their position in the trapline.
• Traps should be shaded by logs, trees, shrubs, etc.; such cover will not alter trapping success and may prevent the death of an animal by heat prostration.
• Use trap sites for three consecutive 24-hour periods.
• Use the same number of traps and trapping configuration during each trapping session.

4 Baiting and setting of traps

• In each habitat type, use different types of traps since these may yield different species of small mammals.
• The proportions of different trap types depend on different species and local conditions.
• Bait: a mixture of peanut butter and maize bran or rolled oats is preferred.
• When trapping in urban areas, it is useful to add some dried fish or sardine oil. When trapping for *Cricetomys* (giant pouched rats) use fresh fruit or green maize.

• Check traps prior to going into the field. To check collapsible live traps, set the trap and touch the treadle (the tripping mechanism) with a pencil or stick. The trap should snap with little pressure.

• Check the traps again while setting. Place rolled oats bait in the rigid live traps though the trap doors. Ensure that no bait has fallen under the treadle at the time of setting.

• Place traps at a slight incline so that bait will shift to the back and away from the treadle.

• Bait collapsible live traps after they have been set at the trapping site. Sprinkle some bait in front of the treadle and around the entrance of the trap.

5 Collecting rodents and recording the trap site for each captured rodent

• Check traps and collect trapped rodents early in the morning before sunrise.

• Place the trap containing a rodent in a plastic bag and tie the bag.

• Label the trap with permanent ink or pencil with the date, the trap line number, the Global Positioning System reference reading and the sequential number of the rodent with respect to other captured rodents on the same date on the same trap line.

• Place a new trap before leaving if necessary.

• It is imperative that traps from different habitats remain segregated at all times.

6 Removing rodents from traps into the anaesthetising jar

• Place a cloth bag over the opening of the trap and then open the trap door through the cloth bag.

• Turn the trap upside down and allow the rodent to fall into the bag. Sometimes the operator needs to gently shake the trap to drop the rodent and debris into the bag.

• Remove the trap from the bag. Hold the mouth of the bag closed with one hand
and with the other hand force the rodent toward the mouth of the bag.

- Grasping the bag behind the rodent will prevent the introduction of bait into the anaesthetising jar.
- Place the mouth of the bag into the anaesthetising jar, and force the rodent into the jar. Quickly cover with the lid.

7 Procedure to anaesthetise a rodent and its fleas

- A wide-mouth quart or gallon glass jar is usually adequate depending on the size of the rodent to the processed.
- Soak a large cotton pad or a stack of gauze pads with an anaesthetic (Metofane, halothane or ether) and place them in the jar.
- Ether must be used carefully because of the danger of accidental explosion.
- Chloroform is not recommended as an anaesthetic because of its presumed carcinogenicity and the possibility that it might interfere with attempts to isolate plague bacteria from sample specimens.
- Observe the rodent and fleas until they become motionless, then pour the rodent and fleas out of the jar into the white enamel flea collecting pan (a depth of 20 cm or more is recommended; a white pan will make fleas more visible).
- If the rodent wakes up during processing, put it back in the jar.
- It is often not necessary to add new anaesthetic for each individual rodent.

8 Collecting fleas from captured rodents

- A white enamel pan will make escaped fleas more visible and easier to capture by using a collection tube with suction bulb or an applicator stick.
- An alternative method to collect fleas is to dip the tip of an applicator stick into an alcohol vial (three drops of glycerin added per quart of 95% ethyl alcohol) and to collect the fleas that adhere to the stick.
- Pour remainder of the contents of the bag into the abovementioned white enamel pan.
- Check the bag for remaining fleas.
- While the rodent is still fully anaesthetised, place it into the enamel pan (see
Figure 14).

**FIGURE 14:**
**METHOD TO REMOVE AN ANAESTHETISED RODENT FROM AN ANAESTHETISING JAR INTO AN ENAMEL PAN**

Source: Adapted from Gage (1999a, p.142)

- Hold the rodent by the hind foot and brush vigorously from the tail end forwards so that brushed fleas fall into the pan.
- A tooth brush with only one row of bristles is a perfect combing tool. Bristles must be stiff and white which make fleas more visible.
  If fleas collected from rodents are to be used for *Y. pestis* isolation, place collected specimens in 2% saline solution.
- Bury debris after the flea collection in order to prevent environment pollution.
- Submit fleas that cannot be identified to the relevant laboratory within the National Health Laboratory Service (see Section 14 of this Annexure).

9 **The identification and measurement of rodents**

- Identify the rodent species (see Annexure 14); and fill in rodent field data forms (see Annexure 27).
- Submit rodents that cannot be identified to the relevant laboratory within the National Health Laboratory Service.
- Identify sex: The opening at the base of the tail of a rodent is the anus. Both sexes have a genital papilla that covers the penis in males and the clitoris in females. **Male:** In juvenile male rodents, the testes are initially located inside the
body (in an abdominal position). As the rodent matures, the testes enlarge and
descend to adopt a scrotal position (inside a hairy scrotal sac - see Figure 15).
**Female:** The anus and genital papilla are close together and the skin between
them is bare or thinly furred. The vagina should be visible just behind the genital
papilla. Only female rodents have teats associated with subcutaneous mammary
glands, which are arranged down either side of the body.

---

**FIGURE 15:**
**COMPARISON BETWEEN JUVENILE AND ADULT MALE RODENTS**

| Juvenile (abdominal testes) | Adult (descended testes) |

Source: Adapted from Aplin, et al. (2003, p.39)

**FIGURE 16:**
**COMPARISON BETWEEN JUVENILE AND ADULT FEMALE RODENTS**

| Juvenile (closed or imperforate vagina) | Adult (open or perforate vagina) |

Source: Adapted from Aplin, et al. (2003, p.39)

- Identify reproductive condition (see Figure 16): In juvenile female rodents, the
  vagina is sealed off by a thin, shiny layer of skin (the hymen). As the rodent
  reaches sexual maturity, the vaginal covering breaks down and the vagina is
open or perforates from then on. The vagina will be widely open if the rodent has recently mated or given birth. It is smaller if the rodent is mature but has never mated, or not recently mated.

- Weight measurement: Record the weight in grams by using an electronic balance or spring balances. When animals are wet, indicate this clearly in the remarks.
- Length measurement (see Figure 17): Make the following measurements (in millimetres) and record them on the rodent field data form.
  - Total length: Body and tail length (use decimals for small species).
  - Tail length: Length of tail from the bending point (anus) to the tail-tip. If a tail is broken, still take measurement but note it in the remarks.
  - Length of the left hind foot: Do not include the nail in this measurement.
  - Ear length: From the basis of the ear (insertion curve) to the ear tip.
  - For the latter two measurements, a caliper may be needed. For the other measurements, a normal ruler will do.

**FIGURE 17:**
LENGTH MEASUREMENTS OF A RODENT

Source: Adapted from Mills, et al. (1995, p.25)
10 Taking of blood samples from rodents

The blood sample needs to be large enough (about 1ml) for laboratory analysis. This requires blood taken from the heart or from the retro-orbital sinus. If the rodent is dead and no more blood can be taken, then the whole heart must be removed and placed in a vial to be forwarded to the laboratory.

10.1 Perform cardiac puncture

- Affix a 22 gauge needle to a 1 or 3 cc syringe, loosen the needle cover, and test the plunger to see that it pulls smoothly;
- Coat the inside of the sterile syringe by aspirating heparin into the syringe and then returning the heparin to the container;
- Place the anaesthetised rodent on a flat surface, ventral side up. Wet the thorax and abdomen with alcohol and wipe with clean gauze;
- The position of the beating heart can often be located by feeling with the index finger;

![CARDIAC PUNCTURE: PROPER POSITIONING OF A RODENT AND SYRINGE](image)

Source: Adapted from Mills, et al. (1995, p.23)

- With the index finger of the left hand, locate the xiphoid process. Holding the syringe in the right hand, insert the needle just below this point and withdraw the plunger gently to create a slight vacuum. Continue to push the needle into the chest cavity at an angle of about 20 degrees above the horizon until the heart is penetrated and blood begins to flow (see Figure 18);
• Withdraw the plunger slowly as the syringe fills, maintaining a slight vacuum;
• If the flow ceases before enough blood has been taken, withdraw the needle slightly (the needle may have withdrawn from the heart), or adjust the position of the needle until the flow of blood is re-established;
• When a sufficient volume (1ml) of blood is obtained, release the negative pressure on the plunger and withdraw the needle from the chest cavity;
• Without removing the needle, slowly expel the blood into a labelled vacuum test tube and dispose of the needle and syringe in the sharps container without replacing the plastic needle cover.

10.2 Perform retro-orbital bleed (alternative methods)

• While facing the back of the rodent, place the thumb of the left hand (right, if the operator is left-handed) on top of the head and the index finger under the throat. Pinch the thumb and index finger together, sliding the skin to the left, causing the skin to become taught around the right side of the animal’s head so that the right eye bulges;

![FIGURE 19: RETRO-ORBITAL BLEED FROM A RODENT](image)

Source: Adapted from Mills, et al. (1995, p.22)

• Insert one end of a heparinized capillary tube into the posterior corner of the eye (lateral canthus), behind the eyeball (see Figure 19). A white pad of fat which is usually visible behind the eye makes a useful target.
• The tube should be perpendicular to the face of the rodent and should tilt down and away from the animal towards an open labelled vial (see Figure 19). When the capillary tube reaches the back of the orbit and the bone is felt, rotate it a few times against the bone to rupture the venules and start the flow of blood;
• Withdraw the tube slightly away from the bone to allow the blood to enter the tube unobstructed. If no blood flows, repeat the procedure;
• When blood begins to flow into the capillary tube, place the free end over the mouth of the vial and allow the blood to drip into the vial. It may be necessary to rotate the tube or move it in and out of the sinus occasionally to maintain the flow of blood;
• Remove the capillary tube from the eye and place it into the vial temporarily;
• Dispose of the capillary tube in the sharps container;
• Tightly replace the cap on the vial. If any blood was spilled on the vial, wipe it off with a paper towel and disinfectant; and
• If a needle stick, bite, or other injury which breaks the skin should occur, stop work and leave the processing area, remove the glove or other skin covering, and clean the site of injury thoroughly with disinfectant. Report the injury immediately to medical personnel for prophylaxis treatment.

11 Dissecting and taking of tissue samples

• If the rodent has not died, it should be euthanized before dissection. This procedure may be accomplished by an overdose of anaesthetic or by cervical dislocation.
• Prepare disinfectant, alcohol and instruments.
• Prepare bucket with formalin for rodent carcasses.
• All tubes and containers are labelled (see Section 12).
• Dissection must be done by means of a sterile method. Wear gloves and protective clothing.
• Using a single set of scissors and forceps; after each rodent, rinse the scissors in alcohol and keep it there until the next dissection;
• Take a pair of small scissors and forceps; dip them in alcohol and flame them with an alcohol burner; use only these instruments for taking out tissue samples.
• Place the animal on its back on a dissection mat;
• Wet the fur on the belly with alcohol;

![FIGURE 20: METHOD TO PINCH AND RAISE SKIN AND MUSCULATURE OF LOWER ABDOMEN IN PREPARATION FOR INCISION](image)

Source: Adapted from Mills, et al. (1995, p.27)

• Pinch the skin of the lower part of the abdomen with fingers or forceps and lift it. Place the scissors below your fingers /forceps and, with a single snip, cut through the skin and abdominal musculature (see Figure 20);
• Insert one blade of the scissors into the incision and make one or two cuts on each side of the abdominal wall in a V-shaped pattern, and pull the cut skin and musculature back to completely expose the abdominal cavity (see Figure 21).
• Lift the stomach to expose the spleen with blunt-end forceps. Grasp the spleen with the forceps and gently pull it loose from the connecting tissue. Place the spleen in a sterile labelled vial;
• Using the same forceps, grasp the kidneys, pull them loose and place them into a second vial;
• Grasp the diaphragm with the forceps and tear it to provide clear access to the thoracic cavity (see Figure 21).
• Grasp and remove the heart and lung and place them in a vial;
• With the forceps, grasp about one third of the liver and place in a vial (Do not collect the gall bladder, and avoid tearing the gall bladder and thereby releasing its enzymes into the sample).
• Disinfect the scissors/forceps in alcohol; clean them with soap and water; rinse with water; keep clean until the next dissection and flame them just before use (the easiest is to have at least five sets of scissors/forceps ready and only clean them after each batch of animals).
• For safety reasons, do not use scalpels when dissecting.
• Sew up the rodent and preserve it in formalin.

12 Labelling rodent and each specimen vial

Each rodent specimen must be assigned a unique identification number. This unique identification number should be present on all data forms, records, slides, vials, etc. In general, pre-printed, pre-numbered standard labels for the rodent specimens should be used. Labels are printed on water-resistant paper (see Figure 22).
FIGURE 22:
A LABEL FOR A TRAPPED RODENT

<table>
<thead>
<tr>
<th>LABEL NO. 1200</th>
<th>RODENT SURVEILLANCE</th>
<th>PLAGUE SURVEILLANCE PROGRAMME, SOUTH AFRICA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Province:</td>
<td>Health District:</td>
<td></td>
</tr>
<tr>
<td>Rodent species:</td>
<td>Municipality:</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td>Official:</td>
<td>Telephone:</td>
</tr>
</tbody>
</table>

Source: Own structured.

As illustrated in Figure 22, the label is pre-numbered as No.1200. Other information to record on the label includes:

- The Province, Health District and Municipality of the capture locality;
- Rodent species: preliminary field identification of the rodent; if the rodent cannot be identified, simply leave a space blank;
- Date: the date of sampling as day/month/year;
- Official and telephone: the name and telephone number of the surveillance officer;
- Any other information can be added on the back of the label. Note that all information must be written with permanent ink or pencil;
- The label should be fixed to the left hind leg of the specimen. Punch a hole where indicated on the label, then fix the label through the thigh muscle;

FIGURE 23:
VIAL LABELS FOR TISSUE AND FLEAS OF RODENTS

Source: Own structured.
• Vial labels for blood, serum, heart/lung, spleen, kidney, liver, stomach/intestines and fleas can be made of 3cm pieces in 1.5cm athletic adhesive tape. Label the vials with the rodent identification number and date (see Figure 23).

13 Fill in the data forms

A rodent field data form is shown in Annexure 27. A rodent specimen data form is shown in Annexure 28. These forms should be completed during rodent and flea processing. The rodent data form must include the following:

• Locality: The rodent capture locality, i.e. the name of the town;
• Official: The person who was actually doing the trapping;
• Date: day/month/year;
• Trap site code;
• Species: Indicate species of rodent; leave blank if specimen is submitted for identification;
• Label number: The number from the specimen label. All material which is collected from the rodent should be marked with the same label number;
• Type of trap;
• Age: Juvenile, adult, old;
• Sex: M=male; F=female;
• Sexual condition: Determine whether the rodent is sexually active or inactive. Males: Testis: abdominal (A) or scrotal (S); Swelling of the cauda epididymis: visible (V) or not (N). For example, for a sexually active male with clearly visible swelling of the epididymis, fill in SV (scrotal visible);
• Females: Vagina: closed (C) or perforated (P); Nipples: small (S) or lactating (L);
• Pregnant: Yes (Y) or No (N). Abdominal distention is apparent in most rodents by 12-14 days of gestation. If the rodent is pregnant, a series of beads may be palpated on either side of the abdomen at 12-14 days after mating.
• GPS reading;
• Remarks: Add any comments as appropriate, e.g. dead in trap. If something disturbed the trapping, note this clearly. Always indicate how many traps were closed without a catch (e.g. after a heavy rain);
• Ectoparasites: indicate the number of fleas collected. If none, indicate none; and
• The rodent specimen data form must indicate the following:
  • Specimens (liver, kidney, spleen, heart/lung, stomach/intestines);
  • Blood samples; and
  • Fleas taken from trapped rodents should be recorded clearly.

14 Shipping specimens

• Requirements determined by national authorities and commercial carriers must be complied with;
• The address label on a package should display the sender as well as the laboratory name with complete addresses and telephone numbers of both the sender and the receiver.
• A package should also contain the appropriate biohazard labels as well as the storage temperature requirements;
• Copies of letters, forms, permits and other identifying/shipping documents for the receiving laboratory should be placed together in a plastic bag and taped onto the outer transport packaging;
• The receiving laboratory should receive a copy of these documents in advance;
• All specimens should be clearly labelled with waterproof labels;
• Rodent specimen data sheets should be included into the package;
• All tubes should be clearly labeled and accompanied by a data sheet;
• Specimens for antigen or antibody detection may be stored at 4-8°C for two days or at -20°C (frozen) for longer periods;
• Rodent carcasses or tissues can be shipped on wet ice, dry ice (frozen CO), freezer packs or in special shipping containers filled with liquid nitrogen. If these are not available, samples (such as livers or spleens) can be taken from carcasses and sent at ambient temperature in Cary-Blair transport medium;
• The appropriately stored specimens should be received by the laboratory within 10 days.
# ANNEXURE 22: IDENTIFICATION FORM FOR COMMENSAL RODENT INFESTATION

<table>
<thead>
<tr>
<th>Province:</th>
<th>Health District:</th>
<th>Form Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipality:</td>
<td>Date: DD / MM / YY</td>
<td>Time:</td>
</tr>
<tr>
<td>Weather:</td>
<td>Official name:</td>
<td>Telephone:</td>
</tr>
<tr>
<td>Locality:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sanitation

<table>
<thead>
<tr>
<th>General conditions</th>
<th>Spilled food</th>
<th>Damaged food containers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rodent proof containers</th>
<th>Plumbing leaks</th>
<th>Drain plugs/lids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>missing or not operable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rubbish/trash</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

### Harborage

<table>
<thead>
<tr>
<th>Harborage conditions</th>
<th>Accumulated debris</th>
<th>Trash stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>Moderate</td>
<td>Ample</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Holes in walls</th>
<th>Enlarged holes around pipes/doors</th>
<th>Tall grass/weed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food/water availability</th>
<th>Shrubs/trees/vines</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
</tr>
</tbody>
</table>

### Rodent signs

<table>
<thead>
<tr>
<th>Mice</th>
<th>Rats</th>
<th>Other</th>
<th>Droppings/Urine</th>
<th>Gnawing</th>
<th>Odors</th>
<th>Nests</th>
<th>Tracks/runways</th>
<th>Burrows</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>Live</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
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</table>

### Rodent access

<table>
<thead>
<tr>
<th>Gap (&gt;7mm) under doors</th>
<th>Enlarged holes in pipes/vents/doors/windows</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td></td>
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</table>

### Recommendation:

Source: Adapted from United States Army Environmental Hygiene Agency. (1992, p.54)
ANNEXURE 23:
DOGS FIELD DATA FORM

<table>
<thead>
<tr>
<th>Province:</th>
<th>Health District:</th>
<th>Municipality:</th>
<th>Form number:</th>
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<table>
<thead>
<tr>
<th>Locality:</th>
<th>Date: DD / MM / YY</th>
<th>Official name:</th>
<th>Telephone:</th>
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<table>
<thead>
<tr>
<th>Serum sample number</th>
<th>Owner’s name</th>
<th>Type of dog</th>
<th>Sex (M / F)</th>
<th>Age</th>
<th>GPS reference E</th>
<th>S</th>
<th>Titre (Lab results)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
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Source: Adapted from Maarschalk.¹ (2005)

ANNEXURE 24: SAFETY GUIDELINES FOR PLAGUE SURVEILLANCE AND CONTROL PERSONNEL

Based on own research findings, safety guidelines for plague surveillance and control personnel are presented below (Aplin, Brown, Jacob, et al., 2003, p.31; Gage, 1999b, pp.141-142; Mills, Childs, Ksiazek, et al., 1995, pp.7-9):

- Surveillance personnel should always wear rubber gloves when handling animals. Dispose of gloves after each working session.
- To avoid being bitten by rodents: Before handling, rodents should be anaesthetised, firmly restrained or humanely killed.
- Reducing the risk of flea bites: Apply insect repellents or insecticides to clothing (e.g. N,N-diethyl-m-toluamide [DEET]).
- Reducing the risk of infection via direct contact and aerosols: Wear respirators fitted with filters.
- Working areas and surfaces should be disinfected with household bleach for five minutes before and after use.
- Discard used needles directly into a sharps container (or plastic bottle with lid), without recapping them.
- Personnel collecting traps should wear gloves, but are not required to wear respirators.
- Cover open wounds, scratches or cracked skin on hands or wrists before handling rodents.
- Wash hands thoroughly as soon as possible after handling rodents or traps.
- All traps and processing equipment should be disinfected by bleach solution after use.
- Receive vaccination.
- Carry a supply of prophylactic antibiotics.
- During rodent handling and dissection, personnel should wear protective clothing and equipment including a proper respirator.
ANNEXURE 25:
RODENT NEST FLEAS FIELD DATA FORM

<table>
<thead>
<tr>
<th>Province:</th>
<th>Health District:</th>
<th>Municipality:</th>
<th>Form number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locality:</td>
<td>Date: DD / MM / YY</td>
<td>Official name:</td>
<td>Telephone:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GPS reference</th>
<th>Rodent species of nest</th>
<th>Number of fleas in rodent nest</th>
<th>Sample number of fleas for plague identification</th>
<th>Laboratory results</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from Maarschalk (see Page 235).
## ANNEXURE 26:
INFORMATION FOR PLAGUE OUTBREAK RESPONSE

<table>
<thead>
<tr>
<th>Suspected bubonic plague, or Suspected plague epizootic (evidenced by rodent die-off)</th>
<th>Who to contact</th>
<th>Specimens</th>
<th>Transport details</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lab investigation advice:</td>
<td>Depending on clinical presentation:</td>
<td>Aspirate: Stab deeply into Cary Blair transport medium</td>
<td>Animal and flea collections should ideally be done by trained and equipped environmental health practitioners</td>
</tr>
<tr>
<td></td>
<td>Special Bacterial Pathogens Units (SBPRU) in the National Institute for Communicable Diseases (NICD)</td>
<td>Bubo aspirate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clotted blood (5 or 10ml)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blood culture</td>
<td>Rodents: Pack in dry salt in closed containers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tracheal or lung aspirate</td>
<td>Fleas: In normal saline</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sputum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dead rodents, fleas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Contact Details

<table>
<thead>
<tr>
<th>Outbreak Hotline</th>
<th>082 883 9920 or (011) 386-6337/082-807-6770 or (011) 386-6379</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Institute for Communicable Diseases: Special Bacterial Pathogens Units (SBPRU)</td>
<td>(011) 489-9344/5/7</td>
</tr>
<tr>
<td>Special Pathogens Unit (SPU)</td>
<td>082-807-6770 / (011) 386-6337</td>
</tr>
<tr>
<td>National Department of Health Communicable Disease Directorate</td>
<td>(012) 312-0104 / 082-450-7308 or (012) 312-0375 / 082-469-5565</td>
</tr>
<tr>
<td>World Health Organisation Regional Office for Africa: Prevention and Control of Diseases</td>
<td>Tel: 1 407 733 92 36 Fax: 1 407 733 9009</td>
</tr>
<tr>
<td>Emerging and other Communicable Diseases Control (EMC)</td>
<td>Tel: 1 407 733 9338, 26311 40 38 23 Fax: 1 407 733 9009</td>
</tr>
<tr>
<td>World Health Organisation Headquarters Communicable Diseases Surveillance and Response (CSR)</td>
<td>Tel: (41 22) 791 2656 / 2850 / 2111 Fax: (41 22) 791 4878 / 0746</td>
</tr>
</tbody>
</table>

Source: Adapted from National Institute for Communicable Diseases. (2005b); World Health Organisation. (1999b, p.18).
ANNEXURE 27:
RODENT FIELD DATA FORM

<table>
<thead>
<tr>
<th>Province</th>
<th>Health District</th>
<th>Municipality</th>
<th>Form Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locality</td>
<td>Date: DD / MM / YY</td>
<td>Official name</td>
<td>Telephone</td>
</tr>
<tr>
<td>Species</td>
<td>Label number</td>
<td>Trap site code</td>
<td>Trap type</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Sexual Condition**

- **Male (M):** Testes Abdominal or Scrotal; Gybernaculum Non-visible or Visible
- **Female (F):** Vagina Closed or Perforated; Nipples Small or Lactating, Pregnant Yes or No

**Age***

- Juvenile, Adult, Old

Source: Modified from Leirs (2004, p.52).
ANNEXURE 28:
RODENT SPECIMEN DATA FORM

<table>
<thead>
<tr>
<th>Province:</th>
<th>Health District:</th>
<th>Municipality:</th>
<th>Form Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locality:</td>
<td>Date: DD / MM / YY</td>
<td>Official name:</td>
<td>Telephone:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blood (Fridge)</th>
<th>Serum (Frozen)</th>
<th>Lung/heart (Frozen)</th>
<th>Spleen (Alcohol)</th>
<th>Kidney (Alcohol)</th>
<th>Liver (Alcohol)</th>
<th>Fleas (Alcohol)</th>
<th>Stomach/intestines (Formalin)</th>
<th>Rodent Number</th>
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