Surveillance of Rodent and Fleas and Prevention of Plague in International Sea Ports in India in the context of International Health Regulations-2005

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Abstract

Rodents are among the most important competitors globally with humans for food and other resources. In the past century alone, more than ten million people died due to rodent borne diseases. Plague is a rodent borne zoonotic disease therefore, absence of human plague cases in a particular ecological zone would not justify the conclusion that plague has disappeared from the area. Plague continues to pose a threat to human health in certain regions of the world where natural foci still exist.

An assessment of the effectiveness of the International Health Regulations (1969) in control of cholera, plague, and yellow fever reveals that WHO member states have not observed the regulations strictly. In consideration of the growth in international travel and trade, and the emergence or re-emergence of international disease threats and other public health risks, the International Health Regulations (2005) were adopted by the Fifty eighth World Health Assembly on 23rd May 2005. It came into force on 15th June 2007. The purpose and scope of IHR (2005) are to prevent, protect against, control and provide a public Health Response to the international spread of the disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade.

The Ship Sanitation Control Exemption Certificate/ Ship Sanitation Control Certificate replaces the narrower in scope Deratting/ Deratting Exemption Certificate as from 15th June 2007. It has greatly expanded the areas for public health inspections on international ships. Contaminated international vessels may transport rodent borne diseases (31-Viral, Bacterial, protozoan, nematode and 11 documented Hunta viruses) across geographical boundaries. Rodents can gain access to ships directly by mooring ropes, hulls and gang ways. Rodents may be concealed in cargo, ship's stores and other materials taken on to the ship.

All the international sea ports in India including residential areas of the ports were jointly surveyed by NCDC, Plague Surveillance Unit, Bangalore and Port Health Organizations in collaboration with Rodent control unit of Port Trusts every year from 2008 to 2011. During the survey, heavy infestation of different species of rodents were detected in and around of sea port areas. *Rattus rattus* and *Bandicoota bengalensis,* which were found to be the predominant rodent sp. in all the port areas along with *Bandicoota indica, Mus musculus, Rattus norvegicus and Meriones hurrianae*. In some ports, absolute and specific flea indices of *Xenopsylla cheopis*, the efficient vector of human plague transmission were found above critical level (≥1.0). Mooring ropes in 73.6 percent of the ships inspected during the survey were without the rodent guards or rodent guards without proper locking system. All the Gang ways in the ships, which were supposed to be lifted during night time to prevent the entry of the rodents were

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kept touching the ground. Suggestions were made for appropriate rodent control measures to keep the sea port areas rodent free.

Keywords: **Rattus rattus, R. norvegicus, Meriones hurrianae, Bandicoota bengalensis, Bandicoota indica, Xenopsylla cheopis, Xenopsylla astia, International health regulation, Bubonic plague.**

Introduction

Rodents are among the most important competitors globally with humans for food and other resources, particularly through the pre-harvest damage they cause to cereals. Rodents destroy more than 42 million tons of food ($1/5^{th}$ to $1/3^{rd}$ of total food production) worth more than $30 billion worldwide. Rodents destroy approximately ten times more through urination and defecation than they actually eat. In the past century alone, more than ten million people died due to rodent borne diseases.

Rodents are involved in the transmission of variety of diseases found around the world. In indirect transmission of diseases, rodents may serve as intermediate hosts for parasites that ultimately infect man and may serve as reservoirs of disease agents which may be picked up by arthropod vectors and transmitted to humans through bites. In direct transmission, rodents may transmit the viruses by inhalation of aerosolized excreta, ingestion of excreta or by direct contact with the rodent itself and may directly transmit a pathogen to man through bite. Of the 128 species of rodents belonging to 46 genera in India, 8 are considered to be the zoonotic reservoirs of different diseases. They are *Rattus rattus-the house rat* (Linnaeus 1758**)**, *R. norvegicus*-the Norway rat**,** *Mus musculus*-the house mouse (Linnaeus 1758), *Tatera indica*-Indian gerbil (Hardwicke 1807), *Bandicota bengalensis*-the lesser bandicoot rat (Gray 1835), *Meriones hurrianae*-the desert gerbil (Jerdon 1867), the Southern palm squirrel-*Fanumbulus palmarum* (Linnaeus) and Marmots-*Marmota himalayana*. Plague is a rodent borne zoonotic disease transmitted by fleas therefore, absence of human plague cases in a particular ecozone would not justify the conclusion that plague has disappeared from the area. With the decline in human plague incidence in a place, the infection probably recedes to its original hosts, the wild rodents.[1]

Plague fulfils all the criteria and hence is a priority. It has impact on health (mortality and morbidity caused), capability of the agent to cause epidemic, potential for prevention and cure, international importance and economical impact. *Yersinia pestis* bacterium is widely available in microbiology banks around the world, making a biological attack a potential problem.

Sea Route Transmission of Plague by Rodents

There were three great pandemics of plague recorded, in 541, 1347, and 1894 CE, each time causing devastating mortality of people and susceptible animal population across countries and continents. These pandemics had different geographic origins and routes of spread. The Justinian Plague of 541 started in central Africa and spread to Egypt and the Mediterranean.

The first recorded outbreak of plague occurred in China in the 1330s, a time when China was engaged in substantial trade with western Asia and Europe. The plague reached Europe in October 1347. It was thought to have been brought into Europe through the port of Messina, Sicily, by a fleet of Genoese trading ships from Kaffa, a seaport on the Crimean peninsula. When the ship left port in Kaffa and reached Messina, the infected rodents that took passage with the ship slipped through mooring ropes unnoticed to shore and carried the disease with them and their fleas. In 1347, the 'Black Death' originated in Asia and spread to the Crimea and then Europe and Russia.[2]

The plague re-emerged from its wild rodent reservoir in the remote Chinese province of Yunnan in 1855. From there, the disease advanced along the tin and opium routes and reached the provincial capital of K'unming in 1866, the Gulf of Tonkin in 1867, and the Kwangtung province port of Pakhoi (now Pei-hai) in 1882. In 1894, it had reached Canton and then spread to Hong Kong. The third pandemic in 1894, originated in Yunnan, China, and spread to Hong Kong and India, and then to the rest of the world. Scientists had a general opinion about the role of rodents and fleas in transmission of plague, and the main means of dissemination-carried from port to port by merchant ships. It had spread to Mumbai by 1896 and by 1900 had reached ports on every continent, carried by infected rats travelling the international trade routes on the new steamships.

In India, the plague was initially spread in port cities, beginning with Mumbai, but later emerged in Pune, Kolkata, and Karachi (now in Pakistan). By 1899, the outbreak spread to many regions of India. The impact of plague epidemics during third pandemic was more in the provinces then designated

as Bombay, Punjab, and the United Provinces while eastern and southern India were not as badly affected. From 1896–1918, plague swept through India (including Pakistan and Bangladesh), taking the lives of over 12.5 million people. According to the World Health Organization, the pandemic was considered active until 1959, when worldwide casualties dropped to 200 per year. The third pandemic waxed and waned throughout the world for the next five decades and did not end until 1959, in that time, plague had caused over 15 million deaths, the majority of which were in India. The last human plague in India occurred in 1966 in Mulbagal, Kolar district, Karnataka.

Global Plague Situation

Plague continues to exist as a major public health problem in many countries of the world.[2] In several countries, plague has remained quiescent for years together before reappearing all of a sudden (Table 1). According to notification received by WHO during the period 1987 to 2009, plague affected 26 countries with 53,417 cases and 4060 (7.6 percent) deaths. During this period, the maximum number of plague cases (5419) occurred in 1997 and the minimum (876) occurred in 1989. Between 2004 and 2009, a total of 12,503 cases of human plague, including 843 (6.7 percent) deaths, were reported by 16 countries in Africa, Asia and Americas. In Asia, China, Cambodia, India, Indonesia, Iran, Kazakhistan, Mongolia, Myanmar, Nepal, Philippines, Lao People's Democratic Republic and Vietnam reported the cases and deaths from 1954 to 2009.[1,3]

An assessment of the effectiveness of the International Health Regulations in control of cholera, plague, and yellow fever reveals that WHO member states have not observed the regulations strictly. One reason could be the fear of excessive measures from other countries if a country notifies these diseases to WHO while others could be WHO's relative inexperience in enforcing legal regimes, the inability of regulations to adopt to changing circumstances in international traffic, trade and public health, their coverage of only three diseases and the lack of surveillance capacity in many WHO member states.[4]

Country	Year of Reappearance	Duration of Quiescence
Botswana	1989	45 years
Kenya	1990	10 years
India	1994	27 years
Indonesia	1997	27 years
Zambia	1997	33 years
Algeria	2003	50 years
Libya	2009	25 years

Table 1.World Notification of Plague 1989 to 2009-after long years of quiescence

Plague in India

The authenticated plague epidemic started in the year 1895-1896 and reached its peak in 1907. During the two decades from 1898-1918, there were over 25 million deaths in India including Bangladesh and Pakistan. The decennial death rate due to plague in India per one lakh population during these decades were 183.3 and 133.8 respectively. During 1949-1958, mortality rate due to plague was calculated to be 1.8 per one lakh population. Since then, mortality due to plague had declined and reached zero level during 1967.[1,5]

The principal plague affected states in India since 1939 were Bihar, Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka, Tamil Nadu, Uttar Pradesh and Punjab. Within this period, West Bengal and Assam were newly affected. No plague death was recorded in Punjab since 1951; in Bihar since 1952; in West Bengal and Maharashtra since 1953; in Madhya Pradesh since 1954; and in Andhra Pradesh and Assam since 1957. The last three states in which human plague deaths were recorded up to 1966 were Uttar Pradesh, Karnataka and Tamil Nadu. Kerala was not affected much with human plague cases like other states in peninsular India.

There was a resurgence of plague in bordering districts of Tamil Nadu, Andhra Pradesh and Karnataka during 1959 to 1966.[1,6,7] The active enzootic foci of plague were, however, confined to Hosur area (Krishnagiri district of Tamil Nadu), Attibele (Bangalore rural district), Kolar (Kolar district, Karnataka), Tangnu and Rohru area (Shimla district, Himachal Pradesh) and Palamneru (Chittoor district, Andhra Pradesh). Though human plague had not been reported from India since 1967, yet sporadic cases of suspected human plague had been reported from Tangnu, Himachal Pradesh during 1966 and 1983, and from Attibele, Karnataka during 1984, and at times localized sylvatic plague incidence encountered in the last decade from the trijunction of Karnataka, Andhra Pradesh and Tamil Nadu in peninsular India. From 1989 to 1994, active zoonotic foci of plague were detected from the

trijunction of Tamil Nadu (Krishnagiri district), Andhra Pradesh (Chittoor district) and Karnataka (Kolar and Bangalore rural district). High sero-positivity rate found in *Rattus rattus* which was considered to be the most susceptible rodent population in plague transmission suggested that this species acquired high tolerance to *Y.pestis* infection particularly from the peri-domestic habitats. Sero-positivity of sylval/ peri-domestic rodents, abundance of vector fleas and hilly terrain in these study zones which offer protection to rodent population from unnatural deaths from floods and human encroachment to their habitats supported perennial transmission of sylvatic plague in these regions. It was established from the study that *Y. pestis* infection was maintained amongst wild rodent population in enzootic foci by *Tatera indica*/ *Bandicota bengalensis* ➔ *X.astia* ➔ *Tatera indica*/ *Bandicota bengalensis* chain from season to season over the number of years.[1]

During 1994, a human bubonic plague outbreak at Mamla village, Beed district, Maharashtra and pneumonic plague outbreak in Surat, Gujarat were recorded. After 8 long years of quiescence, a localized outbreak of pneumonic plague occurred in Hatkoti, Shimla district, Himachal Pradesh in 2002. In 2004, a bubonic plague outbreak occurred in Dangud village, Uttarkashi district, Uttarakhand.[1]

International Health Regulations (IHR) 1969 and 2005

Prior to 15th June 2007, the Deratting/ Deratting Exemption Certificate was the required sanitary document for international shipping under the International Health Regulations (1969) to help monitor and control four serious communicable diseases that had significant potential to spread between countries. The IHR was adopted by the Health Assembly in 1969, having been preceded by the International Sanitary Regulations adopted by the Fourth World Health Assembly in 1951. The 1969 Regulations, which initially covered six "Quarantinable diseases" were amended in 1973 and 1981, primarily to reduce the number of covered diseases from 6 to 3 (Yellow fever, Plague and cholera) after the global eradication of Small pox.[4]

In consideration of the growth in international travel and trade, and the emergence or re-emergence of international diseases' threats and other public health risks, the International Health Regulations (2005) were adopted by the Fifty eighth World Health Assembly on 23rd May 2005. It came into force on 15th June 2007.

The purpose and scope of these regulations are to prevent, protect against, control and provide a public Health Response to the international spread of the disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade.

New or Revised Health Documents

The Ship Sanitation Control Exemption Certificate/ Ship Sanitation Control Certificate replaced the narrower in scope Deratting/ Deratting Exemption Certificate from 15th June 2007. It greatly expanded the areas for public health inspections on international ships. Port health officers inspecting ships for certificates were noting all on board sanitation problems that could lead to international disease spread, and identified the measures required to eliminate or reduce the risk. In keeping with the spirit of new IHR, all international sea ports stepped up their surveillance mechanism.

Risk Factors in International Sea Ports

A seaport is an open environment and has higher levels and variety of international cargo and vessel activities. Ports receive and manage goods and people from all over the world. Therefore, ports are exposed to the risk of introduction of vectors from any part of their host country or any port in the world. The activities undertaken at ports, such as handling foodstuffs, attract many species of vermin. Contaminated international vessels may transport rodent borne diseases (31-viral, bacterial, protozoan, nematode and 11 documented Hunta viruses) across geographical boundaries. Rodents can gain access to ships directly by mooring ropes, hulls and gang ways. Rodents may be concealed in cargo, ship's stores and other materials taken on to the ship.

Sea Port Survey in the context of IHR-2005

All vessels on international voyage must have a Ship Sanitation Certificate as per Annex 3 under Article 39 of IHR-2005. The ship, if during inspection, is found to have any sanitary deficiencies or vectors then a Ship Sanitation Control Certificate with Evidence Report Form (SSCC+ERF) (earlier Deratting certicate) detailing the deficiencies noted during inspection and the action taken like the disinfection or disinsection or decontamination or deratting measures undertaken, and in the event of vectors like rodents, the action taken and the follow up action needed by the ship are mentioned in the SSCC+ERF and the follow up for the next port of

calls to be monitored continuously until the ship is free from vectors within previous six months, or it is issued a Ship Sanitation Exemption Certificate if during inspection it is free from sanitary deficiencies including rodents during the inspection in a designated approved IHR-2005 authorized port, under Article 20 of IHR-2005.

Port Health Organization, Govt. of India

It is an organization of the Ministry of Health, Government of India, performing a host of statutory duties of national as well as international importance. The primary objective of Port/ Airport Health Officer is to prevent entry of pathogens responsible for communicable diseases spread like Plague, Yellow fever, SARS, Avian Influenza, H1N1 and any Public Health Emergency of International Concern (PHEIC). During the last few decades, there has been emergence and re-emergence of a number of communicable diseases with potential for rapid international spread, which has necessitated the need to expand and strengthen the disease surveillance facilities at major international air ports and sea ports in the country catering to the huge international traffic and trade that has increased tremendously in recent years.

Number of National and International ships handled/ Inspected by Port Health Organizations								
Year	**Mumbai**	**Kandla**	**Cochin**	**Marmugao**	**Tuticorin**	**Chennai**	**Visakhapatnam**	**Kolkata**
2005	1874	1725	1241	604		1219	855	2211
2006	1921	1605	1270	644		1144	896	2007
2007	1920	1353	1211	731	214 (from Nov.)	1336	1127	2253
2008	1925	1439	847	754	1494	1304	990	2405
2009	2410	1939	766	889	1351	1521	1233	2542
2010	2622	1730	818	828	1287	1587	1379	2697
2011	2677	3309	869	726	1043	1567	1723	2643
Sanitary Exemption Certificate issued by Port Health Organization								
2005	482	243	277	98	Nil	151	226	134
2006	461	309	680	87	Nil	167	272	157
2007	487	364	107	117	57	340	281	182
2008	615	437	303	142	122	302	390	173
2009	535	393	250	138	142	177	398	238
2010	589	410	134	112	127	165	391	224
2011	737	416	137	116	141	129	418	195
Number of Vessels fumigated/ decontaminated/ deratted								
2005	91	-	19	-	-	Nil	Nil	Nil
2006	82	-	21	1	-	Nil	Nil	Nil
2007	41	2	16	-	Nil	Nil	Nil	Nil
2008	73	17	22	2	5	Nil	Nil	Nil
2009	20	-	28	-	10	Nil	Nil	Nil
2010	86	13	Nil	Nil	17	Nil	Nil	Nil
2011	60	09	Nil	Nil	13	Nil	Nil	Nil

Table 2.Number of National and International ships handled/ inspected and issued Sanitary Exemption certificates by Port Health Organizations in India

International Sea Ports in India

Mechanism of Rodent and Vector Surveillance in Sea Ports

Surveillance in the sea ports is conducted by the Port Health Organization, a statutory body implementing the IHR-2005 and Indian Port Health Rules. All activities are done in co-ordination with Port trust officials, Ship Crew and shipping agents. Surveillance activities are carried out on board including cargo vessels, passenger vessels, coastal vessels, and smaller vessels operating in port waters and fishing vessels. Surveillance activities are also carried out in and around port areas (adjacent municipal areas), port installations and residential colonies in the port area.

Inspection of Ships arriving from plague endemic countries

A medical officer of health inspects, on arrival, any ship which has come from or called at a foreign port in plague endemic countries or plague has occurred or been suspected during the voyage. If, on screening, the ship is free of rodent activity, the ship

is allowed to continue port operations and rodent control measures are advised to be taken continuously during port operations. In the event of evidence of any rodents, the degree of infestation is noted for taking pest control actions allowing port operations with all due precautions for preventing rodent entry. Evidence of suspected plague among rodents or among any crew action is undertaken for further surveillance and sanitary measures and also for ensuring prevention of any suspected rodents entering the port areas. The ship is then issued a SSCC+ERF and after due precautions, the cargo operations will be allowed under the instructions of the Port Health Officer (Table 2).

Survey of Port Areas for Sanitary Conditions and Rodent Harborage

All the international sea ports in India including residential areas of the ports were jointly surveyed by NCDC, Plague Surveillance Unit, Bangalore, and Port Health Organization in collaboration with Rodent control unit of Port Trusts every year from 2008 to 2011. Almost all the establishments i.e. canteens, food godowns, railway yards, open areas, abandoned buildings and residential buildings (abandoned and in use) were inspected for rodent harborage and sanitary conditions prevailing in the areas.

International Sea Ports in India	**Period of Visit**	**No. of rodents collected**						**Total Rodents Coll.(Trap Positivity Rate**	**No. of fleas collected (AFI)**	**Specific flea index**	
		Rr	*Bb*	*Bi*	*Rn*	*Mm*	*Mh*			***Xc***	***Xa***
Chennai (Tamil Nadu)	2008-2011	85	102	7	-	-	-	194(45.8)	87(0.45.)	0.41	0.04
Marmugao (Goa)	2008-2011	15	14	4	2	1	-	35(18.8)	nil	-	-
Cochin (Kerala)	2008-2011	67	27	10	3	1	-	108(27.06)	6(0.06)	(0.06)	0.0
Tuticorin (Tamil Nadu)	2008-2011	27	29	3	-	4	-	63(17.6)	nil	-	-
Visakhapatnam (Andhra Pradesh)	2008-2011	87	64	7	-	2	-	160(24.7)	62(0.39)	0.32	0.07
Kandla (Gujarat)	2008-2011	452	84	18	4	6	16	596(42.3)	684(1.15)	1.11	0.04
Kolkata (West Bengal)	2008-2011	56	138	43	-	1	-	238(41.18)	257(1.08)	1.06	0.02
Mumbai (Maharashtra)	2010	01		19		1		21(44.0)	39(1.86)	1.86	0.0

Rr-Rattus rattus, Bb-Bandicoota bengalensis, Bi-Bandicoota indica, Rn-Rattus norvegicus, Mh-Murines hurriane, Mm-Mus musculus, Xc-Xenopsylla cheopis, Xa-Xenopsylla astia, AFI-Absolute Flea Index

Table 3.Results of Plague Surveillance work at International Sea Ports

Result and Discussion

During the survey of all the port areas in India from 2008 to 2011, heavy infestation of different species of rodents was detected in and around sea port areas, mostly in food grain godowns and canteens. Port wise data on rodent species trapped/ processed, rodent fleas collected/ retrieved from different rodents are furnished in Table 3. *Rattus rattus* and *Bandicoota bengalensis*-susceptible and resistant rodent population to Y. pestis infection, were found to be the predominant rodent species in all the port areas along with *Bandicota indica*, *Mus musculus*, *Rattus norvegicus* and *Meriones hurrianae*. Port wise absolute and specific flea indices of *Xenopsylla cheopis*, the efficient vector of human plague transmission is furnished in Table 3. *X. cheopis* index was found above critical level (≥1.0) in Mumbai, Kandla and Kolkata port areas. Of the 121 ships inspected, mooring ropes of 73.6 percent of the ships were without the rodent guards or rodent guards without proper locking system (Figures 3, 5, and 6). All the gangways in the ships, which were supposed to be lifted during night time to prevent the entry of the rodents were kept touching the ground (Fig. 4). Rodents and fleas are frequently associated with poor sanitary conditions prevailing in the area.

Suggestions/ Recommendations

Rats, gerbils and mice can gain access to ships,- gaining access directly by mooring ropes, hulls and gangways. They may be concealed in cargo, ship's

stores and other materials taken onto the ship. However, prevention of rat harborage through appropriate construction and rat-proofing will ensure almost complete control of rodents aboard the ships. Rats are excellent climbers, jumpers and swimmers. Rat guards were used on tie-up lines where appropriate. Since rodents are nocturnal in habit, lighting up gangways and ramps at night were the routine practice to prevent the entry to ships. Sealing of entry points to the vessel's interior, such as cable chases should be checked, and screens or louvers should be put over windows and vents. Rats particularly like to nest and shelter in trawl, seine nets and coils of ground line. Rodents can hide in containers and in pallets. Multi catch traps should be laid where rodent signs are found (rodent droppings, gnawing mark and pathway), in dark and concealed spaces and near food or garbage. Instructions should be given not to throw a live rat overboard. Rodents are good swimmers and may reach land.

Since the rodent density was found to be very high in some port areas, permanent bait station should be constructed near all the garbage handling areas, canteens, warehouses for food grains and residential areas/ hospitals and office premises. At least 300 permanent bait stations (pre-fabricated concrete bait stations with a concrete roof. Size: rectangular, two walls: Length-60 cms, width-45 cms-blocks; Side walls: Length-45 cms, width-45 cms; Roof top and bottom/ floor: Length-60 cms, width-45 cms; Holes-will be such that hand can be placed inside) in each port should be constructed initially studying the rodent density in the area. Permanent bait stations should be spaced 30-40 feet apart in low density areas and 50-100 feet apart in high density areas (Fig. 1). Bait stations may be constructed in different part of port areas including ware houses, canteens and godowns. Pallets or powder of second generation anticoagulants (Bromadiolone 0.005% a.i. in cereal baits) may be used continuously in the permanent bait stations to kill the rodents simultaneously in all the port areas. Bromadialone baits (ready to use cake or concentrate) can be used, and because of their potential for lethal outcome in a single feeding, they can be more effective than other anti-coagulants in certain situations. Old baits should be discarded periodically and replaced it with fresh baits. Hanging plastic dust bins (as shown in Fig. 2) should be installed in and around port areas to avoid rodent migration from other areas. All the concrete dust bins, which are in use in port areas, should be demolished to control rodent population and rodent borne disease transmission.

Figure 1.Permanent Bait stations

Figure 2.Hanging dust bins in port areas

Figure 3.Rodent guard in mooring rope

Figure 4.Gangway on the ground

Penalty should be imposed for national and international vessels for not having rat guards in all the mooring ropes. Rodent burrows should be sealed with concrete and mortars in and around all food godowns and canteens.

The elimination of rodent population residing inside burrows with non-migratory young ones is essential in obtaining long lasting effects. Fumigation of rodent burrows may be undertaken with fumigants available in the market keeping in view physical properties like diffusion, penetrability, absorption, stability and finally the effectiveness of the fumigants.[8] Fumigation of rodent burrows with aluminum phosphide pallets in and around some ware houses and godowns may be undertaken in rodent infested areas. Aluminum phosphide, a respiratory poison is a preferred chemical for rodent control. It generates phosphine gas, CO_2 and ammonia at atmospheric situations and kills rodents inside their burrows. It is coated with wax to prevent immediate release of phosphine on application. Maximum 3 pellets (1.8gm) can be introduced at a time to achieve 60 percent rodent control success. Fumigation should be carried out in all the port areas simultaneously to avoid 'R' factor of reproduction in rodent population in untreated areas.

Figure 5.Rodent guard not in position

Figure 6.Rodent guard without locking system

Rodent proofing in warehouses and storehouses may be done by proofing-eliminating all openings larger than 1/2 inch for rats and 1/4 for mice including repairing doors and windows that do not operate properly or shut securely. Air vents that may not be in sound working order should be repaired. In some situations, the use of toxic baits is not safe, legal or desired because of possible odors.

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