

# Preliminary Qualitative Risk Assessment for *Peste des petits ruminants* (PPR) in Sheep Exported from Sudan During 2012

**Keywords:** PPR; Sudan; Exported sheep; Qualitative risk assessment

## Abstract

The overall risk of PPR spreading in sheep exports was estimated to be Low. The PPR released risk in sheep value chain, which represent the probabilities of PPRV existence in sheep herds prior to send to livestock markets, within markets, in addition to the virus probabilities to spread in the internal quarantine, was found to be Medium (which means that the risky event is likely to occur more than once in the next three years). The exposure risk which represent the probability of PPRV to spread among the sheep herds selected for exportation and it is depending on the contact with an infected sheep or fomites within the transporting trucks to the terminal quarantine or/and in the terminal quarantine or/and in the fomites of the transporting ship to the importing country. In this study the exposure risk was assessed to be very low (that means the risk of PPRV spread is rare, the risky event may occur in exceptional circumstances).

## Introduction

Sudan is an exporting country for livestock and livestock products. Livestock exports represent the second generating source of foreign exchange currency after oil. The majority of sustained Sudanese exports of live sheep and sheep meat are to The Kingdom of Saudi Arabia, and it faces high competition in terms of price, reliability of regular supply and terms of promotion and trade [1].

Since 1995 Sudan is an observer and still on procedure to gain World Trade Organization (WTO) membership. Being a WTO member may assist Sudanese livestock exporting sector to find new markets internationally, hence the meat of Sudanese livestock is of high quality and its production is depending on natural rangelands. National Sanitary and Phytosanitary Measures (SPS) measures also need to be revised, updated and based on scientific risk analysis to ensure high quality for exports and to protect national human, animal and plant health and life against the imported commodities. This preparedness comprises beside the financial resources, it comprises a technical and scientific support by national expertise for livestock production, animal health, risk analysis and trade facilities [2].

Movement of livestock and their products in different value chains is an important means of disease spread. Risk analysis when combined to value chain analysis will help in understanding these movements which must be taken into account in setting management strategies [3].

This paper is aiming to develop a preliminary qualitative risk assessment model for the exposure, spread and establishment of PPR virus among sheep herds that destined for exportation. The objectives



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of carrying out the risk assessment are the following:

- Analyzing risk factors and determining the risk hotspots in sheep production value chains, which may lead to the exposure and spread of PPR Virus among the exported herds,

- Suggesting evidence-based risk management measures that may ensure the health status of Sudanese exports of live sheep, and could be used as national SPS measures in contribution to the current PPR control efforts.

## Materials and Methods

### Risk assessment for PPR spread in sheep exports from Sudan

The methodology used in this study followed the Import risk analysis as it described in OIE terrestrial animal health code 2014, with some modifications and adjustment to be used for PPR as an endemic disease.

**i. Hazard identification:** In this study the hazard is the PPR virus.

**ii. Risk question:** Study risk question: What is the risk of exporting live sheep which is infected with PPRV to the Kingdom of Saudi Arabia during the year 2012?

**iii. Risk pathway**

**Release assessment pathway:** The release assessment estimated the probability or likelihood of introducing the PPRV to the selected sheep herds within the local markets and collectives quarantines and vaccination centers as shown in Figure 1.

**Exposure assessment pathway:** The exposure assessment estimated the probability or likelihood of the exposure of sheep herds (destined for exportation), to the PPRV during transportation to the terminal quarantine, within terminal quarantine and during shipping to importing country as shown in Figure 2.

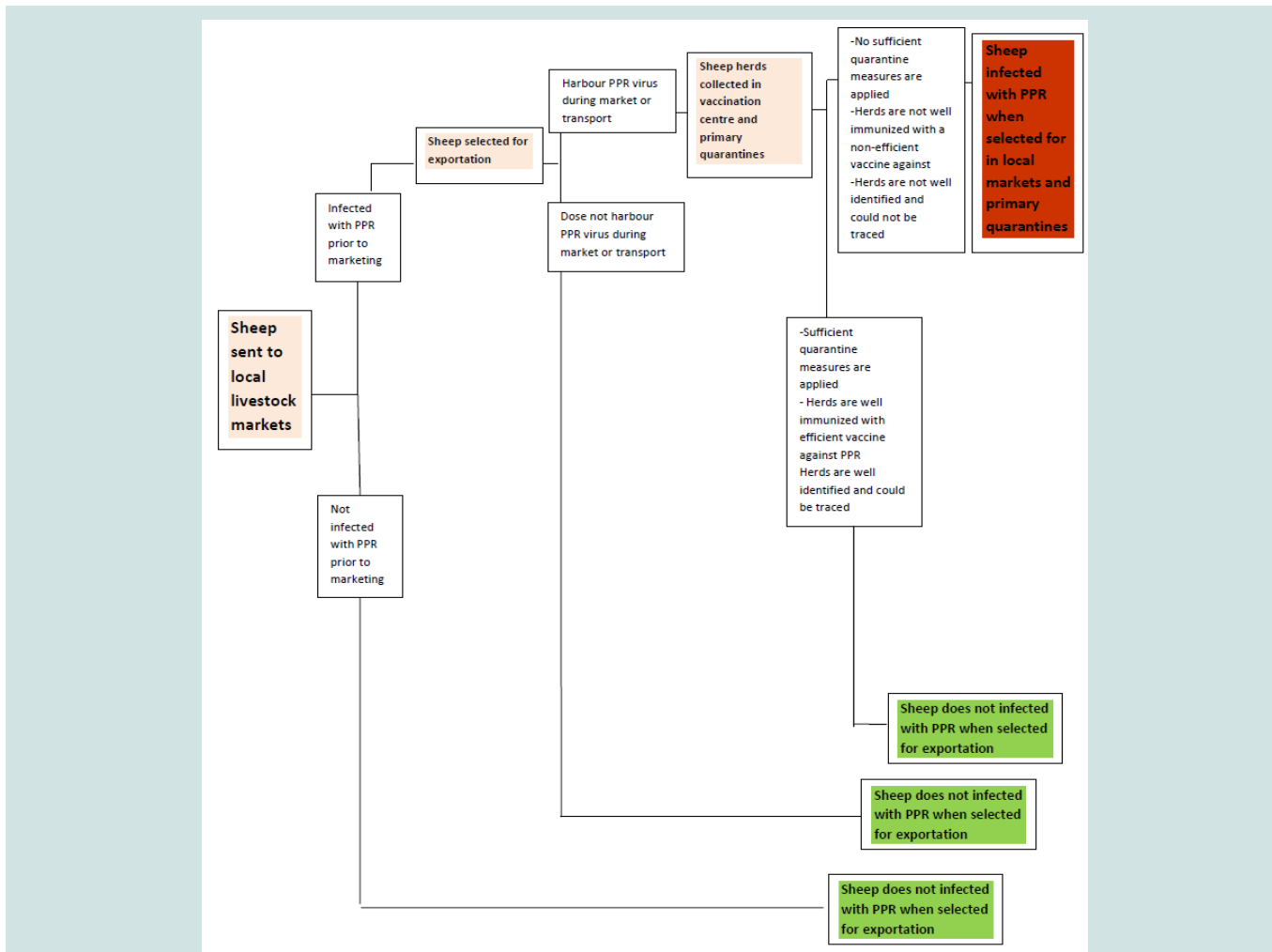


Figure 1: Scenario tree for a release risk assessment.

**Qualitative estimation for the probability (likelihood)**

The risk scoring of the Department of environment, food and rural affairs agency (Defra) in the United Kingdom was used in this study for estimating the likelihood as in Table 1.

**Influential Diagram:** Probability of exporting at least on live sheep infected with PPRV is explained by an influential diagram as shown in Figure 3.

**Consequences assessment:** It describes the potential consequences of an infection of PPR in exported sheep herds and estimates the probability of their occurring

**Overall risk estimation:** A qualitative risk assessment scheme used by Defra in UK was used to estimate the overall risk as shown in Figure 4.

**Results**

**Value chain primary analysis of the live Sheep exportation in Sudan**

Sheep selected for exportation collected from local livestock markets, inspected and vaccinated in vaccination and inspection centers and quarantined in the collective quarantine of Elkadaro then

transmitted to Swakin terminal quarantine as shown in Figure 5.

**Risk assessment for PPR spreading in Sudanese sheep selected for exportation**

**PPR virus release assessment in sheep selected for exportation in local livestock markets and primary quarantines and vaccination centers:** Release risk of PPRV was assessed using the tabular frame for the release risk pathway as shown in Table 2, and the Probability of releasing PPRV in sheep selected for exportation in local livestock markets and primary quarantines and vaccination centers, is found to be:

**Table 1:** Explain the meaning of the different levels of the likelihood provided by Defra- UK.

Likelihood	Description
VL (Very low)	Rare (the risky event may occur in exceptional circumstances)
L (Low)	Possible (the risky event may occur in the next three years)
M (Medium)	Likely (the risky event is likely to occur more than once in the next three years)
H (High)	Almost certain (the risky event is likely to occur this year or in frequent intervals)

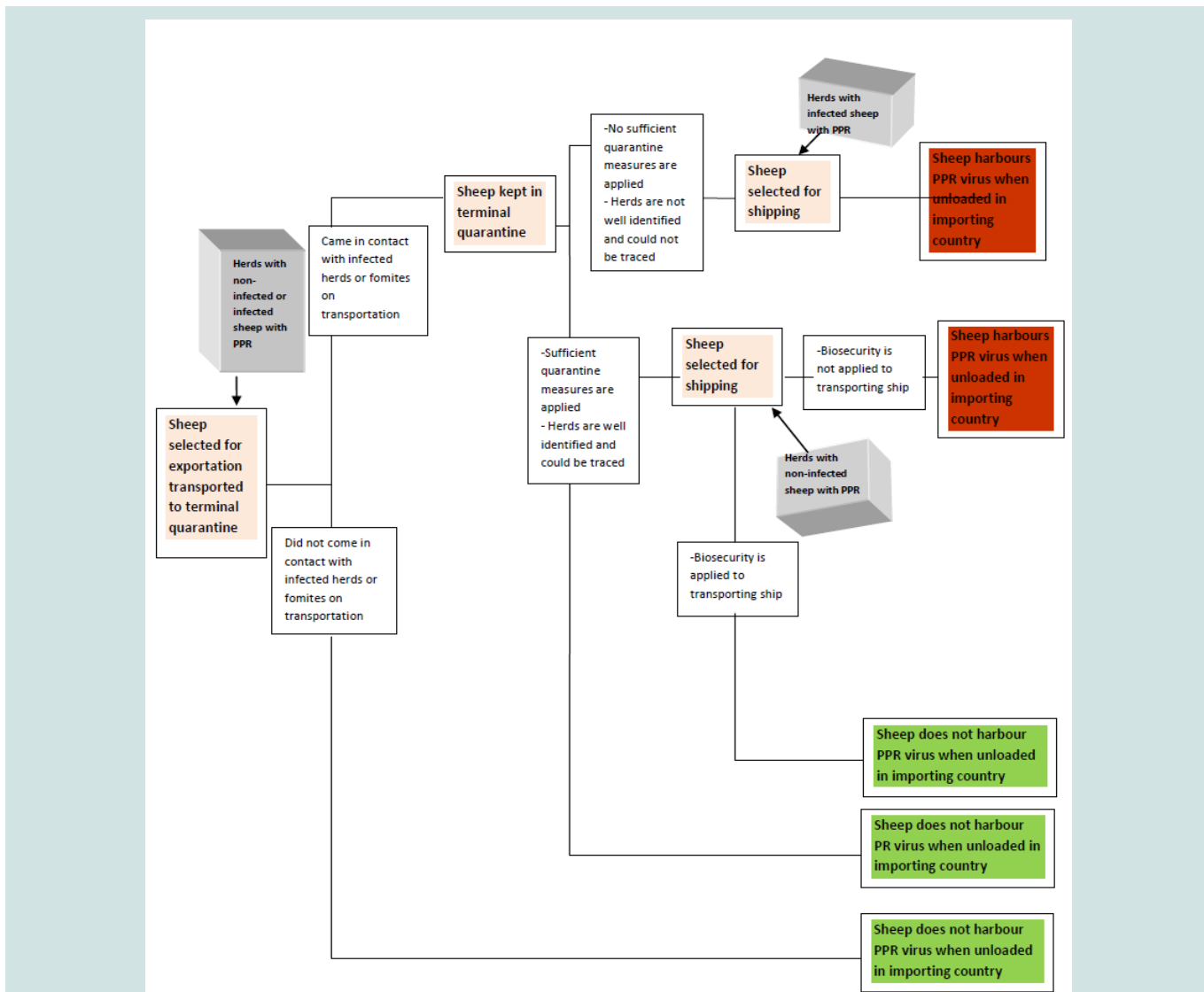


Figure 2: Scenario tree for an exposure risk assessment.

High × High × Low = Medium

**PPR virus exposure assessment in sheep selected for exportation in terminal quarantine and transportation vehicles:** Exposure risk to PPRV was assessed using the tabular frame for the exposure risk pathway as shown in Table 3, and the Probability of exposing to PPRV in sheep selected for exportation during transportation to the terminal quarantine, within it and during transportation from Swakin port to importing country, is found to be:

$$V \text{ Low} \times V \text{ Low} \times V \text{ Low} = V \text{ Low}$$

**Risk estimation for PPR disease spreading in exported herds:** Probability of exporting live sheep infected with PPRV is found to be; release risk × exposure risk = Medium × V Low = Low, as explained by an influential diagram as shown in Figure 6.

**Magnitude of the consequences:** During the year 2012 about (3,399,421) head of live sheep were exported to the Kingdom of Saudi Arabia via Swakin port.

- This number of exports was earning about (318,276,437.45) USD.
- There was no rejection of sheep from the veterinary authority in KSA during the year 2012, although a percentage from annual sheep exports used to be rejected due to sanitary reasons in the past. During the year 1999 (74,868) sheep heads (4.6% of the annual sheep exports) were rejected with suspicion of T.B, vesicular stomatitis and mange, also in 2003 (29,114) head of sheep (2.2% of the annual sheep exports) were rejected with suspicion of vesicular stomatitis and *Brucella* [2].
- In case of disease detection of PPR or any disease, the exported sheep will be rejected from the importing country, which mean loss of hard currency and extra costs and burden on the exporting companies, quarantine staff and affect a lot of people who are working in sheep export value chain.

**Table 2:** Tabular framework of the release assessment for PPRV among sheep exports value chain and the probability of establishing PPR infection prior sending to the terminal quarantine during 2012.

Risk Location		Risk Factors		Partial qualitative risk (Likelihood) estimation	
In the risk pathway	Geographically	Increasing the risk	Decreasing the risk	Criteria for risk scoring	Risk scoring
Probability of sheep were infected prior sending to local livestock market	States of: - Gedarif - North Kordofan state - Kassala state - Khartoum state	1-PPR prevalence: Gedarif state 80.6% for Kassala and Gedarif (Saeed et al. 2010), 46.2% in unvaccinated sheep and goats (Salih et al. 2014). North Kordofan state: 61.2% (Saeed et al. 2010), 74.5% (Shuaib, 2011), 39.8 % in unvaccinated sheep and goats (Salih et al. 2014). Kassal state: 80.6% for (Saeed et al. 2010), 66.2% (Shuaib, 2011). Khartoum state: 55.9% (Osman et al. 2009), 59.7% (Saeed et al. 2010).	Vaccination coverage against PPR comparing to sheep and goats population/state in 2011 and 2012 was: Gedarif state 39.9%. North Kordofan state 8.7%.  Kassal state 99.9%.  Khartoum state 11.4%.	- PPR disease is prevalent in all states from which sheep are selected for export. Despite the efforts devoted for vaccination, the vaccination coverage comparing to the numbers of sheep populations in the states, it is considered weak coverage except in Kassala state.	High
		2-Practised husbandry systems in Gedarif, Kassala and North Kordofan states are trans-human pastoralists and open grazing, which have been proven to have the highest PPR seroprevalence rates in Sudan (Salih et al. 2014)			
		3-Kassal state had reported the highest number of PPR outbreaks in Sudan during the period of 2008 to 2012 (AHEDC, 2008-12).			
		4-Gedarif and Kassala states are located in the eastern borders with foreign country which increase PPR outbreaks; OR=2.942/p-value = .019 (Salih et al. 2015).			
		5-Gedarif and Kassala states are located in the low rainfall woodland savanna, which associated significantly with high outbreaks numbers of PPR (Salih et al. 2015).			
Probability of sheep harbour PPRV Within local markets and during transportation to the primary quarantine	Primary and secondary markets: Elkhiwai (N.Kordofan) Elsemaih (N.Kordofan) Elshwak (Gedarif) Kassala (Kassala) Terminal markets: Ellobied (N.Kordofan) Elmuailleh (Khartoum)	-Majority of primary and secondary markets are without separate pens for herds, no market records and no veterinary health certificates are issued except in Elkhiwai and Elshwak due to the establishment of the vaccinations centers (Edirne et al., 2009).	Terminal markets are well established with fences and pens, veterinary inspection, market records and veterinary health certificates are issued (Edirne et al., 2009).	- Preventive measures are not in place in primary markets- Sheep trade is controlled by a series of brokers and the sheep source, health and vaccination history could not be identified.	High
		-There is no method for animal identification for sheep herds selected for exports like ear tag or electronic microchip(Noticed from personal direct visits)			
		Majority of sheep herds selected from primary and secondary markets are transported on foot to the nearest vaccination centre in the production sites, and during transport it may come across local sheep herds which may be infected (UNEP, 2013). That can accelerate PPR transmission between selected herds and local grazing herds; -highest numbers of sheep are exported in the months from October to December, after the rainy season and at the beginning of winter; which are the season for high numbers of PPR outbreaks (Salih et al., 2014) and (Sarker and Islam, 2011).			

Probability of PPR virus spread in primary quarantine/ vaccination and inspection centers	- The method for animal identification for sheep herds that and tested vaccinated in inspection and vaccination centers is ear tag which could be lost or even cheated, and beside no tracing could be done for source of sheep in case of disease occurrence due infection and improper vaccination (Noticed from personal direct visits)	- All sheep are inspected visually, tested for <i>Brucella</i> and vaccinated against PPR by the team of the Inspection and vaccination centers before reach the collective quarantine of Elkadaro and the Swakin terminal quarantine.	- Sheep are inspected during the quarantine period before sheep transported to terminal quarantine.	Low
	Some brokers during 2011 and 2012 had brought large numbers of hamari sheep from Elkhiwai livestock market to be inspected and vaccinated in Gedarif (UNEP, 2013) this mobility may play a role in diseases spread.	- Sheep is quarantined for 7 to 10 days in separated pens and inspected visually during this period then transported to Swakin terminal quarantine		
	- Vaccination against PPR in vaccination and inspection center is practiced using cold chain attenuated vaccine. The maintenance of cold chain for vaccine efficacy has proven difficult in subtropical countries (Sen et al., 2010), taking into consideration the large numbers of sheep to be vaccinated specially during the season of large numbers of exports.			

### Suggesting risk management strategy

The management should consider the potential epidemiological impact on the disease risk and the economical impact on the livestock value chain. The most important issue is the likelihood and compliance of the stakeholders with the recommended intervention.

PPR risk reduction strategy is a part of the main policy for PPR control in the country and it should consider the following:

**Disease surveillance:** PPR surveillance should include an early warning system (which could be used for other diseases), to track the risk factors in particular the climatic factors since the PPR is more spreading after the rainy season and during the dry cold winters. And also surveillance should monitor the efficacy of vaccination.

Surveillance should be risk- based and involve all people, groups and organization in the livestock sector. Therefore it is very important to strengthening surveillance in the parts where risk cannot be reduced by control measures.

**Vaccination against PPR:** PPR vaccination should be planned, well arranged and implemented by all state before the rainy season according to the livestock movement in nomadic and open grazing systems.

A thermo stable PPR vaccine is recommending to be used in the country to ensure vaccine efficacy in controlling PPR due to the tropical climate of the country which may affect the cold chain vaccine.

**Biosecurity measures applied in livestock value chains:** Integration of production from input supply or production till marketing through linked and traceable channels; compartmentalization.

- Health checking in all livestock markets; inspection.
- Strengthening traceability by using reliable identification method for sheep in vaccination campaigns and local markets which will be of great value for inspection in quarantine and export value chain.

- Animal movement control by setting and activating regulation of animals and animal products movement with certification and enforcement of checks on the routes by veterinary check point; to discover diseases earlier and break the transmission cycle.
- The role of other ruminant (wild life and other domestic) in the maintenance of PPRV.

**Coordination of control efforts:** All stakeholders in livestock value chain should participate and be aware of the PPR control measures. And an extra and continuous coordination should be established between the head quarter epidemiology unit, vaccine production, quarantine and state epidemiology unit.

### Discussion

The overall estimated risk for PPR spread in sheep exports value chain was found to be Low. Which means it is possible and may occur in the next years according to Defra risk scoring. Possibility of PPR spreading in export value chain requires a stricter animal health and quarantine measures applied in all steps of value chain to minimize the risk.

The PPR release in sheep value chain was found to be Medium, which means that the risky event is likely to occur more than once in the next three years.

In release assessment, the probability of selected sheep that infected with PPR was found to be high because PPR is considered as an endemic disease in Sudan with estimated prevalence at 54% by Haroun et al. 50.6% by Osman et al. 61.8% by Abdalla et al. 62.8% by Saeed et al. 70.2% by Shuaib and 45.6% by Salih et al. [4-9].

The second event affect the release of PPRV is its probability in spread within local livestock markets and in the routes to the primary quarantine or vaccination and inspection centers was also found to be high. Majority of primary and secondary livestock markets are lacking for separated pens [1] and there is no regular application for bio-security measures which considered a risky hotspots that increase

**Table 3:** Tabular framework of exposure assessment for PPRV and the probability of establishing PPR infection during transportation to and within the terminal quarantine and final shipping to the importing country during 2012.

Risk Location		Risk Factors		Partial qualitative risk (Likelihood) estimation	
In the risk pathway	Geographically	Increasing the risk	Decreasing the risk	Criteria for risk scoring	Risk scoring
Probability of selected sheep come in contact with infected herds with PPR or Fomites during transportation to Terminal quarantine	- Road from Elkhawai and Elarahad in North Kordofan through White Nile state, Khartoum state and River Nile state to Swakin terminal quarantine in the Red Sea state. 2- Road from Elkadaro collective quarantine in Khartoum state through River Nile state to Swakin terminal quarantine in the Red Sea state. 3-Road from Elshwak in Gedarif state through Kassala state to Swakin terminal quarantine in the Red Sea state. 4-Road from Kassala center to Swakin terminal quarantine in the Red Sea state.	- Sheep are transported through states with high numbers of PP outbreaks and with high PPR seroprevalence rates (Saeed et al., 2010) and (Salih et al., 2014)	- Sheep selected for exportation are vaccinated against PPR.	- PPR can be transmitted by aerosol but the virus is fragile and the sheep selected for exportation are vaccinated against PPR, quarantined and inspected by quarantines vet officers.	V. Low
		- PPR is transmitted by aerosol and high wind speed during winter season may play an important role in PPR transmission between infected herds and sheep selected for exportation (Salih et al., 2014) and (Sarker and Islam, 2011), especially in the case of in proper vaccination.	- Sheep transported in big trucks examined by quarantines vet officers who issuing the Pass permit with date and sheep numbers, according to the suitable number of sheep in every truck with the attached vaccination certificate and Brucella test results.		
		- There are no strict Biosecurity measures are applied to the cleaning and disinfecting of transporting trucks (Noticed from personal direct visits).	- PPRV is a fragile virus which cannot survive for long time outside the host, its half life has been estimated to be 2.2 minutes at 56 C and 3.3 hours at 37 C (Chauhan et al., 2009).		
Probability that sheep with PPR infection couldn't be detected, diagnosed and rejected from Swakin terminal quarantine	Swakin terminal quarantine in the Red Sea state	- Sheep develop PPR in terminal quarantine after getting in contact with infected herds during transportation due to proper vaccination or incomplete quarantine period after vaccination in the collective quarantine or in case of Sheep come directly from the inspection and vaccination centers to Swakin, especially during the season of large number of exports during Pilgrim.	Quarantine procedures are applied in Swakin terminal quarantine as the following: - Animals are kept for 21 days under monitoring in the quarantine without Therapy or vaccination as recommended in the OIE code. - The animals when brought to Swakin quarantine; vet officers verify The vaccination certificate, <i>Brucella</i> test certificate, certificate of origin and road document. the animals are counted, and first visual examination is made before the animals enter the Quarantine. - A day before shipping, A second inspection is made by visual examination for all animals, and accordingly, apparently diseased animals are rejected from exports. - Thereafter the animals are counted, weighed and examined visually before Shipping.		V. Low
Probability that sheep get infected by PPRV from Infected fomites in the transporting ships	Transporting ships from Swakin to Jeddah	- PPRV is highly contagious and exists in all discharges from sick animals (Chauhan et al., 2009). - Ship containers for animal transportation are in high humidity environment. - No laboratory specimens are taken from the ship fomites to ensure the hygiene and the efficacy of the disinfectant that used.	- The team of quarantine examine the ship to ensure that ventilation and sanitation, are provided as confirmed by a certificate given to them by the Captain of the ship, finally the responsible veterinary inspector from the quarantine signs the certificates which consist of: - <i>Brucella</i> free certificate, certificate of origin , FMD free certificate and the veterinarian health certificate. These documents are given to the exporting company to be handed to the importers.		V. Low

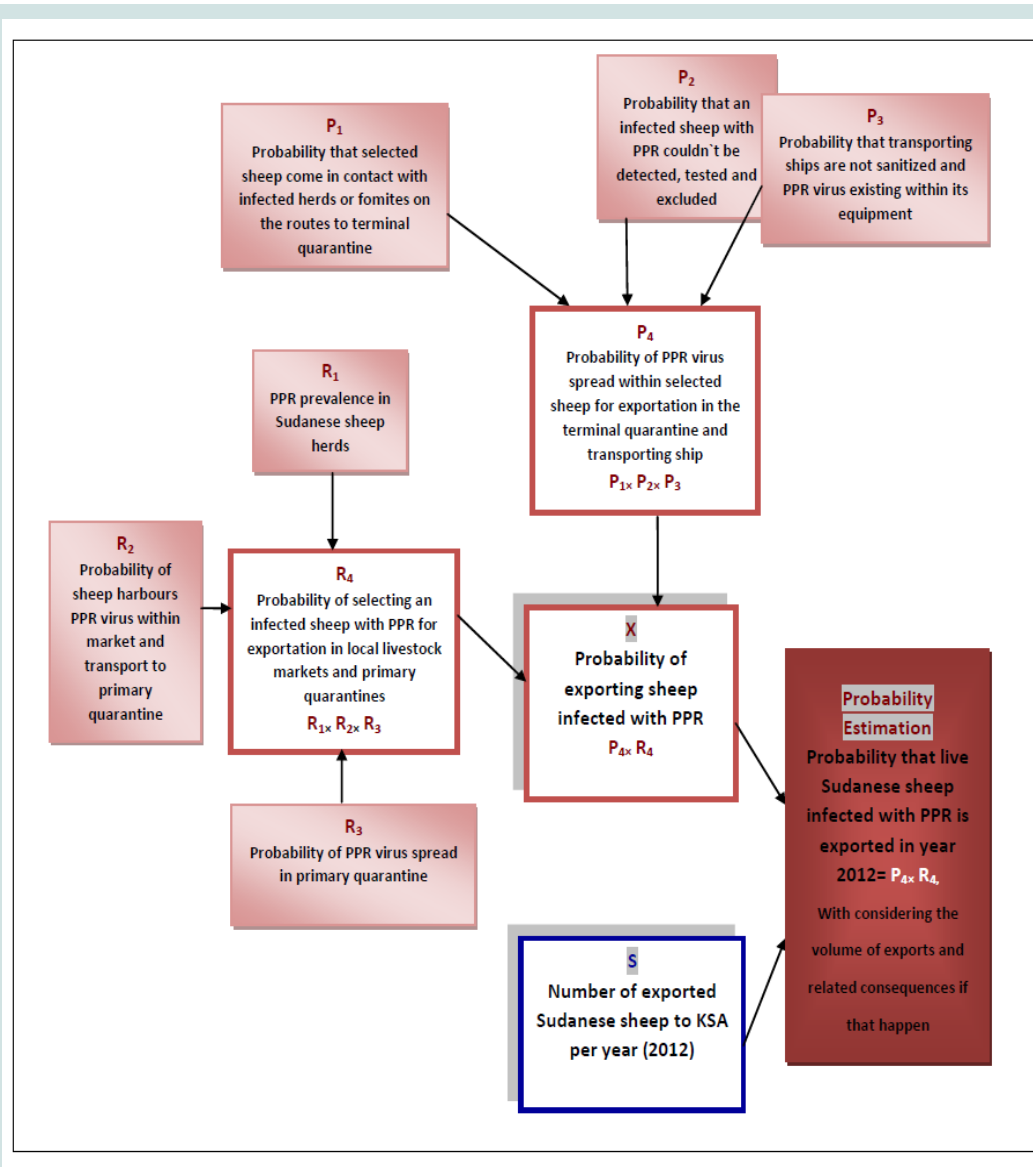


Figure 3: Influential diagram modeling risk probabilities of exporting Sudanese live sheep infected with PPR virus.

Likelihood ↑	H	M	M	H	H'
	M	L	M	M	H
	L	VL	L	M	M
	VL	VL	VL	L	M
		VL	L	M	H
	Impact →				

Figure 4: Risk estimation scheme by Defra.

the disease transmission. Also some of selected sheep are transported in trucks and some are taken on foot to the nearest vaccination and inspection centers and come into contact with local herds that may be infected with PPR as noticed from direct observations.

PPRV release could be minimized through a risk-based control strategy for PPR. Vaccination is considered the most effective way of controlling PPR [10]. The approach to control the disease can

be divided into three inter-dependent stages, based on prioritizing available resources. These stages are; (i) reducing disease intensity through vaccinating targeted populations, (ii) controlling PPR by intensive vaccination and (iii) implementing mass vaccination campaigns that provide high levels of vaccination coverage [10].

Vaccination coverage against PPR in the country during 2011 and 2012 was estimated between 0.46% to 42% in all states except

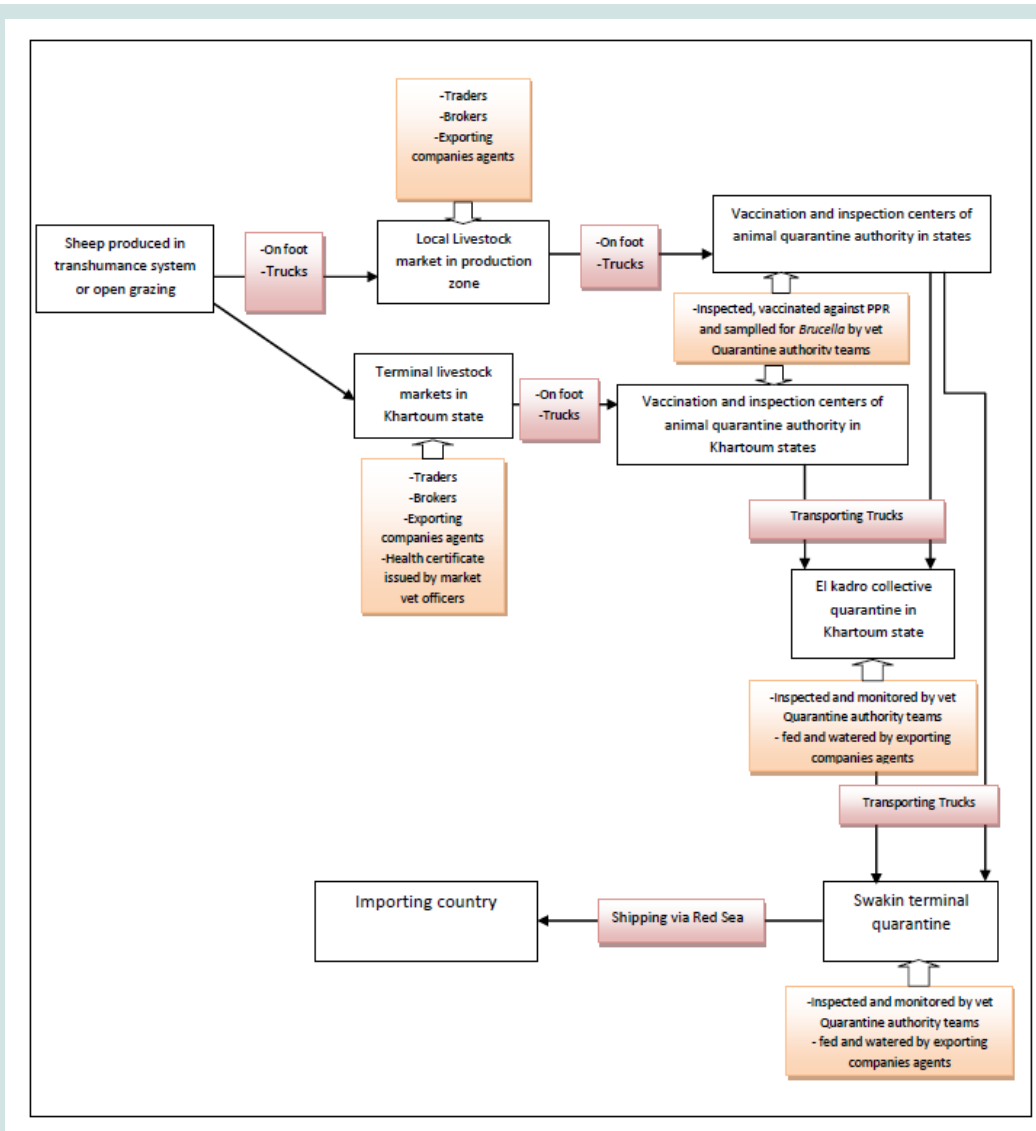


Figure 5: Shows the preliminary mapping for sheep exports value chain in Sudan.

Kassala state which cover 99.9% of sheep and goat population [11]. The coverage considered very weak comparing to the proportion of susceptible population needed to be immune for PPR become stable which estimated by 85.4% [12]. Timing is a very important factor in PPR vaccination which is better achieved before the rainy and cold seasons which are characterized with high numbers of outbreaks [9,13].

The third event that affects the release risk of PPRV is the probability of PPRV spread into the primary quarantines which is found to be Low. Primary quarantine and vaccination and inspection centers are responsible of sheep inspection during the primary quarantine period for 7 or 10 days, identification, vaccination against PPR and other diseases, and sampling for *Brucella* test. It was discovered that some exporters transport selected sheep from North Kordofan livestock markets to quarantined, sampled and vaccinated in Gedarif vaccination and inspection center due to the near distance to Swakin from Gedarif [14]. During inspection and sampling many

sheep excluded from exportation and may have its way to Gedarif market or farms, this step could be a hotspot for PPR and other diseases spread and should be taken into consideration by animal health authorities of Gedarif.

Control of sheep movement is very important for disease control and couldn't be achieved without sheep identification which is very crucial for inspection, transportation and disease control in quarantine channels. Animal identification and traceability are tools for addressing animal health (including Zoonoses) and food safety issues and these tools may significantly improve the effectiveness of disease management, control of animal movement, surveillance, early response, vaccination and application of zoning and compartmentalization [15,16].

Plastic ear tags with serial numbers are used for identification of exported sheep, but more accurate methods could be used like electronic ear tags or microchips to provide more information about



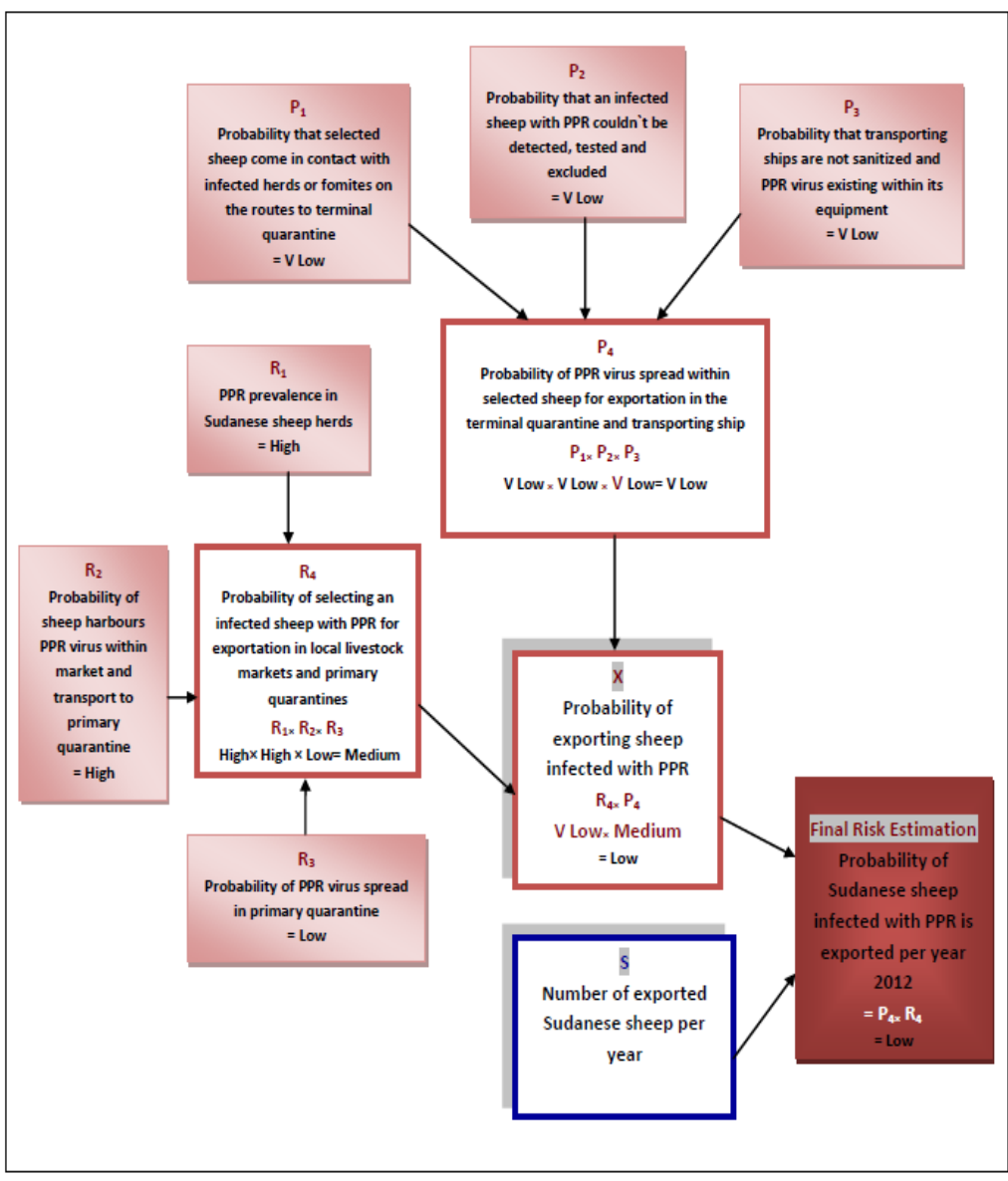


Figure 6: Influential diagram modeling the risk of exporting a Sudanese live sheep infected with PPR virus.

the animal origin, vaccination history and movement.

The exposure assessment which represents the probability of PPRV to spread among the sheep herds selected for exportation and it is depending on the contact with an infected sheep or fomites within the transporting trucks to the terminal quarantine or/and in the terminal quarantine or/and in the fomites of the transporting ship to the importing country. In this study the exposure risk was found to be very low (V Low), that means the risk of PPRV spread is rare (the risky event may occur in exceptional circumstances). The justification for this result is built upon the characteristics of the PPRV which is fragile with half-life of 2 hours at 37 and susceptible to the most common disinfectants [10]. But since the virus could be found in infected animal discharges which can contaminate materials such as water, feed and bedding to make them another source of infection

[17], so it is very important for the transporting vehicles to be cleaned and disinfected after every shipment.

The most important factor in reducing the risk of PPRV spread and other disease agents in the terminal quarantine is the application of Biosecurity measures and reliable inspection and disease detection methods. During the study period in 2012 about 37,291 sheep were rejected from Swakin quarantine due to emaciation and disease signs including swelling of lymph nodes, mange, Diarrhoea, sheep pox and postulates depending on visual inspection.

38.7% of this rejected sheep were excluded from the export herd due to swelling of lymph nodes, 11.4% for Diarrhoea and 1.5% due postulates. The excluded sheep taken out of the quarantine without knowing the exact reason for disease sign, despite that the diagnosis

and knowledge about the reason and tracing the origin of infected animals can contribute to the control of many diseases and also may give a clue about the efficacy of vaccination, Biosecurity measures and inspection along sheep export value chain.

The probability of ship fomites get contaminated and may contribute to disease transmission was found to be very low (V LOW), depending on the fragile nature of PPRV and the inspection made by Swakin quarantine officers in ship after receiving the disinfection certificate form ship captain. Laboratory testing for ship hygiene may be needed to assess ship Biosecurity and assure the health status of exported sheep.

Referring to the findings of the conducted studies in this research of PPR disease in Sudan, it is concluded that PPR disease was found to be endemic spreading all over the country with high rate of occurrence in states near country borders. Also PPR prevalence was mostly associated with high rainfall rated and high wind speed. It was concluded the pastoralists and open grazing among the different husbandry systems were most important for PPR occurrence. PPR was found to be more prevalent in female and small ruminant of more than 12 months of age. The risk of PPR spread in sheep exports chain was assessed to be Low; which is possible and may occur in the next years. Depending on research conclusions the following is recommended:

- Conducting studies to evaluate the efficacy of the local PPR vaccine when administered in field conditions.
- Studying the feasibility of producing and using thermo stable vaccine against PPR [18].
- Increasing the coverage of PPR vaccination to reach at least 70% of sheep and goats population in every state.
- Arranging the date of vaccination against PPR before the rainy season.
- Improving the control and the monitoring of animal movement at country borders and intrastate.
- Applying stricter Biosecurity measures in livestock markets, quarantines and transporting vehicles.
- Improving animal traceability in sheep and goats export chains and applying an identification method that gives data about the origin of animal and its vaccination history.
- Conducting thorough routine laboratory diagnosis for animals excluded from exports due to disease signs in the terminal quarantine.
- Adopting risk assessment by national veterinary authorities to establish an early warning system for animal diseases and to assess and evaluate animal health and quarantine procedures and regulations.
- Encouraging scientific researches in the fields of; PPR risk factors and the sanitary status in exports chain.

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