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ASSESSING COSTS AND EFFECTIVENESS OF SAFETY MEASURES FOR THE TRANSIT OF SMALL TYPE A PACKAGES THROUGH ROAD TUNNELS

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ABSTRACT

The Mont Blanc Tunnel is situated under the highest mountain in Europ. Being 12 km long, it is also one of the longest road tunnels in the world. Local authorities have to state whether the general regulations for the road transportation of radioactive materials, as defined by the IAEA, apply, or whether additive measures need to be taken. Whereas an activity limit - A_2 - applies only to the content of a type A package containing dispersible materials, a derived limit applying to the whole cargo of a truck has been in use in the tunnel and can be redefined. The present paper deals with the question of the choice of a proper figure for such a limit, that might regulate the transit under the tunnel for Technetium generators (ELUMATIC III from ORIS FRANCE).

The first step of the study is a risk assessment, with the truck content as an explicit parameter. The yearly traffic is of 150 trucks, carrying, on the average, 26 Ci of Technetium 99 m in ELUMATIC generators at the time of the crossing. Still on a yearly basis, about $5\ 10^{-6}$ road accidents might be expected, while the expected radiological fatalities would amount to approximately $2\ 10^{-8}$ and the expected monetary loss would be $ 10. The second step is the implementation of decision aiding techniques based on the previous estimates. As the mathematical expectations of such risk indices were not dependent on the shipped activity, a classical approach, the cost effectiveness curve did not lead to an optimum. Other approaches and other criteria were searched for, such as the comparison with other hazardous materials, the likelihood of lethal or morbidity effects and ground contamination. Should the latter criterion be considered as pertinent, it would lead to set a limit of 130 Ci of Technetium at the time the truck crosses the tunnel.

1 - SCOPE OF THE STUDY

The transportation of small quantities of dispersible radioactive materials is allowed on the european roads, accordingly to the IAEA standards /1/ in the so called "A package", up to a certain limit in activity for a single package (the "A_2 limit" which depends on the radionuclide). Under specific traffic conditions, namely when crossing the 12 km long tunnel under the Mont Blanc, more restrictive standards can prove to the necessary. A possibility is to prohibit the crossing when the content of a whole cargo is above a certain activity limit. This measure was applied, with a very restrictive limit, until recently. The question is then to determine the authorized activity in the tunnel, and the purpose of this paper is to show the analyses supporting a decision in this field.

2 - THE TRANSPORTATION SYSTEM

The traffic of Technetium generators

There are three transits weekly through the tunnel. The vehicle in use is generally a light truck. Its cargo content, expressed in actual activity averages to 54 Ci, ranging from half to twice this figure. It consists of various radioisotopes, but the Technetium generators accounts for 99 % of this activity (28 Ci of Molibdenum and 25.5 Ci of technetium).

This device shipped in a type A package, contains Molybdenum 99 (half life 66 h), which is transformed gradually in Technetium 99 m (half life 6 h). Generators of this kind can provide Technetium during a week for medical scanning purposes. Although its content in activity can vary, the generator itself, the ELUMATIC III from ORIS, is always the same. It contains, within a parallepipedic plastic box of about 20 cm, a system to extract the required solution of technetium out of a small glass column in which both isotopes are contained and a biological shielding of 13 kg of lead (see figure 1).

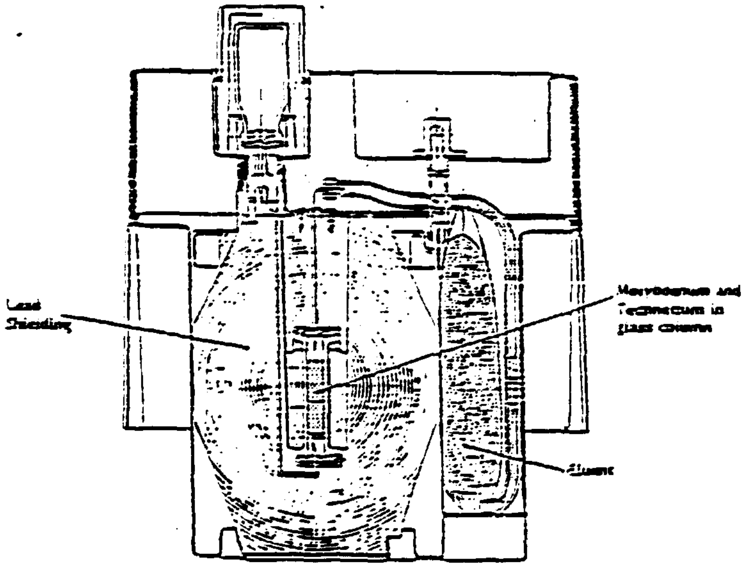

Figure 1 : The ORIS technetium generator

The tunnel environment

The total length of the tunnel is 12 km and there is one lane in each direction. On the average there are about 30 vehicles in the tunnel at a given time /2/. Should an accident occur that would shut one lane, about 90 people might be subjected to potential consequences, and possibly 10 vehicles might be trapped behind the truck. The physical parameters of the tunnel are its shape and its ventilation system. The cross section is the typical horseshoe, however the air ducts are underneath the roadway.

At last, the emergency response system comprises fire extinguishers dispatched in the tunnel ; this allowed to extinguish 13 of the 14 fires which took place under the tunnel. At the portals, an emergency vehicle is equipped with more powerful extinguishers and breathing apparatus. With regard to radiation hazard there is no monitoring device available at the tunnel site. The decontamination teams would have to come from Lyon which is located at 200 km from the tunnel (/2/ and /3/).

3 - THE RISK ASSESSMENT

Possible consequences of an accident

There are two main categories for the possible consequences of an accident. First the economic impacts can be the cost of monitoring, the cost of decontamination and the loss of earnings due to the shutting-down of the tunnel. Second the radiation health effects can be either short term effetcs or long term stochastic effects. Table I summarizes the main impacts of an accident and the way they will be quantified. They are not of the same importance. Some are very unlikely, others are almost certain. The risk assessment comprises two steps ; computation of the consequences of an accident and probabilistic assessment.

Table I Impacts of the loss of package contents and quantitative indices

IMPACT ·	INDEX
Immediate death	Probability of occurrence
Morbidity	Probability of occurrence
Late Radiation Effets	Collective dose
Shut-down of tunnel	Monetary unit
Radiation control	Monetary unit
Decontamination	Monetary unit

Computation of the consequences of a release

The packages contain Molybdenum and Technetium, its filiation product. For 1 Ci guaranteed to the customer, (one can speak of "nominal" activity), there is, at the time the truck reaches the tunnel, 2.1 Ci of Technetium and 2.3 Ci of Molybdenum. The radiological hazard can arise from external irradiation and inhalation. External irradiation results from a loss of shielding. Neglecting its contribution to the collective dose, a lethal area (10^{-3} m^2 per "nominal" Ci at the 5 Sv threshold) and a morbidity area (10^{-2} m^2 "nominal" Ci at the .5 Sv threshold) correspond to the hypothesis that a bystander would stay half an hour. Inhalation occurs when the products are airborne. In this case a model must be implemented for atmospheric transport. Before it reaches the lining (about 15 sec. after the release) the initial puff can be assumed to be gaussian and immediate effects may be observed. Lethal (25 Gy to the lung and 30 Gy to the intestine) and morbidity areas can be computed as previously, but they are five time larger. For distances larger than about fifty meters a box model is applied. Only delayed effects are expected in this case and a collective dose (1.5 10^{-3} Man Sv per airborne "nominal" Ci) for an average location of the release and an average number of people in the tunnel, accounts for them.

The loss of toll fees is directly linked to the duration of the closure of the tunnel. Any accident implying a truck would lock the tunnel for about one hour. An average figure of $ 2000 can be assumed for the loss of earnings. Should there be any doubt on the integrity of the cargo, a radiological survey team would be called upon and radiological monitoring expenses would follow. Team work would be to check the cargo and the cars which were behind it. In addition, the roadway and walls are to be monitored. These costs are almost unsensitive to the amount of damage to the packages. The work would last about five hours, since three are needed for the team to get to the tunnel location. The total cost, is estimated to $ 17,000, and the loss of earnings remains the main component.

The previous calculations performed with the box model allow one to compute the ground contamination. It requires the definition of an acceptable level of ground contamination : 50 m Ci. m^{-2} of Molybdenum should be acceptable for a location that is not a working place. The tunnel is divided into 40 sections of 300 m, corresponding to the ventilation system. The probability to have one of these sections contaminated is dependent on the released activity. It vanishes when the release is below 60 "nominal" Ci. If the contamination is very slight (little release, or simple loss of biological shielding) it can be assumed that the control team might handle the problem within one hour. This implies one hour more of tunnel shut-down. When a whole 300 m section is to be decontamined, one other team is necessary, and the operation would take about 8 hours.

Various impacts have been computed (see table II), that can or cannot be observed according to the type of the accident. In every case but the last one (the probability to have one whole action to decontaminate depends on the activity), the economic impacts are not dependent on the carried activity. On the other hand, the health impacts are proportional to this parameter.

Table II Magnitude of the impacts for various accident scenarios

	Cost of traffic interrupt* $	Cost of control $	Cost of decontamination $	Probability of morbidity	Probability of mortality	Collective dose (ManSv)
Trivial accident	2 000	-	-	-	-	-
Suspected loss of content	10 000	7 000	-	-	-	-
Loss of biological shielding	12 000	6 000	1 000	-	-	-
Actual airborne release	12 000	6 000	1 000	$2.5\ 10^{-3}$ x A.f	$2.5\ 10^{-4}$ x A.f	$1.5\ 10^{-3}$ x A.f
Actual airborne release and decontamination of a tunnel section	28 000	7 000	14 000	$2.5\ 10^{-3}$ x A.f	$2.5\ 10^{-4}$ x A.f	$1.5\ 10^{-3}$ x A.f

A.f : Released fraction of expressed in "nominal" Ci (1 "nominal" Ci : 2.3 Ci of Molybdenum).

Probabilistic assessment

The aim of the probabilistic part of the assessment is to establish the accident scenarios that can result in the "consequence scenarios" stated above, and to compute their probabilities.

Although some statistics are available on type A package accidents (/4/ and /5/), they are not specific of Technetium generators. A crush and fire experiment has been performed in the Amersham center with a light truck containing a mixed cargo of type A and B packages /6/. An interesting feature was the very short time which was necessary for a fire to encompass the whole vehicle. However the results of the regulatory tests, the analyses of a train accident, and the destructive fire test performed in June 1985 are specific of the french "Elumatic" Technetium generator.

A review of these data and of the tunnel accident record allowed to focus on four accident scenarios, with the following consequences :

- light crash : no loss of shielding,
- frontal collision (i.e about 120 km^{-1}) : loss of shieding, 1 % airborne material
- short fire : no effect
- strong fire (i.e destroyed vehicle) : 75 % airborne material.

The probability of a light crash is 3.5 10^{-6} at each crossing of the tunnel, half of them requiring monitoring. This probability is 4 10^{-7} for a collision, 8 10^{-7} for a light fire and 5 10^{-8} for a severe fire. On the basis of the actual traffic of 150 passages with 12 Ci of nominal activity, (25.2 Ci of ^{99m}Tc and 27.5 Ci of ^{99}Mo) the risk is as follows :

- accident probability	7.1 10^{-4}
- expected monetary loss	\$ 6.5
- expected collective dose	1.11 10^{-7} Man Sv
- probability of a lethal effect	1.85 10^{-8}
- probability of reversible effect	1.85 10^{-7}

The level of risk appears to be low, and this not only due to the small amount of traffic. For instance, the number of health effects is one thousand times lower than the expected number of deaths due to the traffic accidents themselves.

4 - ELEMENTS FOR THE DECISION MAKING PROCESS

The cost benefit analyses

The question is to know whether there is an optimum in a possible allowed nominal activity for the Technetium generators. One must therefore look over the costs and the benefits of an increase in this level. The benefit arises from the reduction in the number of shipments. The "cost" of the measure was expected to be an increase in the risk level. In principle, there should be an optimum when balancing these figures. It has already been stressed that most of the costs of the accident were not dependent on the carried activity, and that the health effects were linearly connected with it. Increasing the allowed limit means decreasing the number of shipments and therefore the accident probability. The conclusion, (see figure 2) is that the expected number of health effects remains constant, while the monetary cost of the accidents decreases.

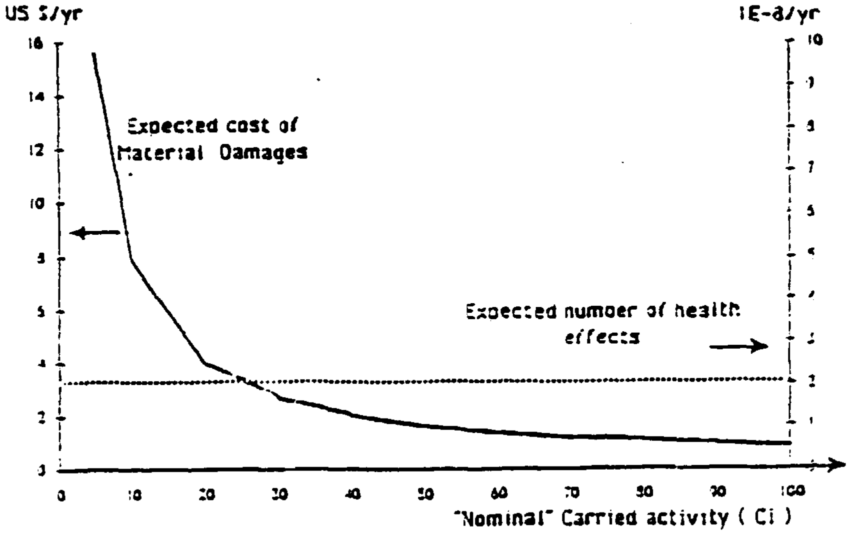

Figure 2 : Evolution of the annual expectation for the economic and health impacts according to the shipped activity

This is a situation in which cost benefit analysis does not lead to an optimal level. Thus a limit must the be searched for among the constraints that might apply to this kind of transportation. The analysis was however of some interest. It illustrated the orders of magnitude of the impacts and it showed that increasing the limit is sound.

Other criteria

A regulatory constraint, the Transportation Index, makes it difficult to reach figures higher than 100 Ci, but it is technically feasible. An other criterion arises from the comparison with other hazardous materials. It whould lead to allowed amounts well beyond plausible figures. Looking at the consequences of the major event, here a large fire, two other criteria appear. For about 1 000 Ci, the likelihood for inducing a lethal effect becomes of some magnitude. The same was computed for 100 Ci looking at morbidity effects. At last an interesting figure corresponds to the amount above which, still in the worst case accident, it would be likely to have to decontaminate a whole 300 m section of the tunnel. This quantity is around 60 Ci of "nominal" activity. This criterion is worthwhile to consider since such work would have a considerable impact on public opinion.

5 - CONCLUSION

This study has a clear result. It demonstrates the low level of the risk associated with the transportation of medical sources under the tunnel, both from a probabilistic and a "worst case" view point. However the use of a traditional cost benefit approach is not possible because there are only advantages, when dealing with the mathematical expectation of the cost and benefits, in releasing the limits. Due to the difficulty with that objective criterion, other criteria of more subjective nature have been examined.

The limit above which important decontamination work would have to be undertaken after a very serious accident was found to be a criterion of interest. This is due to the economic impact, but especially to the potential effect on the public opinion of a long shut-down of the tunnel attributable to a radioactive material incident. It would lead to choose a value of about 130 Ci of Tc at the time the truck crosses the tunel (60 Ci of "nominal" activity). Although it clearly appears that the last figure relies on a subjective judgment, and that the final decision should carefully weight these subjective factors, this study illustrated how a quantitative assessment and a formal approach prove useful when dealing with decisional problems of that kind.

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