

ESTIMATED ANNUAL WORLDWIDE SHIPMENTS OF RADIOACTIVE MATERIAL

R.B. POPE

International Atomic Energy Agency,
Vienna

J.D. McCLURE

Sandia National Laboratories,
Albuquerque, New Mexico,
United States of America

Abstract

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Data on shipments within or from 35 Member States of the IAEA have been used to estimate the volume of radioactive material shipments worldwide. The data have been extrapolated on the basis of gross domestic product and population, and it is estimated that from 18 to 38 million package shipments were made annually in the early 1980s.

INTRODUCTION

At the first meeting of the International Atomic Energy Agency's Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM) held in Vienna in October 1978, it was recommended that "a system should be developed by the Agency for the collection, storage and retrieval of information on the worldwide volume of traffic in all types of radioactive materials by all modes of transport." The purpose of this effort was to develop a database which would assist in assessing the adequacy of the requirements set forth in the Regulations for the Safe Transport of Radioactive Material, Safety Series No. 6, and thereby guide the revision of these Regulations.

In considering this recommendation, it was decided that it would be unrealistic to seek such data on a continuing basis. Therefore, the Agency responded to this advice in February 1980 by sending forms to all Member States requesting

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"summary information based on the best data available to or collected by the competent authorities over an initial one-year reporting period." It was felt that this "would be a reasonable compromise between the desirability of receiving exact data on a continuing basis and the necessity of having adequate, representative, worldwide data." Furthermore, it was planned that these data would be compiled and stored in the Agency's computer for future use and reference by both the Agency and Member States. This paper provides a status report on this activity, an overview of the data provided, and an estimate of the worldwide volume of shipping based on an extrapolation of the data in terms of gross domestic product and population.

DATA COLLECTION PROCEDURES

The methods used in collecting the data were left to the discretion of each Member State. Four sets of forms were provided for summarizing data to the Agency:

- (1) **Form A** — Summary of Package Movements for International Transport (exports only). This form included requests for information in terms of total annual number of packages, transport index and distance by package classification (Exempt, LSA or LLS, Type A, etc.) and by transport mode (road, rail, sea, etc.); and number of packages by labelling category (Exempt, I-WHITE, II-YELLOW, III-YELLOW and Fissile).
- (2) **Form B** — Summary of Package Movements for Domestic Transport. This form included requests for the same type of data as in Form A.
- (3) **Form C** — Summary of Consignment Movements. This form included requests for data on specific types of material consignments (plutonium, radiopharmaceuticals, UF_6 , UO_2 , etc.) in terms of total activity, number of packages, transport index and distance by transport mode.
- (4) **Form D** — Summary of Movements of Substantial Quantities. This form included requests for similar data by radionuclide and chemical form.

In anticipation of the receipt of the data, Mr. D.R. Hopkins of the United States of America worked as a consultant to the Agency in 1982 and established the elements which would be required in a computer code and provided data consistency checks to be used prior to computer input. As the data arrived at the Agency, the checks performed by Agency staff indicated that most data were not internally consistent and further work was needed to clarify the problems. Mr. B.G. Pettersson of Sweden worked as a consultant in 1983 and identified a number of major problems with the data. These problems were of sufficient magnitude that it became clear computerization would not be possible as originally foreseen. It was decided that the inconsistencies with the data could only be resolved by using Agency staff and an additional consultant to assess the data on a case-by-case basis, identify inconsistencies and clarify their causes. The following summarizes the results of these efforts.

OVERVIEW OF DATA

A total of 49 countries responded to the request. Data from 35 countries have been used in the summary contained in this paper. Some countries provided data which could not be included in the database. For example, to prevent 'double-counting' of international shipments, only export shipment data were requested; however, Austria provided only air import shipment data, and Egypt provided only data on packages transiting the Suez Canal. In addition, 12 countries acknowledged the request but did not send data.

The data provided were for a one-year period, centred on 1981. Table I lists: the countries which provided data; whether the data were for domestic or international shipments, or both; the time period for which the data apply; and the Agency's assessment whether the data were complete.

For many of the countries, it was acknowledged or it became apparent that the data were not complete. For example: Italy and Spain provided no data on Exempt packages (now known as Excepted in the 1985 Edition of Safety Series No. 6); Australia, Finland, Hungary, Ireland, Italy and Poland provided no data on packages containing LLS or LSA (known as LSA or SCO in the 1985 Edition of Safety Series No. 6); Norway noted their data were not extrapolated to all shippers and were only about 70% accurate; Switzerland only provided data for fissile packages; the UK data are only for certain establishments; and the US data are for domestic shipments only, are known to underestimate the total packages shipped domestically by at least 500 000, and do not account for multi-modal transport of packages. It has since become apparent that one large commercial shipper was not included in the Netherlands data; inclusion of this shipper could have increased their reported package shipments by 500 000 to as much as 1 000 000.

Of the 32 countries which sent data of the Form A and/or Form B type:

- (1) 21 provided data on international shipments, and 10 of these were judged to be incomplete; and
- (2) 31 provided data on domestic shipments, and 12 of these were judged to be incomplete.

Data from Belgium, Brazil and Thailand were included in this review by adjusting the data to the Form A/Form B format.

COUNTING OF SHIPMENTS

As the data were reviewed, it became apparent that the statistics were developed differently by different countries.

Safety Series No. 6 defines "shipment" as "the specific movement of a consignment from origin to destination". A consignment can consist of one package or of many packages.

TABLE I. COUNTRIES PROVIDING DATA USED IN THIS REPORT

Key to table: (N = no data, D = data, I = incomplete data provided)

Country	International shipments	Domestic shipments	Time period of data reported
Albania	N	D	81/82
Australia	I	I	80
Canada	D	D	81
Chile	D	D	79
El Salvador	N	D	80-82
Finland	I	I	80
France	D	D	80
Germany, Fed. Rep. of	D	D	80/81
Greece	N	D	-
Hungary	I	I	80
Ireland	I	I	80
Italy	I	I	82
Japan	D	D	80
Jordan	N	D	79/80
Republic of Korea	N	D	80
Luxembourg	D	D	80
Netherlands	N	I	-
New Zealand	D	D	79/80
Norway	I	I	81
Peru	N	D	-
Philippines	D	N	79
Poland	I	I	80/81
Senegal	N	D	-
Singapore	D	D	80
South Africa	D	D	80/81
Spain	I	I	80
Sweden	D	D	80
Switzerland	I	I	80
Syrian Arab Republic	N	D	82
Turkey	N	D	80
UK	I	I	80
USA	N	I	81/82

----- Other data -----

Austria	Import by air only for 1979
Belgium	Reported general data for 1977
Brazil	Forms C & D only for 1979 (assumed to be domestic)
Egypt	Packages transiting Suez Canal in 1979
Thailand	Form C, only for 1980 (assumed to be domestic)

For accounting purposes with this study, two terms were defined as follows:

- (1) **Package Shipment (PS)** shall mean a single package transported by a single mode of transport from an origin to a destination.
- (2) **Package Combined Shipment (PCS)** shall mean a single package transported by one or more modes of transport, from its initial point of origin (where it is loaded with radioactive material) to its destination (where its contents are removed or otherwise used).

Thus, a PCS is composed of one or more PS, and therefore

$$\text{Number of PS} \geq \text{Number of PCS}$$

As an example of the above, consider a single package which may go first by truck from a plant to an airport, next by aircraft from airport to airport, and finally by truck from airport to using facility. In this case, PS = 3 and PCS = 1.

The numbers of PS were requested in the Agency's survey in the Package Classification/Mode data sheets (top parts of Forms A and B), whereas the numbers of PCS were requested in the Statistical Data on Packages by Labelling Category (bottom parts of Forms A and B).

To allow for consistent reporting of the data in this report, the package shipments, PS, were calculated or estimated for each country where possible.

TOTAL PACKAGE SHIPMENTS

Table II shows the total number of package shipments reported by each country. For the countries shown, when known inaccuracies are considered, the total package shipments per year exceed ten million.

The countries reporting data are 'ranked' from the largest shipper to the smallest shipper in Table III. It can be seen that, in order to gain a perspective on worldwide shipping, only a limited number of countries need be considered. In this case, the top 12 countries account for 99% of all package shipments reported.

While studying the data, and following discussions with experts in various Member States, it was concluded that the greatest uncertainty probably lies with Exempt packages. Table IV lists the 'Top 20 Countries' which are shippers of radioactive material packages other than Exempt packages. Here it can be seen, for example, that the ranking of the USA and Canada is reversed, which is more consistent with the relative populations of the two countries. It was therefore concluded that the Canadian data fairly represent the proportion of Exempt packages shipped, whereas the US data do not. The US data are further complicated in that the numbers are package combined shipments (PCS), not package shipments (PS).

TABLE II. SUMMARY OF PACKAGE SHIPMENTS^a (PS), BY COUNTRY, BASED ON DATA SUPPLIED BY MEMBER STATES TO THE IAEA

Country	International package shipments	Domestic package shipments	Total package shipments
Albania	—	133	133
Australia	555 ^b	56 331 ^b	56 886 ^b
Belgium	—	78 422 ^b	78 422 ^b
Brazil	— — (Not Specified)	— —	11 144
Canada	433 088	3 947 341	4 380 429
Chile	1	1 463	1 464
El Salvador	—	294	294
Finland	1 ^b	24 502 ^b	24 503 ^b
France	34 802	84 757	119 559
Germany, Fed. Rep. of	46 882	414 532	461 414
Greece	—	1 338	1 338
Hungary	2 099 ^b	23 824 ^b	25 923 ^b
Ireland	60 ^b	15 500 ^b	15 560 ^b
Italy	8 166 ^b	197 505 ^b	205 671 ^b
Japan	18 459	705 055	723 514
Jordan	—	116	116
Rep. of Korea	—	5 977	5 977
Luxembourg	21	37	58
Netherlands	—	10 359 ^b	10 359 ^b
New Zealand	35	21	56
Norway	6 706 ^c	10 298 ^c	17 004 ^c
Peru	—	19	19
Philippines	587	—	587
Poland	8 258 ^b	25 048 ^b	33 306 ^b
Senegal	—	168	168
Singapore	166	886	1 052
South Africa	80	12 154	12 234
Spain	107 ^b	48 894 ^b	49 001 ^b
Sweden	3 760	119 151	122 911
Switzerland	774 ^d	284 ^d	1 058 ^d
Syrian Arab Rep.	—	100	100
Thailand	— — (Not Specified)	— —	89
Turkey	—	621	621
UK	208 168 ^b	190 013 ^b	398 181 ^b
USA	—	2 819 308 ^e	2 819 308 ^e
		TOTAL	~9 578 459 ^f

a Including Full Load

b Data incomplete

c Estimated to account for only ~70% of shipments

d Fissile shipments only, data incomplete

e Known to be low by at least 500 000, data incomplete, data are package combined shipments, not package shipments

f When known inaccuracies in data from Norway and the USA are added in, the total exceeds 10 000 000 package shipments

TABLE III. SUMMARY OF THE 'TOP 20 COUNTRIES', THE LARGEST SHIPPERS OF RADIOACTIVE MATERIAL PACKAGES BASED UPON DATA SUPPLIED BY MEMBER STATES TO THE IAEA (footnotes are explained in Table IV)

Country	Number of package shipments
1. Canada	4 380 429
2. USA	2 819 308 ^{a,b}
3. Japan	723 514
4. Germany, Fed. Rep. of	461 414
5. UK	398 181 ^c
6. Italy	205 671 ^d
7. Sweden	122 911
8. France	119 559
9. Belgium	78 422 ^{b,e}
10. Australia	56 886 ^f
11. Spain	49 001 ^e
12. Poland	33 306 ^f
----- 99% of total	
13. Hungary	25 923 ^f
14. Finland	24 503 ^f
15. Norway	17 004 ^g
16. Ireland	15 560 ^f
17. South Africa	12 234
18. Brazil	11 144
19. Netherlands	10 359 ^{b,h}
20. Rep. of Korea	5 977 ^b
TOTAL	$\sim 10 \times 10^6$

SHIPMENTS BY PACKAGE TYPE

Table V presents a summary of the data provided from 16 of the 'Top 20' countries, showing the percentage, by package type, of each country's total number of package shipments (data from Belgium, Brazil, Netherlands and the Republic of Korea were insufficient for this assessment). It can be seen that there are wide differences in the reported data for various package types. For example, Canada and Sweden reported more than 80% of their package shipments were Exempt packages, whereas Australia, Finland, France, Hungary, Italy, Norway, Poland, South Africa, Spain and the USA reported less than 30% were Exempt package shipments. For the latter countries it is postulated that many of the Exempt package shipments were not identified.

TABLE IV. SUMMARY OF THE 'TOP 20 COUNTRIES', THE LARGEST SHIPPERS OF RADIOACTIVE MATERIAL PACKAGES, EXCLUDING EXEMPT PACKAGES, BASED ON DATA SUPPLIED BY MEMBER STATES TO THE IAEA

Country	Number of package shipments
1. USA	2 402 429 ^b
2. Canada	612 632
3. Japan	353 054
4. UK	242 268 ^c
5. Italy	205 679 ^f
6. Germany, Fed. Rep. of	155 408
7. France	99 617
8. Belgium	78 422 ^b
9. Spain	49 425
10. Australia	45 208 ^f
11. Poland	32 208 ^f
12. Sweden	21 751
13. Hungary	18 423 ^f
14. Finland	17 753 ^f
15. Norway	16 604 ^g
16. South Africa	11 418
----- 99% of total	
17. Brazil	11 011
18. Netherlands	10 359 ^{b,h}
19. Ireland	8 560 ^f
20. Rep. of Korea	5 220 ^b
TOTAL	~4.4 × 10 ⁶

Footnotes to Tables III and IV

- a Data are known to be low by at least 500 000 Exempt packages
- b Domestic shipments only
- c Data are incomplete, data are from selected shippers only
- d Data are incomplete, no data on Exempt packages or LSA/LLS shipments
- e No data on Exempt packages
- f No data on LSA/LLS shipments
- g Estimated to be low by ~30%
- h Data are **suspected** to be low by at least 500 000 package shipments, and data reported are PCS, not PS

TABLE V. PACKAGE SHIPMENTS BY PACKAGE TYPE — IN PERCENTAGE

Country	Total number of package shipments	Package type					
		Exempt	LSA/LLS	Type A	Type B(U)	Type B(M)	Other
Australia	56 886	20.6	0	78.6	0	0	0.8
Canada	4 380 429	86.2	1.0	9.0	1.8	~0	2.0
Finland	24 503	27.5	0	72.4	0.1	0	0
France	119 559	16.6	0.3	49.9	0.8	0.2	32.2
Germany, Fed. Rep. of	461 414	66.3	0.04	31.7	1.2	0.01	0.75
Hungary	25 923	28.9	0	58.6	7.1	0	5.4
Ireland	15 560	45.0	0	6.5	48.5	0	0
Italy	205 671	0	0	96.7	3.25	0.01	0.04
Japan	723 514	51.1	0.08	29.35	0.05	0.02	19.4
Norway	17 004	2.3	0.1	95.9	1.5	0	0.2
Poland	33 306	7.2	0	50.17	16.0	0.03	26.6
South Africa	12 234	6.7	1.0	76.7	15.5	0	0.1
Spain	49 001	0	69.7	27.6	2.6	0.1	0
Sweden	122 911	82.3	6.9	10.5	0.2	~0	0.1
UK	398 181	38.9	0.4	57.8	1.0	0.2	1.7
USA	2 819 308	14.8	17.0	63.5	N/A	3.4	1.3
USA corrected for known missing Exempt packages	3 319 308	27.6	14.5	53.9	N/A	2.9	1.1

ASSESSMENT OF UTILITY OF THE DATA

Many problems, a few of which have been outlined above, led to the conclusion that the data provided to the IAEA were not of sufficient quality to justify further analysis or effort. The data could not be used, except in a very general sense, to assess the adequacy of the Transport Regulations or to perform risk assessments.

The following demonstrates the extent to which the database appears to be incomplete. The total package shipments by sea which were reported were 16 500; yet Egypt reported a through-country transit in the Suez Canal of 52 000 packages per year. Thus it appears many shipments are not accounted for by the data provided to the Agency.

ESTIMATED WORLDWIDE SHIPPING VOLUME

In addition to the incomplete nature of the data provided by many countries, many of the Agency's Member States which would be significant shippers of radioactive material provided no data whatsoever. This includes Argentina, Austria, Bulgaria, China, Czechoslovakia, Denmark, the German Democratic Republic, India, Indonesia, Islamic Republic of Iran, Iraq, Israel, Mexico, Pakistan, Portugal, the USSR, Venezuela and Yugoslavia. Therefore, the database, corrected for known deficiencies for certain countries providing data, was examined from the point of view of gross domestic product (GDP) and population. Data were provided by countries representing approximately 26% of the world's population, 55% of the world's GDP and 80% of the world's installed nuclear power generating capacity.

If it is assumed that the GDP is the best indicator for extrapolating to obtain a measure of the volume of package shipments worldwide, then approximately 8 million package shipments of non-Exempt packages and approximately 10 million additional Exempt package shipments are made each year. Conversely, if it is assumed that the population is the best indicator for extrapolating, then approximately 17 million package shipments are made per year of non-Exempt packages and approximately 21 million additional Exempt package shipments are made each year.

Thus, considering all types of radioactive material packages, 18 to 38 million package shipments were made worldwide annually in the early 1980s, with 8 to 17 million of these of the non-Exempt types (Industrial Packages, Type A and Type B).

Irrespective of the basis of extrapolation, this is a much larger shipping volume than previously estimated.

CONCLUSIONS

The following conclusions can be drawn about the shipping data provided:

- (1) The data are **incomplete**; many countries provided **partial** data and many countries provided no data.
- (2) The data are **inaccurate**; many inconsistencies were identified in data sheets and many contributors acknowledged that data were extrapolations from random or partial surveys.
- (3) Very few of the data sets are complete.
- (4) However, the data do provide a basis for approximating the magnitude of the transport of radioactive material worldwide; and it can be concluded that from 18 to 38 million package shipments were made each year in the early 1980s.
- (5) Finally, if similar data collection activities are attempted in the future, it is recommended that: (a) the data collection sheets should be much simpler; (b) the data collection activity should be less ambitious; (c) data need only be collected from approximately 20 countries (the largest shippers) to obtain a good estimate; and (d) clear detailed instructions, with examples, should be provided.