MINISTRY
FOR THE ECOLOGICAL TRANSITION
AND THE DEMOGRAPHIC CHALLENGE

SECRETARY OF STATE
FOR THE ENVIRONMENT

DIRECTORATE GENERAL FOR
ENVIRONMENTAL QUIALTY AND ASESSMENT

ENVIRONMENTAL LIABILITY INFORMATION SYSTEM (SIRMA)

USER´S GUIDE

SIRMA
Sistema de Información de Responsabilidad Medioambiental

ANNEX I: Bibliographic references – ARM probabilities

TECHNICAL COMMISSION OF PREVENTION AND REMEDIATION OF ENVIRONMENTAL DAMAGES

INDEX

1. BASIC EVENT BIBLIOGRAPHIC PROBABILITIES

A. HSE 2019 - *Failure Rate and Event Data for use within Risk Assessments (02/02/19). Health and Safety Executive (HSE).*

Source of danger	Basic event	Probability	Unit	Page
Large vessels >12000 m3	Catastrophic release	5,00E-06	$year^{-1}vessel^{-1}$	7
Large vessels >12000 m3	Major release (hole diameter 1000 mm)	1,00E-04	$year^{-1}vessel^{-1}$	7
Large vessels >12000 m3	Minor release (hole diameter 300 mm)	2,50E-03	$year^{-1}vessel^{-1}$	7
Large vessels >12000 m3	Roof release	2,00E-03	$year^{-1}vessel^{-1}$	7
Large vessels 12000-4000 m3	Catastrophic release	5,00E-06	$year^{-1}vessel^{-1}$	7
Large vessels 12000-4000 m3	Major release (hole diameter 750 mm)	1,00E-04	$year^{-1}vessel^{-1}$	7
Large vessels 12000-4000 m3	Minor release (hole diameter 225 mm)	2,50E-03	$year^{-1}vessel^{-1}$	7
Large vessels 12000-4000 m3	Roof release	2,00E-03	$year^{-1}vessel^{-1}$	7
Large vessels 4000-450 m3	Catastrophic release	5,00E-06	$year^{-1}vessel^{-1}$	7
Large vessels 4000-450 m3	Major release (hole diameter 500 mm)	1,00E-04	$year^{-1}vessel^{-1}$	7
Large vessels 4000-450 m3	Minor release (hole diameter 150 mm)	2,50E-03	$year^{-1}vessel^{-1}$	7
Large vessels 4000-450 m3	Roof release	2,00E-03	$year^{-1}vessel^{-1}$	7
Small and medium atmospheric tanks (SMATS). Non Flammable Contents	Catastrophic release	8,00E-06	$year^{-1}vessel^{-1}$	9
Small and medium atmospheric tanks (SMATS). Non Flammable Contents	Large release	5,00E-05	$year^{-1}vessel^{-1}$	9
Small and medium atmospheric tanks (SMATS). Non Flammable Contents	Small release	5,00E-04	$year^{-1}vessel^{-1}$	9

Source of danger	Basic event	Probability	Unit	Page
Small and medium atmospheric tanks (SMATS). Flammable Contents	Catastrophic release	1,60E-05	$year^{-1}vessel^{-1}$	9
Small and medium atmospheric tanks (SMATS). Flammable Contents	Large release	1,00E-04	$year^{-1}vessel^{-1}$	9
Small and medium atmospheric tanks (SMATS). Flammable Contents	Small release	1,00E-03	$year^{-1}vessel^{-1}$	9
Single walled vessels >12000 m3	Catastrophic failure	4,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels >12000 m3	Major failure (hole diameter 1000 mm)	1,00E-04	$year^{-1}vessel^{-1}$	12
Single walled vessels >12000 m3	Minor failure (hole diameter 300 mm)	8,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels >12000 m3	Failure with a release of vapour only	2,00E-04	$year^{-1}vessel^{-1}$	12
Single walled vessels 12000-4000 m3	Catastrophic failure	4,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels 12000-4000 m3	Major release (hole diameter 750 mm)	1,00E-04	$year^{-1}vessel^{-1}$	12
Single walled vessels 12000-4000 m3	Minor release (hole diameter 225 mm)	8,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels 12000-4000 m3	Failure with a release of vapour only	2,00E-04	$year^{-1}vessel^{-1}$	12
Single walled vessels 4000-450 m3	Catastrophic failure	4,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels 4000-450 m3	Major release (hole diameter 500 mm)	1,00E-04	$year^{-1}vessel^{-1}$	12
Single walled vessels 4000-450 m3	Minor release (hole diameter 150 mm)	8,00E-05	$year^{-1}vessel^{-1}$	12
Single walled vessels 4000-450 m3	Failure with a release of vapour only	2,00E-04	$year^{-1}vessel^{-1}$	12
Double walled vessels >12000 m3	Catastrophic failure	5,00E-07	$year^{-1}vessel^{-1}$	12
Double walled vessels >12000 m3	Major failure (hole diameter 1000 mm)	1,00E-05	$year^{-1}vessel^{-1}$	12
Double walled vessels >12000 m3	Minor failure (hole diameter 300 mm)	3,00E-05	$year^{-1}vessel^{-1}$	12
Double walled vessels >12000 m3	Failure with a release of vapour only	4,00E-04	$year^{-1}vessel^{-1}$	12
Double walled vessels 12000-4000 m3	Catastrophic failure	5,00E-07	$year^{-1}vessel^{-1}$	12
Double walled vessels 12000-4000 m3	Major failure (hole diameter 750 mm)	1,00E-05	$year^{-1}vessel^{-1}$	12

Source of danger	Basic event	Probability	Unit	Page
Double walled vessels 12000-4000 m3	Minor failure (hole diameter 225 mm)	3,00E-05	$year^{-1}vessel^{-1}$	12
Double walled vessels 12000-4000 m3	Failure with a release of vapour only	4,00E-04	$year^{-1}vessel^{-1}$	12
Double walled vessels 4000-450 m3	Catastrophic failure	5,00E-07	$year^{-1}vessel^{-1}$	12
Double walled vessels 4000-450 m3	Major failure (hole diameter 500 mm)	1,00E-05	$year^{-1}vessel^{-1}$	12
Double walled vessels 4000-450 m3	Minor failure (hole diameter 150 mm)	3,00E-05	$year^{-1}vessel^{-1}$	12
Double walled vessels 4000-450 m3	Failure with a release of vapour only	4,00E-04	$year^{-1}vessel^{-1}$	12
Double wall vessels >12000 m3	Catastrophic failure	5,00E-08	$year^{-1}vessel^{-1}$	15
Double wall vessels >12000 m3	Major failure (hole diameter 1000 mm)	1,00E-06	$year^{-1}vessel^{-1}$	15
Double wall vessels >12000 m3	Minor failure (hole diameter 300 mm)	3,00E-06	$year^{-1}vessel^{-1}$	15
Double wall vessels >12000 m3	Failure with a release of vapour only	4,00E-05	$year^{-1}vessel^{-1}$	15
Double walled vessels 12000-4000 m3	Catastrophic failure	5,00E-08	$year^{-1}vessel^{-1}$	15
Double walled vessels 12000-4000 m3	Major release (hole diameter 750 mm)	1,00E-06	$year^{-1}vessel^{-1}$	15
Double walled vessels 12000-4000 m3	Minor release (hole diameter 225 mm)	3,00E-06	$year^{-1}vessel^{-1}$	15
Double walled vessels 12000-4000 m3	Failure with a release of vapour only	4,00E-05	$year^{-1}vessel^{-1}$	15
Double walled vessels 4000-450 m3	Catastrophic failure	5,00E-08	$year^{-1}vessel^{-1}$	15
Double walled vessels 4000-450 m3	Major release (hole diameter 500 mm)	1,00E-06	$year^{-1}vessel^{-1}$	15
Double walled vessels 4000-450 m3	Minor release (hole diameter 150 mm)	3,00E-06	$year^{-1}vessel^{-1}$	15
Double walled vessels 4000-450 m3	Failure with a release of vapour only	4,00E-05	$year^{-1}vessel^{-1}$	15
Single walled vessels 4000-2000 m3	Catastrophic failure	2,20E-05	$year^{-1}vessel^{-1}$	16
Single walled vessels 4000-2000 m3	Major failure (hole diameter 400 mm)	1,00E-04	$year^{-1}vessel^{-1}$	16
Single walled vessels 4000-2000 m3	Minor failure (hole diameter 120 mm)	8,00E-05	$year^{-1}vessel^{-1}$	16
Single walled vessels 200-2000 m3	Catastrophic failure	2,20E-05	$year^{-1}vessel^{-1}$	16
Single walled vessels 200-2000 m3	Major failure (hole diameter 250 mm)	1,00E-04	$year^{-1}vessel^{-1}$	16

Source of danger	Basic event	Probability	Unit	Page
Single walled vessels 200-2000 m3	Minor failure (hole diameter 75 mm)	8,00E-05	$year^{-1}vessel^{-1}$	16
Cluster tanks 4000-2000 m3	Simultaneous catastrophic failure of all tanks in cluster	1,00E-06	$year^{-1}$	16
Cluster tanks 4000-2000 m3	Catastrophic failure of single tank in cluster	1,00E-06	$year^{-1}tank^{-1}$	16
Cluster tanks 4000-2000 m3	Major failure (hole diameter 400 mm)	1,00E-05	$year^{-1}tank^{-1}$	16
Cluster tanks 4000-2000 m4	Minor failure (hole diameter 120 mm)	5,00E-05	$year^{-1}tank^{-1}$	16
Cluster tanks 200-2000 m3	Simultaneous catastrophic failure of all tanks in cluster	1,00E-06	$year^{-1}$	16
Cluster tanks 200-2000 m3	Catastrophic failure of single tank in cluster	1,00E-06	$year^{-1}tank^{-1}$	16
Cluster tanks 200-2000 m3	Major failure (hole diameter 250 mm)	1,00E-05	$year^{-1}tank^{-1}$	16
Cluster tanks 200-2000 m4	Minor failure (hole diameter 75 mm)	5,00E-05	$year^{-1}tank^{-1}$	16
Pressure Vessels	Catastrophic release (upper failures)	6,00E-06	$year^{-1}vessel^{-1}$	18
Pressure Vessels	Catastrophic release (median failures)	4,00E-06	$year^{-1}vessel^{-1}$	18
Pressure Vessels	Catastrophic release (lower failures)	2,00E-06	$year^{-1}vessel^{-1}$	18
Pressure Vessels	50 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	18
Pressure Vessels	25 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	18
Pressure Vessels	13 mm diameter hole release	1,00E-05	$year^{-1}vessel^{-1}$	18
Pressure Vessels	6 mm diameter hole release	4,00E-05	$year^{-1}vessel^{-1}$	18
Chlorine pressure Vessels	Catastrophic release (use where site specific factors increase likehood of failure)	4,00E-06	$year^{-1}vessel^{-1}$	23
Chlorine pressure Vessels	Catastrophic release (normal value)	2,00E-06	$year^{-1}vessel^{-1}$	23
Chlorine pressure Vessels	50 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	23
Chlorine pressure Vessels	25 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	23
Chlorine pressure Vessels	13 mm diameter hole release	1,00E-05	$year^{-1}vessel^{-1}$	23

Source of danger	Basic event	Probability	Unit	Page
Chlorine pressure Vessels	6 mm diameter hole release	4,00E-05	$year^{-1}vessel^{-1}$	23
LPG pressure Vessels	Catastrophic release (cold vessel failures)	2,00E-06	$year^{-1}vessel^{-1}$	25
LPG pressure Vessels	BLEVE (Boiling liquid expanding vapour explosion)	1,00E-05	$year^{-1}vessel^{-1}$	25
LPG pressure Vessels	50 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	25
LPG pressure Vessels	25 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	25
LPG pressure Vessels	13 mm diameter hole release	1,00E-05	$year^{-1}vessel^{-1}$	25
Spherical Vessels	Catastrophic release (upper failures)	6,00E-06	$year^{-1}vessel^{-1}$	28
Spherical Vessels	Catastrophic release (median failures)	4,00E-06	$year^{-1}vessel^{-1}$	28
Spherical Vessels	Catastrophic release (lower failures)	2,00E-06	$year^{-1}vessel^{-1}$	28
Spherical Vessels	50 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	28
Spherical Vessels	25 mm diameter hole release	5,00E-06	$year^{-1}vessel^{-1}$	28
Spherical Vessels	13 mm diameter hole release	1,00E-05	$year^{-1}vessel^{-1}$	28
Spherical Vessels	6 mm diameter hole release	4,00E-05	$year^{-1}vessel^{-1}$	28
Chemical reactors	Catastrophic release	1,00E-05	$year^{-1}reactor^{-1}$	29
Chemical reactors	50 mm diameter hole release	5,00E-06	$year^{-1}reactor^{-1}$	29
Chemical reactors	25 mm diameter hole release	5,00E-06	$year^{-1}reactor^{-1}$	29
Chemical reactors	13 mm diameter hole release	1,00E-05	$year^{-1}reactor^{-1}$	29
Chemical reactors	6 mm diameter hole release	4,00E-05	$year^{-1}reactor^{-1}$	29
Manual valves (Exc. Human error)	Failure to close	1,00E-04	$failure^{-1}demand^{-1}$	32
Remotely Operated Shutoff Valves (ROSOV) (Inc. Human error)	Failure to close	3,00E-02	$failure^{-1}demand^{-1}$	32
Automatic shut-off valves (ASOV)	Failure to close	1,00E-02	$failure^{-1}demand^{-1}$	32
Excess flow valves (XSFV) valves	Failure to operate	1,30E-02	$failure^{-1}demand^{-1}$	32

Source of danger	Basic event	Probability	Unit	Page
Valves	Spray release	2,00E-04	$year^{-1}valve^{-1}$	32
Pumps	Failure of casing	3,00E-05	$year^{-1}pump^{-1}$	36
Pump single seal	Spray release	5,00E-04	$year^{-1}pump^{-1}$	36
Pump double seal	Spray release	5,00E-05	$year^{-1}pump^{-1}$	36
Hose and coupling basic facilities	Guillotine failure	4,00E-05	$transfer^{-1}$	39
Hose and coupling average facilities	Guillotine failure	4,00E-06	$transfer^{-1}$	39
Hose and coupling multi safety system facilities	Guillotine failure	2,00E-07	$transfer^{-1}$	39
Hose and coupling basic facilities	15 mm diameter hole	1,00E-06	$transfer^{-1}$	39
Hose and coupling average facilities	15 mm diameter hole	4,00E-07	$transfer^{-1}$	39
Hose and coupling multi safety system facilities	15 mm diameter hole	4,00E-07	$transfer^{-1}$	39
Hose and coupling basic facilities	5 mm diameter hole	1,30E-05	$transfer^{-1}$	39
Hose and coupling average facilities	5 mm diameter hole	6,00E-06	$transfer^{-1}$	39
Hose and coupling multi safety system facilities	5 mm diameter hole	6,00E-06	$transfer^{-1}$	39
Hose and coupling	Spray release	1,20E-07	$transfer^{-1}$	39
Hard arms	Guillotine failure	2,00E-07	$transfer^{-1}$	43
Hard arms	15 mm diameter hole	4,00E-07	$transfer^{-1}$	43
Hard arms	5 mm diameter hole	6,00E-06	$transfer^{-1}$	43
Flanges and gaskets	Failure of one segment of a gasket	5,00E-06	$year^{-1}joint^{-1}$	45
Flanges and gaskets	Failure of spiral wound gasket	1,00E-07	$year^{-1}joint^{-1}$	45
Fixed pipe flange	Spray release	5,00E-06	$year^{-1}flange^{-1}$	45
Pipework (diameter 0-49mm)	Hole size 3mm diameter	1,00E-05	$year^{-1}metre^{-1}$	48

Source of danger	Basic event	Probability	Unit	Page
Pipework (diameter 50-149mm)	Hole size 3mm diameter	2,00E-06	year^{-1}metre^{-1}	48
Pipework (diameter 150-299mm)	Hole size 4mm diameter	1,00E-06	year^{-1}metre^{-1}	48
Pipework (diameter 300-499mm)	Hole size 4mm diameter	8,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 500-1000mm)	Hole size 4mm diameter	7,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 0-49mm)	Hole size 25mm diameter	5,00E-06	year^{-1}metre^{-1}	48
Pipework (diameter 50-149mm)	Hole size 25mm diameter	1,00E-06	year^{-1}metre^{-1}	48
Pipework (diameter 150-299mm)	Hole size 25mm diameter	7,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 300-499mm)	Hole size 25mm diameter	5,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 500-1000mm)	Hole size 25mm diameter	4,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 150-299mm)	Hole size 1/3 pipework diameter	4,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 300-499mm)	Hole size 1/3 pipework diameter	2,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 500-1000mm)	Hole size 1/3 pipework diameter	1,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 0-49mm)	Hole size: guillotine	1,00E-06	year^{-1}metre^{-1}	48
Pipework (diameter 50-149mm)	Hole size: guillotine	5,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 150-299mm)	Hole size: guillotine	2,00E-07	year^{-1}metre^{-1}	48
Pipework (diameter 300-499mm)	Hole size: guillotine	7,00E-08	year^{-1}metre^{-1}	48
Pipework (diameter 500-1000mm)	Hole size: guillotine	4,00E-08	year^{-1}metre^{-1}	48
Above ground pipelines in gas installation	Rupture (>110mm diameter)	6,50E-09	year^{-1}metre^{-1}	58
Above ground pipelines in gas installation	Large Hole (>75 – ≤110mm)	3,30E-08	year^{-1}metre^{-1}	58
Above ground pipelines in gas installation	Small Hole (>25 mm – ≤75 mm diameter)	6,70E-08	year^{-1}metre^{-1}	58
Above ground pipelines in gas installation	Pin Hole (≤25 mm diameter)	1,60E-07	year^{-1}metre^{-1}	58
Centrifugal compressor	Rupture (>110mm diameter)	2,90E-06	year^{-1}compressor^{-1}	61
Centrifugal compressor	Large Hole (>75 – ≤110mm)	2,90E-06	year^{-1}compressor^{-1}	61

Source of danger	Basic event	Probability	Unit	Page
Centrifugal compressor	Small Hole (>25 mm – ≤75 mm diameter)	2,70E-04	$year^{-1}compressor^{-1}$	61
Centrifugal compressor	Pin Hole (≤25 mm diameter)	1,20E-02	$year^{-1}compressor^{-1}$	61
Reciprocating compressor	Rupture (>110mm diameter)	1,40E-05	$year^{-1}compressor^{-1}$	61
Reciprocating compressor	Large Hole (>75 – ≤110mm)	1,40E-05	$year^{-1}compressor^{-1}$	61
Reciprocating compressor	Small Hole (>25 mm – ≤75 mm diameter)	3,30E-03	$year^{-1}compressor^{-1}$	61
Reciprocating compressor	Pin Hole (≤25 mm diameter)	8,60E-02	$year^{-1}compressor^{-1}$	61
Tank containers with a pressure relief system	Catastrophic failure	4,00E-06	$year^{-1}vessel^{-1}$	63
Tank containers with no pressure relief system	Catastrophic failure	3,00E-06	$year^{-1}vessel^{-1}$	63
Tanks containers	50 mm diameter hole	3,00E-05	$year^{-1}vessel^{-1}$	63
Tanks containers	25 mm diameter hole	3,00E-05	$year^{-1}vessel^{-1}$	63
Tanks containers	13 mm diameter hole	6,00E-05	$year^{-1}vessel^{-1}$	63
Tanks containers	4 mm diameter hole	3,00E-04	$year^{-1}vessel^{-1}$	63
Tanks containers	vapour release (50 mm diameter hole)	5,00E-04	$year^{-1}vessel^{-1}$	63
Tanks containers	50 mm diameter hole (Failures due to dropping of the tank < 5 metres)	6,00E-07	$year^{-1}lift^{-1}$	63
Tanks containers	Catastrophic failure (Failures due to dropping of the tank > 5 metres)	3,00E-08	$year^{-1}lift^{-1}$	63
Tanks containers	50 mm diameter hole (Failures due to dropping of the tank > 5 metres)	6,00E-07	$year^{-1}lift^{-1}$	63
Tanks containers	50 mm diameter hole (Failures due to a container being dropped on to the tank)	9,00E-11	$year^{-1}pass^{-1}$	63
Road tankers	Serious accident rate	2,20E-07	km^{-1}	65
LPG road tanker	LPG road tanker BLEVE (sites with small tanks)	1,00E-07	$year^{-1}delivery^{-1}$	67
LPG road tanker	LPG road tanker BLEVE (sites with large tanks)	1,10E-08	$year^{-1}delivery^{-1}$	67

Source of danger	Basic event	Probability	Unit	Page
Incompatible deliveries: below average	Incompatible deliveries: below average	6,00E-06	year^{-1}delivery^{-1}	69
Incompatible deliveries: average	Incompatible deliveries: average	1,00E-07	year^{-1}delivery^{-1}	69
Incompatible deliveries: above average	Incompatible deliveries: above average	5,00E-08	year^{-1}delivery^{-1}	69
Transfer of liquefied gases (when 1 arm used)	Guillotine break	7,00E-06	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 1 arm used)	Hole=0,1 cross sectional area of pipe	8,00E-06	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 2 arms used)	Guillotine break	1,30E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 2 arms used)	Hole=0,1 cross sectional area of pipe	1,60E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 2 arms used)	Simultaneous guillotine breaks (for multiple arms)	1,00E-07	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 3 arms used)	Guillotine break	1,90E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 3 arms used)	Hole=0,1 cross sectional area of pipe	2,40E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquefied gases (when 3 arms used)	Simultaneous guillotine breaks (for multiple arms)	1,00E-07	year^{-1}transfer operation^{-1}	73
Transfer of liquid cargo (when 1 arm used)	Guillotine break	3,80E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquid cargo (when 1 arm used)	Hole=0,1 cross sectional area of pipe	3,30E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquid cargo (when 2 arms used)	Guillotine break	5,00E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquid cargo (when 2 arms used)	Hole=0,1 cross sectional area of pipe	6,60E-05	year^{-1}transfer operation^{-1}	73
Transfer of liquid cargo (when 2 arms used)	Simultaneous guillotine breaks (for multiple arms)	2,60E-06	year^{-1}transfer operation^{-1}	73

Source of danger	Basic event	Probability	Unit	Page
Transfer of liquid cargo (when 3 arms used)	Guillotine break	6,20E-05	$year^{-1}$transfer operation^{-1}	74
Transfer of liquid cargo (when 3 arms used)	Hole=0,1 cross sectional area of pipe	9,90E-05	$year^{-1}$transfer operation^{-1}	74
Transfer of liquid cargo (when 3 arms used)	Simultaneous guillotine breaks (for multiple arms)	2,60E-06	$year^{-1}$transfer operation^{-1}	74
Drums 1 te	Spontaneous drum failure	2,00E-06	$year^{-1}$. average number of drums stored on site	77
Drums 1 te	Coupling failure (guillotine)	1,20E-06	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Coupling failure (leak)	5,00E-06	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Coupling error (liquid) (Liquid off-take plants x 10 for sites with automatic)	4,50E-06	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Coupling error (liquid) (Gas off-take plant)	4,50E-06	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Coupling error (vapour)	1,00E-05	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Uncoupling error (liquid)	9,00E-05	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Uncoupling error (vapour)	1,00E-06	$year^{-1}$. total number of drums used on the site	77
Drums 1 te	Pipework	1,00E-08	$year^{-1}$. total number of drums used on the site	77
Drums 210 litre	Catastrophic (2 × drum contents released)	1,00E-06	$year^{-1}$. total number of drums used on the site	77

Source of danger	Basic event	Probability	Unit	Page
Drums 210 litre	Catastrophic (1 × drum contents released)	1,00E-05	$year^{-1}$. total number of drums used on the site	77
Drums 210 litre	Major failure of 2 drums (10 mm hole)	1,00E-04	$year^{-1}$. total number of drums used on the site	77
Drums 210 litre	Major failure of 1 drum (10 mm hole)	3,00E-06	$year^{-1}$. total number of drums used on the site	77
Human Factors	Human factors	1,00E-01	$year^{-1}$	98

Source of danger	Basic event	Probability 1	Probability 2	Unit 1	Unit 2	Page
IBCs (Intermediate Bulk Containers)	Catastrophic	7,10E-05	1,40E-05	$year^{-1}n^{-1}$	$year^{-1}N^{-1}$	82
IBCs (Intermediate Bulk Containers)	Major (10 mm hole)	1,13E-04	1,30E-05	$year^{-1}n^{-1}$	$year^{-1}N^{-1}$	82
IBCs (Intermediate Bulk Containers)	Minor (5 mm hole)	5,20E-05	9,30E-04	$year^{-1}n^{-1}$	$year^{-1}N^{-1}$	82

* n (nº containers passing through the site)

** N (average nº of containers continuously in store)

Source of danger	Basic event	Probability	Unit	Page
Drums 210 litre	Catastrophic (2 × drum contents released)	0,000084*T/4	$year^{-1}$	79
Drums 210 litre	Catastrophic (1 × drum contents released)	0,000002*T/4	$year^{-1}$	79
Drums 210 litre	Major failure of 2 drums (10 mm hole)	0,000036*T/4	$year^{-1}$	79
Drums 210 litre	Major failure of 1 drum (10 mm hole)	0,000002*T/4	$year^{-1}$	79
Drums 210 litre	Minor failure of 1 drum (5 mm hole)	(6*10^-6 T/4) + (8*10^-5Q)	$year^{-1}$	79

* T is the throughput per year

** Q is the maximum number of drums in storage at any time

Source of danger	Basic event	Probability	Unit	Page
Portable containers	Catastrophic container failure	2,00E-06	$year^{-1}$ N^{-1}	84
Portable containers	Holes in container (large - 10mm)	1,20E-06	$year^{-1}$ n^{-1}	84
Portable containers	Holes in container (small - 5mm)	5,00E-06	$year^{-1}$ n^{-1}	84

* N is the average number of containers stored on site

** n is the number of movements per container x the total number of containers passing through the site per year

B. FG 2009 - *Handbook failure frequencies 2009 for drawing a safety report. Flemish Government. LNE Department. Environment, Nature and Energy Policy Unit. Safety Reporting Division.*

Source of danger	Basic event	Probability	Unit	Page
Storage tanks above ground, road tankers and tankwagons	Small leak (0,1 < d ≤ 10 mm (deq = 10 mm))	1,20E-05	$year^{-1}tank^{-1}$	12
Storage tanks above ground, road tankers and tankwagons	Medium leak (10 < d ≤ 50 mm (deq = 25 mm))	1,10E-06	$year^{-1}tank^{-1}$	12
Storage tanks above ground, road tankers and tankwagons	Large leak (50 < d ≤ Dmax (deq = DL, max))	1,10E-06	$year^{-1}tank^{-1}$	12
Storage tanks above ground, road tankers and tankwagons	Complete outflow (Complete outflow in 10 min)	3,20E-07	$year^{-1}tank^{-1}$	12
Storage tanks above ground, road tankers and tankwagons	Rupture	3,20E-07	$year^{-1}tank^{-1}$	12
Underground or mounded	Small leak (0,1 < d ≤ 10 mm (deq = 10 mm))	1,20E-05	$year^{-1}tank^{-1}$	12
Underground or mounded	Medium leak (10 < d ≤ 50 mm (deq = 25 mm))	1,10E-06	$year^{-1}tank^{-1}$	12
Underground or mounded	Large leak (50 < d ≤ Dmax (deq = DL, max))	1,10E-06	$year^{-1}tank^{-1}$	12
Underground or mounded	Complete outflow (Complete outflow in 10 min)	1,00E-07	$year^{-1}tank^{-1}$	12
Underground or mounded	Rupture	1,00E-07	$year^{-1}tank^{-1}$	12
Process installations and other	Small leak (0,1 < d ≤ 10 mm (deq = 10 mm))	1,20E-04	$year^{-1}tank^{-1}$	12
Process installations and other	Medium leak (10 < d ≤ 50 mm (deq = 25 mm))	1,10E-05	$year^{-1}tank^{-1}$	12

Source of danger	Basic event	Probability	Unit	Page
Process installations and other	Large leak (50 < d ≤ Dmax (deq = DL, max))	1,10E-05	$year^{-1}tank^{-1}$	12
Process installations and other	Complete outflow (Complete outflow in 10 min)	3,20E-06	$year^{-1}tank^{-1}$	12
Process installations and other	Rupture	3,20E-06	$year^{-1}tank^{-1}$	12
Gas cylinder	Leak (deq=Dmax)	-	$year^{-1}cylinder^{-1}$	13
Gas cylinder	Rupture	1,10E-06	$year^{-1}cylinder^{-1}$	13
Pressure vessel	Leak (deq=Dmax)	1,10E-05	$year^{-1}cylinder^{-1}$	13
Pressure vessel	Rupture	1,10E-06	$year^{-1}cylinder^{-1}$	13
Storage tank type 1 (incl. road tankers and tankwagons), 2, 3, 4 and underground or mounded	Small leak (0,1 < d ≤ 10 mm; deq = 10 mm)	2,40E-03	$year^{-1}tank^{-1}$	14
Process installations and other	Small leak (0,1 < d ≤ 10 mm; deq = 10 mm)	2,40E-02	$year^{-1}tank^{-1}$	14
Storage tank type 1 (incl. road tankers and tankwagons), 2, 3, 4 and underground or mounded	Medium leak (10 < d ≤ 50 mm; deq = 25 mm)	2,20E-04	$year^{-1}tank^{-1}$	14
Process installations and other	Medium leak (10 < d ≤ 50 mm; deq = 25 mm)	2,20E-03	$year^{-1}tank^{-1}$	14
Storage tank type 1 (incl. road tankers and tankwagons), 2, 3, 4 and underground or mounded	Large leak (50 < d ≤ Dmax; deq = DL,max)	2,20E-04	$year^{-1}tank^{-1}$	14
Process installations and other	Large leak (50 < d ≤ Dmax; deq = DL,max)	2,20E-03	$year^{-1}tank^{-1}$	14
Storage tank type 1	Complete outflow in 10 min	5,00E-06	$year^{-1}tank^{-1}$	14
Storage tank type 2	Complete outflow in 10 min	5,00E-07	$year^{-1}tank^{-1}$	14
Storage tank type 3	Complete outflow in 10 min	1,20E-08	$year^{-1}tank^{-1}$	14
Storage tank type 4	Complete outflow in 10 min	1,00E-08	$year^{-1}tank^{-1}$	14

Source of danger	Basic event	Probability	Unit	Page
Underground or mounded storage tanks	Complete outflow in 10 min	1,00E-08	$year^{-1}tank^{-1}$	14
Process installations and other	Complete outflow in 10 min	5,00E-05	$year^{-1}tank^{-1}$	14
Storage tank type 1	Rupture	5,00E-06	$year^{-1}tank^{-1}$	14
Storage tank type 2	Rupture	5,00E-07	$year^{-1}tank^{-1}$	14
Storage tank type 3	Rupture	1,20E-08	$year^{-1}tank^{-1}$	14
Storage tank type 4	Rupture	1,00E-08	$year^{-1}tank^{-1}$	14
Underground or mounded storage tanks	Rupture	1,00E-08	$year^{-1}tank^{-1}$	14
Process installations and other	Rupture	5,00E-05	$year^{-1}tank^{-1}$	14
Tank with external floating roof	Tank fire (P1 liquid)	2,50E-04	$year^{-1}tank^{-1}$	16
Tank with external floating roof	Tank fire (P2 liquid)	7,60E-05	$year^{-1}tank^{-1}$	16
Tank with external floating roof	Tank fire (P3 and P4 liquids)	2,30E-05	$year^{-1}tank^{-1}$	16
Tank with fixed roof without nitrogen blanket	Tank fire (P1 liquid)	6,90E-04	$year^{-1}tank^{-1}$	16
Tank with fixed roof without nitrogen blanket	Tank fire (P2 liquid)	2,10E-04	$year^{-1}tank^{-1}$	16
Tank with fixed roof without nitrogen blanket	Tank fire (P3 and P4 liquids)	6,20E-05	$year^{-1}tank^{-1}$	16
Tank with fixed roof with nitrogen blanket	Tank fire (P1 liquid)	2,50E-04	$year^{-1}tank^{-1}$	16
Tank with fixed roof with nitrogen blanket	Tank fire (P2 liquid)	7,60E-05	$year^{-1}tank^{-1}$	16
Tank with fixed roof with nitrogen blanket	Tank fire (P3 and P4 liquids)	2,30E-05	$year^{-1}tank^{-1}$	16
Pipe heat exchangers	Small leak. 0 < d ≤ 25 mm (deq = 10 mm)	6,00E-03	$year^{-1}$heat exchanger^{-1}	17
Pipe heat exchangers	Medium leak. 25 < d ≤ 50 mm (deq = 35 mm)	3,90E-03	$year^{-1}$heat exchanger^{-1}	17
Pipe heat exchangers	Large leak. 50 < d ≤ 150 mm (deq = 100 mm)	1,60E-05	$year^{-1}$heat exchanger^{-1}	17
Pipe heat exchangers	Rupture	1,30E-05	$year^{-1}$heat	17

Source of danger	Basic event	Probability	Unit	Page
			exchanger^{-1}	
Plate heat exchangers (Working pressure (P) < 5 bar)	Small leak. 0 < d ≤ 25 mm (deq = 10 mm)	4,6E-03	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) < 5 bar)	Medium leak. 25 < d ≤ 50 mm (deq = 35 mm)	2,0E-03	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) < 5 bar)	Rupture	5,5E-06	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 5 - 8 bar)	Small leak. 0 < d ≤ 25 mm (deq = 10 mm)	7,0E-03	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 5 - 8 bar)	Medium leak. 25 < d ≤ 50 mm (deq = 35 mm)	3,0E-03	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 5 - 8 bar)	Rupture	8,3E-06	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 8 bar)	Small leak. 0 < d ≤ 25 mm (deq = 10 mm)	3,6E+02	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 8 bar)	Medium leak. 25 < d ≤ 50 mm (deq = 35 mm)	7,2E-03	year^{-1}plate heat exchanger^{-1}	18
Plate heat exchangers (Working pressure (P) >= 8 bar)	Rupture	2,0E-05	year^{-1}plate heat exchanger^{-1}	18
Centrifugal pumps with gaskets	Leak. deq = 0,1 Dmax	4,4E-03	year^{-1}pump^{-1}	19
Reciprocating pumps	Leak. deq = 0,1 Dmax	4,4E-03	year^{-1}pump^{-1}	19
Compressors	Leak. deq = 0,1 Dmax	4,4E-03	year^{-1}compressor^{-1}	19
Centrifugal pumps without gaskets	Leak. deq = 0,1 Dmax	1,00E-04	year^{-1}pump^{-1}	19
Compressors	Rupture	1,0E-04	year^{-1}compressor^{-1}	19
Reciprocating pumps	Rupture	1,0E-04	year^{-1}pump^{-1}	19
Above ground pipeline	Small leak. deq = 0,1 D	2,80E-07	L/D year^{-1}	20

Source of danger	Basic event	Probability	Unit	Page
Above ground pipeline	Medium leak. deq = 0,15 D	1,20E-07	L/D $year^{-1}$	20
Above ground pipeline	Large leak. deq = 0,36 D	5,00E-08	L/D $year^{-1}$	20
Above ground pipeline	Rupture	2,20E-08	L/D $year^{-1}$	20
Underground pipeline	Crack. deq = 10 mm	7,90E-08	$year^{-1}metre^{-1}$	20
Underground pipeline	Hole. deq = 0,5 D	6,90E-08	$year^{-1}metre^{-1}$	20
Underground pipeline	Rupture	2,80E-08	$year^{-1}metre^{-1}$	20
(Un)loading arm	Leak. deq=0,1 D(max. 50 mm)	3,00E-07	$hour^{-1}$	21
(Un)loading arm	Rupture	3,00E-08	$hour^{-1}$	21
Hose	Leak. deq=0,1 D(max. 50 mm)	4,00E-05	$hour^{-1}$	21
Hose	Rupture	4,00E-06	$hour^{-1}$	21
Hose for LPG	Leak. deq=0,1 D(max. 50 mm)	5,40E-06	$hour^{-1}$	21
Hose for LPG	Rupture	5,40E-07	$hour^{-1}$	21
Fire in warehouse without an automatic fire fighting system	Fire	2,50E-03	$year^{-1}$fire $compartment^{-1}$	22
Fire in warehouse with an automatic fire fighting system	Fire	6,90E-04	$year^{-1}$fire $compartment^{-1}$	22
Packaging unit storage	One packaging unit fails	2,50E-05	packaging unit $year^{-1}$	23
Packaging unit handling	One packaging unit fails	2,50E-05	handling of packaging $unit^{-1}$	23
Packaging unit handling	All packaging units on a pallet fail	2,50E-06	handling of packaging $unit^{-1}$	23

C. VROM 2005 - *Guidelines for quantitative risk assessment. PUBLICATIEREEKS GEVAARLIJKE STOFFEN. Publication Series on Dangerous Substances* (PGS 3). *Ministerie van Verkeer en Waterstaat.*

Source of danger	Basic event	Probability	Unit	Page
Stationary tanks and vessels, pressurised. Pressure vessel	Instantaneous release of the complete inventory	5,00E-07	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Pressure vessel	Continuous release of the complete inventory in 10 min at a constant rate of release	5,00E-07	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Pressure vessel	Continuous release from a hole with an effective diameter of 10 mm	1,00E-05	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Process vessel	Instantaneous release of the complete inventory	5,00E-06	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Process vessel	Continuous release of the complete inventory in 10 min at a constant rate of release	5,00E-06	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Process vessel	Continuous release from a hole with an effective diameter of 10 mm	1,00E-04	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Reactor vessel	Instantaneous release of the complete inventory	5,00E-06	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Reactor vessel	Continuous release of the complete inventory in 10 min at a constant rate of release	5,00E-06	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels, pressurised. Reactor vessel	Continuous release from a hole with an effective diameter of 10 mm	1,00E-04	$year^{-1}vessel^{-1}$	3.3
Stationary tanks and vessels,atmospheric. Singlecontainment tank	Instantaneous release of the complete inventory directly to the atmosphere	5,00E-06	$year^{-1}tank^{-1}$	3.6

Source of danger	Basic event	Probability	Unit	Page
Stationary tanks and vessels,atmospheric. Singlecontainment tank	Continuous release of the complete inventory in 10 min at a constant rate of release directly to the atmosphere	5,00E-06	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Singlecontainment tank	Continuous release from a hole with an effective diameter of 10 mm directly to the atmosphere	1,00E-04	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Tank with a protective outer shell	Instantaneous release of the complete inventory directly to the atmosphere	5,00E-07	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Tank with a protective outer shell	Instantaneous release of the complete inventory from the primary container into the unimpaired secondary container or outer shell	5,00E-07	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Tank with a protective outer shell	Continuous release of the complete inventory in 10 min at a constant rate of release directly to the atmosphere	5,00E-07	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Tank with a protective outer shell	Continuous release of the complete inventory in 10 min at a constant rate of release from the primary container into the unimpaired secondary container or outer shell	5,00E-07	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Tank with a protective outer shell	Continuous release from a hole with an effective diameter of 10 mm from the primary container into the unimpaired secondary container or outer shell	1,00E-04	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Double containment tank	Instantaneous release of the complete inventory directly to the atmosphere	1,25E-08	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Double containment tank	Instantaneous release of the complete inventory from the primary container into the unimpaired secondary container or	5,00E-08	$year^{-1}tank^{-1}$	3.6

Source of danger	Basic event	Probability	Unit	Page
	outer shell			
Stationary tanks and vessels,atmospheric. Double containment tank	Continuous release of the complete inventory in 10 min at a constant rate of release directly to the atmosphere	1,25E-08	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Double containment tank	Continuous release of the complete inventory in 10 min at a constant rate of release from the primary container into the unimpaired secondary container or outer shell	5,00E-08	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Double containment tank	Continuous release from a hole with an effective diameter of 10 mm from the primary container into the unimpaired secondary container or outer shell	1,00E-04	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Full containment tank	Instantaneous release of the complete inventory directly to the atmosphere	1,00E-08	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. In-ground tank	Instantaneous release of the complete inventory from the primary container into the unimpaired secondary container or outer shell	1,00E-08	$year^{-1}tank^{-1}$	3.6
Stationary tanks and vessels,atmospheric. Mounded tank	Instantaneous release of the complete inventory directly to the atmosphere	1,00E-08	$year^{-1}tank^{-1}$	3.6
Gas cylinders. Gas cylinder	Catastrophic failure (instant release)	1,00E-06	$year^{-1}cylinder^{-1}$	3.4
Pipes. Pipeline, nominal diameter < 75 mm	Full bore rupture	1,00E-06	$year^{-1}metre^{-1}$	3.7
Pipes. Pipeline, nominal diameter < 75 mm	Leak	5,00E-06	$year^{-1}metre^{-1}$	3.7
Pipes. Pipeline, 75 mm ≤ nominal diameter ≤ 150 mm	Full bore rupture	3,00E-07	$year^{-1}metre^{-1}$	3.7

Source of danger	Basic event	Probability	Unit	Page
Pipes. Pipeline, 75 mm ≤ nominal diameter ≤ 150 mm	Leak	2,00E-06	year^{-1}metre^{-1}	3.7
Pipes. Pipeline, nominal diameter > 150 mm	Full bore rupture	1,00E-07	year^{-1}metre^{-1}	3.7
Pipes. Pipeline, nominal diameter > 150 mm	Leak	5,00E-07	year^{-1}metre^{-1}	3.7
Pumps. Pumps without additional provisions	Catastrophic failure	1,00E-04	year^{-1}pump^{-1}	3.9
Pumps. Pumps without additional provisions	Leak	5,00E-04	year^{-1}pump^{-1}	3.9
Pumps. Pumps with a wrought steel containment	Catastrophic failure	5,00E-05	year^{-1}pump^{-1}	3.9
Pumps. Pumps with a wrought steel containment	Leak	2,50E-04	year^{-1}pump^{-1}	3.9
Pumps. Canned pumps	Catastrophic failure	1,00E-05	year^{-1}pump^{-1}	3.9
Pumps. Canned pumps	Leak	5,00E-05	year^{-1}pump^{-1}	3.9
Heat exchangers. Heat exchanger, dangerous substance outside pipes	Instantaneous release of the complete inventory	5,00E-05	year^{-1}heat exchanger^{-1}	3.10
Heat exchangers. Heat exchanger, dangerous substance outside pipes	Continuous release of the complete inventory in 10 min at a constant rate of release	5,00E-05	year^{-1}heat exchanger^{-1}	3.10
Heat exchangers. Heat exchanger, dangerous substance outside pipes	Continuous release from a hole with an effective diameter of 10 mm	1,00E-03	year^{-1}heat exchanger^{-1}	3.10
Heat exchangers. Heat exchanger, dangerous substance inside pipes, design pressure outer shell less than pressure of dangerous substance	Full bore rupture of ten pipes simultaneously, outflow from both sides of the full bore rupture	1,00E-05	year^{-1}heat exchanger^{-1}	3.10
Heat exchangers. Heat exchanger, dangerous substance inside pipes, design pressure outer shell less than pressure of dangerous substance	Full bore rupture of one pipe outflow from both sides of the full bore rupture	1,00E-03	year^{-1}heat exchanger^{-1}	3.10

Source of danger	Basic event	Probability	Unit	Page
Heat exchangers. Heat exchanger, dangerous substance inside pipes, design pressure outer shell less than pressure of dangerous substance	Leak, outflow from a leak with an effective diameter of 10% of the nominal diameter, with a maximum of 50 mm	1,00E-02	$year^{-1}$heat $exchanger^{-1}$	3.10
Heat exchangers. Heat exchanger, dangerous substance inside pipes, design pressure outer shell more than pressure of dangerous substance	Full bore rupture of ten pipes simultaneously, outflow from both sides of the full bore rupture	1,00E-06	$year^{-1}$heat $exchanger^{-1}$	3.10
Pressure relief devices. Pressure relief device	Discharge of a pressure relief device with maximum discharge rate	2,00E-05	$year^{-1}devices^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection levels 1 and 2	Handling solids: dispersion of a fraction of the packaging unit inventory as respirable powder	1,00E-05	handling of packaging $unit^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection levels 1 and 2	Handling liquids: spill of the complete packaging unit inventory (liquid spill)	1,00E-05	handling of packaging $unit^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection levels 1 and 2	Emission of unburned toxics and toxics produced in the fire (fire)	8,80E-04	$year^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection level 3	Handling solids: dispersion of a fraction of the packaging unit inventory as respirable powder	1,00E-05	handling of packaging $unit^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection level 3	Handling liquids: spill of the complete packaging unit inventory (liquid spill)	1,00E-05	handling of packaging $unit^{-1}$	3.11
Warehouses. Storage of substances in warehouses with protection level 3	Emission of unburned toxics and toxics produced in the fire (fire)	1,80E-04	$year^{-1}$	3.11
Storage of explosives. Storage of explosives	Mass detonation	1,00E-05	$year^{-1}$	3.12
Road tankers and tank wagons. Tank, pressurised	Instantaneous release of the complete inventory	5,00E-07	$year^{-1}tank^{-1}$	3.14

Source of danger	Basic event	Probability	Unit	Page
Road tankers and tank wagons. Tank, pressurised	Continuous release from a hole the size of the largest connection. If the tank is (partly) filled with liquid, the release is modelled from the liquid phase out of the largest liquid connection.	5,00E-07	$year^{-1}tank^{-1}$	3.14
Road tankers and tank wagons. Tank, pressurised	Full bore rupture of the loading/unloading hose. The outflow is from both sides of the full bore rupture.	4,00E-06	$hour^{-1}$	3.14
Road tankers and tank wagons. Tank, pressurised	Leak of the loading/unloading hose. The outflow is from a leak with an effective diameter of 10% of the nominal diameter, with a maximum of 50 mm.	4,00E-05	$hour^{-1}$	3.14
Road tankers and tank wagons. Tank, pressurised	Full bore rupture of the loading/unloading arm. Outflow from both sides of the full bore rupture	3,00E-08	$hour^{-1}$	3.14
Road tankers and tank wagons. Tank, pressurised	Leak of the loading/unloading arm. Outflow from a leak with an effective diameter of 10% of the nominal diameter, with a maximum of 50 mm	3,00E-07	$hour^{-1}$	3.14
Road tankers and tank wagons. Tank, pressurised	Fire under tank, to be modelled as an instantaneous release of the complete inventory of the tank	1,00E-06	$year^{-1}tank^{-1}$	3.14
Road tankers and tank wagons. Tank, atmospheric	Instantaneous release of the complete inventory	1,00E-05	$year^{-1}tank^{-1}$	3.14
Road tankers and tank wagons. Tank, atmospheric	Continuous release from a hole the size of the largest connection. If the tank is (partly) filled with liquid, the release is modelled from the liquid phase out of the largest liquid connection.	5,00E-07	$year^{-1}tank^{-1}$	3.14

Source of danger	**Basic event**	**Probability**	**Unit**	**Page**
Road tankers and tank wagons. Tank, atmospheric	Full bore rupture of the loading/unloading hose. The outflow is from both sides of the full bore rupture.	4,00E-06	hour^{-1}	3.14
Road tankers and tank wagons. Tank, atmospheric	Leak of the loading/unloading hose. The outflow is from a leak with an effective diameter of 10% of the nominal diameter, with a maximum of 50 mm.	4,00E-05	hour^{-1}	3.14
Road tankers and tank wagons. Tank, atmospheric	Full bore rupture of the loading/unloading arm. Outflow from both sides of the full bore rupture	3,00E-08	hour^{-1}	3.14
Road tankers and tank wagons. Tank, atmospheric	Leak of the loading/unloading arm. Outflow from a leak with an effective diameter of 10% of the nominal diameter, with a maximum of 50 mm	3,00E-07	hour^{-1}	3.14
Road tankers and tank wagons. Tank, atmospheric	Fire under tank, to be modelled as an instantaneous release of the complete inventory of the tank	1,00E-05	year^{-1}tank^{-1}	3.14
Ships in an establishment. Single-walled liquid tanker	Full bore rupture of the loading/unloading arm outflow from both sides of the full bore rupture	6,00E-05	transhipment^{-1}	3.15
Ships in an establishment. Single-walled liquid tanker	Leak of the loading/unloading arm outflow from a leak with an effective diameter equal to 10% of the nominal diameter, with a maximum of 50 mm	6,00E-04	transhipment^{-1}	3.15
Ships in an establishment. Single-walled liquid tanker	External impact, large spill, continuous release of 75 m3 in 1800 s	6,70E-12	Total number of ships per year on the transport route or in the harbour^{-1}average duration of loading/unloading per ship (in hours)$^{-1}$Number of transhipments per year^{-1}	3.15

Source of danger	Basic event	Probability	Unit	Page
Ships in an establishment. Single-walled liquid tanker	External impact, small spill, continuous release of 30 m3 in 1800 s	1,34E-11	Total number of ships per year on the transport route or in the harbour^{-1}average duration of loading/unloading per ship (in hours)$^{-1}$Number of transhipments per year^{-1}	3.15
Ships in an establishment. Double-walled liquid tanker	Full bore rupture of the loading/unloading arm outflow from both sides of the full bore rupture	6,00E-05	transhipment^{-1}	3.15
Ships in an establishment. Double-walled liquid tanker	Leak of the loading/unloading arm outflow from a leak with an effective diameter equal to 10% of the nominal diameter, with a maximum of 50 mm	6,00E-04	transhipment^{-1}	3.15
Ships in an establishment. Double-walled liquid tanker	External impact, large spill, continuous release of 75 m3 in 1800 s	4,02E-13	Total number of ships per year on the transport route or in the harbour^{-1}average duration of loading/unloading per ship (in hours)$^{-1}$Number of transhipments per year^{-1}	3.15
Ships in an establishment. Double-walled liquid tanker	External impact, small spill, continuous release of 20 m3 in 1800 s	1,01E-13	Total number of ships per year on the transport route or in the harbour^{-1}average duration of loading/unloading per ship (in hours)$^{-1}$Number of transhipments per year^{-1}	3.15
Ships in an establishment. Gas tanker	Full bore rupture of the loading/unloading arm outflow from both sides of the full bore rupture	6,00E-05	transhipment^{-1}	3.15

Source of danger	Basic event	Probability	Unit	Page
Ships in an establishment. Gas tanker	Leak of the loading/unloading arm outflow from a leak with an effective diameter equal to 10% of the nominal diameter, with a maximum of 50 mm	6,00E-04	$transhipment^{-1}$	3.15
Ships in an establishment. Gas tanker	External impact, large spill, continuous release of 180 m3 in 1800 s	1,68E-12	Total number of ships per year on the transport route or in the $harbour^{-1}$average duration of loading/unloading per ship (in $hours)^{-1}$Number of transhipments per $year^{-1}$	3.15
Ships in an establishment. Gas tanker	External impact, small spill, continuous release of 90 m3 in 1800 s	8,04E-15	Total number of ships per year on the transport route or in the $harbour^{-1}$average duration of loading/unloading per ship (in $hours)^{-1}$Number of transhipments per $year^{-1}$	3.15
Ships in an establishment. Semi-gas tanker	Full bore rupture of the loading/unloading arm outflow from both sides of the full bore rupture	6,00E-05	$transhipment^{-1}$	3.15
Ships in an establishment. Semi-gas tanker	Leak of the loading/unloading arm outflow from a leak with an effective diameter equal to 10% of the nominal diameter, with a maximum of 50 mm	6,00E-04	$transhipment^{-1}$	3.15
Ships in an establishment. Semi-gas tanker	External impact, large spill, continuous release of 126 m3 in 1800 s	1,68E-12	Total number of ships per year on the transport route or in the $harbour^{-1}$average duration of loading/unloading per ship (in $hours)^{-1}$Number of transhipments per $year^{-1}$	3.15

Source of danger	Basic event	Probability	Unit	Page
Ships in an establishment. Semi-gas tanker	External impact, small spill, continuous release of 32 m3 in 1800 s	8,04E-15	Total number of ships per year on the transport route or in the harbour^{-1}average duration of loading/unloading per ship (in hours)$^{-1}$Number of transhipments per year^{-1}	3.15

2. CONDITIONING FACTORS BIBLIOGRAPHIC PROBABILITIES

A. HSE 2003 - *Assessment of benefits of fire compartmentation in chemical warehouses. Prepared by WS Atkins Consultants Ltd for the Health and Safety Executive.*

Category	System type	Probability	Unit	Page
Detection	Manual (Fuel Type 1)	9,00E-01	demand^{-1}	26
Detection	Manual (Fuel Type 2)	8,00E-01	demand^{-1}	26
Detection	Manual (Fuel Type 3)	7,00E-01	demand^{-1}	26
Detection	Manual (Fuel Type 4)	9,00E-01	demand^{-1}	26
Detection	Manual (Fuel Type 5)	8,00E-01	demand^{-1}	26
Detection	Automatic (Fuel Type 1)	2,00E-01	demand^{-1}	26
Detection	Automatic (Fuel Type 2)	2,00E-01	demand^{-1}	26
Detection	Automatic (Fuel Type 3)	2,00E-01	demand^{-1}	26
Detection	Automatic (Fuel Type 4)	2,00E-01	demand^{-1}	26
Detection	Automatic (Fuel Type 5)	2,00E-01	demand^{-1}	26

Category	System type	Probability	Unit	Page
Detection	Manual and automatic (Fuel Type 1)	1,80E-01	$demand^{-1}$	26
Detection	Manual and automatic (Fuel Type 2)	1,60E-01	$demand^{-1}$	26
Detection	Manual and automatic (Fuel Type 3)	1,40E-01	$demand^{-1}$	26
Detection	Manual and automatic (Fuel Type 4)	1,80E-01	$demand^{-1}$	26
Detection	Manual and automatic (Fuel Type 5)	1,60E-01	$demand^{-1}$	26
Suppression system	Water sprinklers (Fuel Type 1)	4,00E-01	$demand^{-1}$	28
Suppression system	Water sprinklers (Fuel Type 2)	3,00E-01	$demand^{-1}$	28
Suppression system	Water sprinklers (Fuel Type 3)	2,00E-01	$demand^{-1}$	28
Suppression system	Water sprinklers (Fuel Type 4)	1,00E-01	$demand^{-1}$	28
Suppression system	Water sprinklers (Fuel Type 5)	1,50E-01	$demand^{-1}$	28
Suppression system	Foam/water sprinklers (Fuel Type 1)	2,00E-01	$demand^{-1}$	28
Suppression system	Foam/water sprinklers (Fuel Type 2)	1,00E-01	$demand^{-1}$	28
Suppression system	Foam/water sprinklers (Fuel Type 3)	5,00E-02	$demand^{-1}$	28
Suppression system	Foam/water sprinklers (Fuel Type 4)	5,00E-02	$demand^{-1}$	28
Suppression system	Foam/water sprinklers (Fuel Type 5)	1,00E-01	$demand^{-1}$	28
Suppression system	Gaseous (Fuel Type 1)	2,00E-01	$demand^{-1}$	28
Suppression system	Gaseous (Fuel Type 2)	1,00E-01	$demand^{-1}$	28
Suppression system	Gaseous (Fuel Type 3)	5,00E-02	$demand^{-1}$	28
Suppression system	Gaseous (Fuel Type 4)	8,00E-01	$demand^{-1}$	28
Suppression system	Gaseous (Fuel Type 5)	9,00E-01	$demand^{-1}$	28
Suppression system	Manual (Fuel Type 1)	9,00E-01	$demand^{-1}$	28
Suppression system	Manual (Fuel Type 2)	8,00E-01	$demand^{-1}$	28
Suppression system	Manual (Fuel Type 3)	6,00E-01	$demand^{-1}$	28

Category	System type	Probability	Unit	Page
Suppression system	Manual (Fuel Type 4)	6,00E-01	$demand^{-1}$	28
Suppression system	Manual (Fuel Type 5)	8,00E-01	$demand^{-1}$	28

Fuel Type	
Fuel Type 1	Highly flammable liquid
Fuel Type 2	Flammable liquid
Fuel Type 3	Combustible liquid
Fuel Type 4	Metal compound
Fuel Type 5	Strong oxidising agent

B. FG 2009 - *Handbook failure frequencies 2009 for drawing a safety report. Flemish Government. LNE Department. Environment, Nature and Energy Policy Unit. Safety Reporting Division.*

Category	System type	Probability	Unit	Page
Blocking system	Automatic simple system	1,00E-01	$demand^{-1}$	24
Blocking system	Automatic redundant system	1,00E-02	$demand^{-1}$	24
Blocking system	Automatic diversely redundant system	1,00E-03	$demand^{-1}$	24
Blocking system	Semi-automatic	[0,1-0,01]	$demand^{-1}$	24
Excess flow valve	Outflow rate ≤ set value	1,00E+00	$demand^{-1}$	24
Excess flow valve	Set value < outflow rate ≤ 1.2 × set value	1,20E-01	$demand^{-1}$	24
Excess flow valve	Outflow rate > 1.2 × set value	6,00E-02	$demand^{-1}$	24
Non-return valve tested regularly	Non-return valve tested regularly	6,00E-02	$demand^{-1}$	24
Operator intervention during (un)loading activity	Operator intervention during (un)loading activity	1,00E-01	$demand^{-1}$	24
Passive repression systems	Passive repression systems	0,00E+00	$demand^{-1}$	24
Other repression systems	Other repression systems	1,00E-01	$demand^{-1}$	27

C. **VROM 2005 -** ***Guidelines for quantitative risk assessment. PUBLICATIEREEKS GEVAARLIJKE STOFFEN. Publication Series on Dangerous Substances (PGS 3). Ministerie van Verkeer en Waterstaat*.**

Category	Probability	Unit	Page
Automatic blocking system	1,00E-03	$demand^{-1}$	4.5
Remote-controlled blocking system	1,00E-02	$demand^{-1}$	4.5
Hand-operated blocking system	1,00E-02	$demand^{-1}$	4.5
Other repression systems	5,00E-02	$demand^{-1}$	4.6

MINISTRY
FOR THE ECOLOGICAL TRANSITION
AND THE DEMOGRAPHIC CHALLENGE

SECRETARY OF STATE
FOR THE ENVIRONMENT

DIRECTORATE GENERAL FOR
ENVIRONMENTAL QUALITY AND ASSESSMENT

ENVIRONMENTAL LIABILITY INFORMATION SYSTEM (SIRMA)

USER´S GUIDE

ANNEX II: IDM agents-resources combinations

TECHNICAL COMMISSION OF PREVENTION AND REMEDIATION OF ENVIRONMENTAL DAMAGES

1. INTRODUCTION

This annex includes a series of indications to help users in the interpretation and use of the agents-resources combinations considered within the IDM application, that is show below.

<table>
<tr><th colspan="3" rowspan="4"></th><th colspan="8">Resource</th></tr>
<tr><th colspan="3">Water</th><th rowspan="3">Continental shelf and seabed</th><th rowspan="3">Soil</th><th rowspan="3">Sea and estuary banks</th><th colspan="2">Species</th></tr>
<tr><th rowspan="2">Marine</th><th colspan="2">Continental</th><th rowspan="2">Plants</th><th rowspan="2">Fauna</th></tr>
<tr><th>Surface</th><th>Underground</th></tr>
<tr><td rowspan="15">Agent causing the damage</td><td rowspan="7">Chemical</td><td>Halogenated VOC</td><td rowspan="5">Group 1</td><td rowspan="7">Group 2</td><td rowspan="7">Group 5</td><td></td><td rowspan="7">Group 9</td><td rowspan="5">Group 10</td><td rowspan="7">Group 11</td><td rowspan="7">Group 16</td></tr>
<tr><td>Non-halogenated VOC</td><td></td></tr>
<tr><td>Halogenated SVOC</td><td></td></tr>
<tr><td>Non-halogenated SVOC</td><td></td></tr>
<tr><td>Fuels and NVOC</td><td rowspan="3">Group 7</td></tr>
<tr><td>Inorganic substances</td><td></td><td></td></tr>
<tr><td>Explosives</td><td></td><td></td></tr>
<tr><td rowspan="3">Physical</td><td>Extraction/Disappearance</td><td></td><td>Group 3</td><td>Group 6</td><td></td><td rowspan="2">Group 3</td><td></td><td>Group 12</td><td>Group 17</td></tr>
<tr><td>Inert waste discharge</td><td></td><td></td><td></td><td>Group 8</td><td></td><td></td><td></td></tr>
<tr><td>Temperature</td><td></td><td>Group 4</td><td></td><td></td><td>Group 4</td><td></td><td>Group 13</td><td>Group 18</td></tr>
<tr><td colspan="2">Fire</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Group 14</td><td>Group 19</td></tr>
<tr><td rowspan="4">Biological</td><td>GMO</td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">Group 15</td><td rowspan="3">Group 20</td></tr>
<tr><td>Invasive alien species</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Virus and bacteria</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fungi and insects</td><td></td><td></td><td></td><td></td><td></td><td></td><td>Group 15</td><td></td></tr>
</table>

Figure AI.1.-1 IDM agent-resources combinations. Source: Regulation of partial development of Law 26/2007

2. SPECIFIC INDICATIONS

2.1. MARINE WATER

Marine water damages will affect its chemical properties and/or its environmental status.

In the group of chemical pollutants, the only ones not included in the table are: 1) explosive substances denser than water, because it is considered they would provoke damages to the seabed and not the marine water itself; and 2) those substances that are foreseen to dissolve in the water (inorganic substances and some explosives), since being marine waters a very resilient resource, it has not been possible to identify specific remediation techniques for them.

The same applies for physical damages caused by abstraction of seawater. For this damage to be relevant, it would be necessary to be of high magnitude. The same applies to damages caused by temperature.

Some combinations such as the spill of inert substances in marine waters, are already covered in other combinations, in this case a damage by inert substances to seabed.

Biological damages are note considered in the table, since they would be related to marine species and not marine waters itself.

2.2. CONTINENTAL SURFACE WATERS

As in the case of marine waters, in continental surface waters it is only considered those agents that affect their chemical properties and environmental damage.

In the same way, the spill of inert substances is considered as a damage to the continental bed.

Biological damages are note considered in the table, since they would be related to the species and not the continental waters.

2.3. CONTINENTAL GROUNDWATER

As in the previous cases, groundwater damage is only considered by those agents that affect their physic-chemical properties and environmental damage.

Due to its depth and difficulty to access them, it is considered they can not be affected by inert substances of temperature variations.

Biological damages would be excluded for the same reason given for marine waters and continental surface waters.

2.4. CONTINENTAL SHEALF AND SEABED

Only substances denser than water can affect these resources. Therefore volatile and semi volatile chemical substances are excluded in this case.

The damages caused by the rest of agents (temperature, fire and biological) are not considered as being able to cause damage to these resources.

2.5. SOIL

Soil damage is considered as a modification of its physic-chemical properties.

Therefore, the only agents that are not considered relevant to cause damage to soil are fire and biological agents. A fire would only affect the top layer of the terrain and not damaging a significant amount of the resource, and its remediation would be linked to a remediation of the plants or fauna present in the soil.

2.6. SEA AND ESTUARY BASINS

This resource is linked to marine waters resource since the most common damages that can affect both resources are caused by fuels, VOC and SVOC.

In the rest of options not included in the table, the approach would be similar to that in the case of soil or a combination of soil and water.

As in the case of soil and water, fire and biological agents are not considered as having an impact.

2.7. PLANTS

In the damages caused to plants only two agents are not considered:

- Inerts. The surface affected by inter substances are not usually high enough to cause significant damage to plants. In case this occurs, they could be treated as a combination of soil and damage to plants by extraction.
- Viruses and bacteria. They are considered to cause damage only to fauna.

2.8. FAUNA

As in the case of plants (or flora), only two agents are not considered:

- Inerts. Due to the movility of fauna it is not likely to affect them. In any case, it could be treated as a damage to soil and fauna by extraction.

- Fungi and insects. They usually affect flora.

For determining if a specie is threatened it is proposed to use as a source of information the categories of the International Union for Conservation of Nature (IUCN). In this sense, the species considered as threatened will be those in the category of critical danger, in danger and vulnerable. The rest will ben considered as non threatened.

MINISTRY
FOR THE ECOLOGICAL TRANSITION
AND THE DEMOGRAPHIC CHALLENGE

SECRETARY OF STATE
FOR THE ENVIRONMENT

DIRECTORATE GENERAL FOR
ENVIRONMENTAL QUALITY AND ASSESSMENT

ENVIRONMENTAL LIABILITY INFORMATION SYSTEM (SIRMA)

USER´S GUIDE

SIRMA
Sistema de Información de Responsabilidad Medioambiental

ANNEX III: IDM modifiers

TECHNICAL COMMISSION OF PREVENTION AND REMEDIATION OF ENVIRONMENTAL DAMAGES

1. INTRODUCTION

This annex includes a description of the modifier used in the IDM equation and are taken from the Regulation of partial development of Law 26/2007.

In the equation of the IDM, the modifiers that allow for the estimation of the affected resources based on the amount of agent released (type B modifiers) make up the characteristics of the damage causing agent and the environment that condition their greater or lesser diffusion in the receiving environment. Likewise, modifiers of the unit cost estimator (type A modifiers) and the revision and control cost estimator (type C modifiers) have been identified.

The following figure shows the different types of modifiers (A, B and C) indicated in the IDM equation.

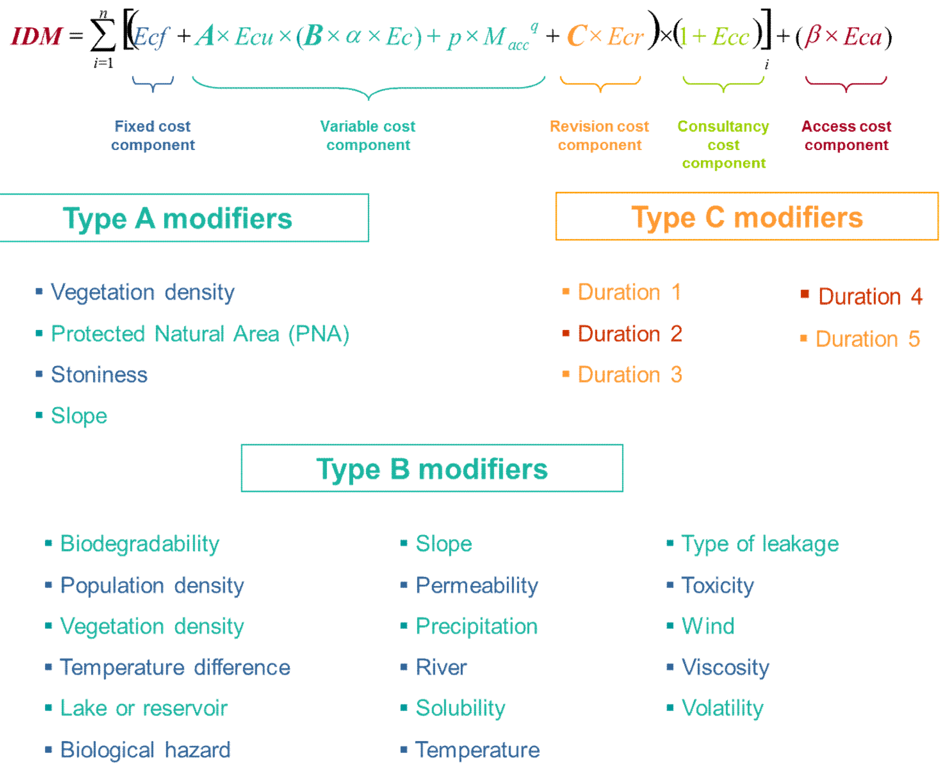


Figure 1. IDM Estimation: list of type A, B and C modifiers. Source: Prepared by the authors.

2. DESCRIPTION OF THE MODIFIERS

2.1. MODIFIER OF THE COST UNIT ESTIMATOR (M_A)

2.1.1. VEGETATION DENSITY

As modifier o the cost unit, and considering "Tragsa rates 2007", vegetation density determines the remedial technique, according to the number of feet per hectare needed to replant in case of trees and a mean density in the case of scrub and grassland.

Cathegories	Description	Value
Very dense	Foot density higher than 700 feet/ha. Scrub or grassland very dense	1,20
Medium	Foot density 50-700 feet/ha. Scrub or grassland density medium	1,00
Low density	Foot density lower than 50 pies/ha. Scrub or grassland low density	0,50

2.1.2. PROTECTED NATURAL AREA (PNA)

IDM methodology takes into account the possible damage protected natural areas, as an increase in the remedial project cost.

Cathegories	Description	Value
PNA	Possible damage to a PNA	1,25
No PNA	No damage to a PNA	1,00

2.1.3. STONINESS

In order to determine the difficulty to access da place where the damage occurs, two categories have been described. They are based on the costs of reforestation in Tragsa costs 2007.

Cathegories	Description	Value
Stony soil	Soil with rocks of all sizes. Irregular soils	1,10
Non Stony soil	Soils with compacted materials. Soils easily passable.	1,00

2.1.4. Slope

The slope is very indicative in the remedial techniques costs taking into account Tragsa costs 2007.

Cathegories	Description	Value
High	Average slope > 50%	1,50
Medium	Average slope between 30 and 50%	1,25
Low	Average slope < 30%	1,00

2.2. Modifiers of the amount of receptor affected (M_B)

2.2.1. Biodegradability

There are different expressions to represent biological degradability. To evaluate this modifier, it is recommended to check the security sheets as those gathered in the European Chemical Substances Information System (http://esis.jrc.ec.europa.eu/)

Cathegories	Description	Value
High	High biodegradability	1,00
Medium	Medium biodegradability	0,90
Low	Low biodegradability	0,80

2.2.2. Population density

IDM methodology proposes a scale based on semiquantitative criteria to establish the population density in the area affected by a damage:

Cathegories	Description	Value
Very dense	There are many references on the presence of the specie in the area. There is a high number of individuals per surface unit compared with other comparable populations of the same species.	2,00
Medium	There is a high number of references on the presence of the specie in the area. There is a medium number of individuals per surface unit compared with other comparable populations of the same species.	1,50
Low density	There are scarce references on the presence of the specie in the area. There is a low number of individuals per surface unit compared with other comparable populations of the same species.	1,00

2.2.3. VEGETATION DENSITY

Vegetation density has been classified taking into account the number of feet per hectare needed for carrying out the reforestation, in the case of forests, and an average qualitative density in the case of scrub and grassland. The use of this modifier is based on the information required by the BEHAVE (USDA) fire forest model.

Cathegories	Description	Value
Very dense	Foot density higher than 700 feet/ha. Scrub or grassland very dense	1,20
Medium	Foot density 50-700 feet/ha. Scrub or grassland density medium	1,00
Low density	Foot density lower than 50 pies/ha. Scrub or grassland low density	0,50

2.2.4. TEMPERATURA DIFFERENCE

In the case of damages caused by temperature, it has been considered that the difference of temperature between the agent and the resource determines the amount of resource potentially affected. The different categories have been established taking into account the average temperature difference of the water in a river in Spain (between 5ºC and 25 ºC) and the range of temperatures in a common industrial spill (between 5ºC and 100 ºC). These ranges have been considered taking into account expert´s criteria.

Cathegories	Description	Value
High	Temperature differece > 50 ºC	2,00
Medium	Temperature differece between 20 and 50 ºC	1,50
Low	Temperature differece < 20 ºC	1,00

2.2.5. LAKE OR RESERVOIR

The information on the size of lakes or reservoirs have been obtained from the Spanish Inventory of Dams and Reservoirs (MITERD).

Cathegories	Description	Value
Big	Volume > 100 hm^3	3,00
Mediourn size	Volume between 5 and 100 hm^3	2,00
Small	Volume < 5 hm^3	1,50
No damage	No damage	1,00

2.2.6. Hazard or danger

This is taken into account in damages caused by biological agents only (GMO, alien species or pathogen microorganisms). The higher their hazard level, the bigger the damages they can cause. The technical criteria taken into account have been based on the legislation on genetically modified organisms (GMO).

Cathegories	Description	Value
High	Very high probability of causing a severe illness or replace other organisms and high probability of propagation to other collectives. In the case of GMO it refers to a moderate or high confinement degree (GMO 3 or 4)	3,00
Medium	Possibility of causing illness or replace other organisms but low probability of propagation to other collectives. In the case of GMO it refers to a medium confinement degree (GMO 2)	2,00
Low	Very low probability of causing illness or replace other organisms. In the case of GMO it refers to a low confinement degree (GMO 1)	1,00

2.2.7. Slope

Based on the BEHAVE (USDA) model.

Cathegories	Description	Value
High	Average slope > 10%	2,50
Medium	Average slope between 5 and 10%	1,00
Low	Average slope < 5%	0,50

2.2.8. Permeability 1

This modifier refers to soil. Based on (GRIMAZ, S., 2007 y 2008).

Cathegories	Description	Value
High	High permeability soil (gravel, sand, fractured limestone, etc.)	2,00
Medium	Medium permeability soil (silts, etc.)	1,50
Low	Low permeability soil (clays, non fractured rock, etc.)	1,00

2.2.9. Permeability 2

This modifier refers to groundwater. Based on (GRIMAZ, S., 2007 y 2008).

Cathegories	Description	Value
High	High permeability soil (gravel, sand, fractured limestone, etc.)	3,00
Medium	Medium permeability soil (silts, etc.)	2,00
Low	Low permeability soil (clays, non-fractured rock, etc.)	1,00

2.2.10. Rainfal

Based on BEHAVE (USDA) and the Iberian Climatic Atlas (MITERD, 2011).

Cathegories	Description	Value
Dry area	Average rainfall < 400 mm	2,50
Medium rainfal area	Average rainfall between 400 and 700 mm	1,00
Wet area	Average rainfall > 700 mm	0,50

2.2.11. River tipology

River typologies according to their flow where an industrial spill can occur are classified according to the Environmental Profile of Spain (MITERD)

Cathegories	Description	Value
Average Flow high	Average Flow >100 m^3/s	2,00
Average Flow moderate	Average Flow between 5 and 100 m^3/s	1,50
Average Flow low	Average Flow < 5 m^3/s	1,25
No damage	No damage	1,00

2.2.12. Solubility

Based on FAO (2000).

Cathegories	Description	Value
Non soluble	Solubility < 0,1 mg/l of water at 20ºC	1,00
Solubility low	Solubility between 0,1 and 10 mg/l of water at 20ºC	0,90
Solubility high	Solubility > 10 mg/l of water at 20ºC	0,80

2.2.13. TEMPERATURE

Air temperature has been introduced based on BEHAVE (USDA) and the Iberian Climatic Atlas (MITERD, 2011).

Cathegories	Description	Value
High	Air temperature > 17,5 ºC	2,50
Medium	Air temperature between 10 and 17,5 ºC	1,00
Low	Air temperature < 10 ºC	0,50

2.2.14. TIPE OF LEAKAGE

Based on GRIMAZ, S. (2007 y 2008).

Cathegories	Description	Value
Growing leakage	The volume of the leakage increases through time	1,50
Continiuos leakage	The volume of the leakage is constant through time	1,25
Instantaneous leakage	The volume of the leakage is almost instantaneous	1,00

2.2.15. TOXICITY

Chemical substances toxicity is described in three categories based on the intensity of the adverse effects the organisms exposed to them experience in a time period. The adverse effects are related to mortality, immobility, growth inhibition, etc (ECB, 2003).

Cathegories	Description	Value
High	Substances with clear and short-term adverse effects, with evident consequences on the ecosystems and their habitats and species. Foreseen effect in at least 50% of the population exposed to the agent causing the damage	2,00
Medium	Substances with possible and long-term adverse effects in 10% to 50% of the population exposed to the agent causing the damage	1,50
Low	Substances that may affect at least at 1% of the population exposed to the agent causing the damage	1,00

2.2.16. WIND

Based on BEHAVE (USDA) and Atlas Nacional de España (ANE).

Cathegories	Description	Value
Strong	Average wind speed > 5 m/s	2,50
Medium	Average wind speed between 1 and 5 m/s	1,00
Low	Average wind speed < 1 m/s	0,50

2.2.17. VISCOSITY

Based on GRIMAZ, S. (2007 y 2008).

Cathegories	Description	Value
Low viscosity	Substances such as water, solvents, etc.	1,25
Medium viscosity	Medium viscosity substances	1,10
High viscosity	High viscosity substances such as resins, Sustancias de elevada viscosidad como resinas, bituminous material, etc.	1,00

2.2.18. VOLATILITY

Based on the scale used to classify chemical substances using the boiling point used in MORA.

Cathegories	Description	Value
Low	Boiling point > 325 ºC	1,00
Medium	Boiling point between 100 and 325 ºC	0,90
High	Boiling point < 100 ºC	0,80

2.3. MODIFIERS OF REVISION AND CONTROL COST ESTIMATOR (M_C)

The IDM methodology defines damage duration the time elapsed between the moment the damage occurs, and the remedial measures restore the natural resources to its baseline condition. The longer the duration, the higher the revision and control costs associated to the remedial project.

Five different scales have been created to adapt it to the different agent-resource combinations:

2.3.1. DURATION MODIFIER 1

Based on the information on surface water remedial measures provided by FRTR (since 1990).

Cathegories	Description	Value
High	> 1 year	1,25
Medium	6 months - 1 year	1,10
Low	< 6 months	1,00

2.3.2. DURATION MODIFIER 2

Based on the information on groundwater remedial measures provided by FRTR (since 1990).

Cathegories	Description	Value
High	> 10 years	1,25
Medium	3 years – 10 years	1,10
Low	< 3 years	1,00

2.3.3. DURATION MODIFIER 3

Based on the information on soil remedial measures provided by FRTR (since 1990).

Cathegories	Description	Value
High	> 2 years	1,25
Medium	6 months – 2 years	1,10
Low	< 6 months	1,00

2.3.4. DURATION MODIFIER 4

Addressed to flora based on the time needed to obtain a mass of vegetation similar to that affected.

Cathegories	Description	Value
High	Mature woodland, older than 30 years	1,25
Medium-high	Young Woodland, younger than 30 años	1,10
Medium-low	Scrub	1,05
Low	Grassland	1,00

2.3.5. DURATION MODIFIER 5

For fauna, the information has been derived from the MORA methodology, that is based on the information provided by the autonomous communities within the Technical commission of prevention and remediation of environmental damages.

Cathegories	Description	Value
High	Mammals	1,25
Low	Other species	1,00

MINISTRY
FOR THE ECOLOGICAL TRANSITION
AND THE DEMOGRAPHIC CHALLENGE

SECRETARY OF STATE
FOR THE ENVIRONMENT

DIRECTORATE GENERAL FOR
ENVIRONMENTAL QUALITY AND ASSESSMENT

ENVIRONMENTAL LIABILITY INFORMATION SYSTEM (SIRMA)

USER´S GUIDE

SIRMA
Sistema de Información de Responsabilidad Medioambiental

ANNEX IV: PRACTICAL EXAMPLE

TECHNICAL COMMISSION FOR THE PREVENTION AND REMEDIATION OF ENVIRONMENTAL DAMAGES

ÍNDICE

1. OBJECTIVE OF THE PRACTICAL EXAMPLE

The objective of this practical example is to illustrate the use of the Environmental Liability Information System (SIRMA), and more specifically the ARM, IDM and MORA applications. Its purpose is to identify each accident scenario resulting from basic or initiating events of a hypothetical installation and know its characteristics, as well as to estimate the IDM associated to each of them to select the reference accident scenario on which the monetization of the environmental damage will be carried out to calculate the amount of the financial security.

The example refers to an annex III of Law 26/2007 facility, although it is necessary to clarify that this is just a hypothetical example where substances and their volumes, probabilities and even accident scenarios have been randomly selected for illustration purposes. Therefore, there is no specific installation that groups all the identified scenarios and that has served as the basis for the drafting of this practical example, since the sole purpose of the example is to illustrate the way in which the amount of the financial security must calculate to comply with the obligations established by the Regulation of Partial Development of Law 26/2007, of October 23.

With the aim of simplifying the example, a facility that handles few substances and therefore has few scenarios has been assumed, and only the probability associated with a single scenario has been entered into detail, giving, of the rest of the accidental scenarios, only the final values that would result for each of them.

2. DESCRIPTION OF THE FACILITY AND ACTIVITY

In this section the substances that can damage the natural resources that can be affected are described, as well as the characteristics of the environment that are relevant for the estimation of the IDM.

It is important to mention that, as a rule, this section should provide, in addition to the aspects included in this document, a summary of the general characteristics of the activity carried out as well as a description of the different phases of the production process in the facility. This complementary information, which in any case should accompany the Environmental Risk Analysis (ARM for its acronym in Spanish), has been omitted in the preparation of this practical case to focus specifically on the use of SIRMA for this example.

2.1. SUBSTANCES

In the current practical example, it has been supposed that, among the total substances handled the ones that can produce an environmental damage on natural resources in the scope of Law 26/2007 are only seven. The rest of substances are considered not as so dangerous or not handled in enough amounts to produce an environmental damage. It is important to highlight that, as will be describe in the following sections, in this example some scenarios in which do not exist a chemical substance causing them have been identified (fires).

A table is attached below with the relevant physic-chemical properties, with a view to estimating the IDM, of each of these substances.

Substances	Physic-chemical properties				
	Degradability	Solubility	Toxicity	Viscosity	Volatility
Substance A	High	Little soluble	High	Medium	High
Substance B	Medium	Insoluble	Medium	High	Medium
Substance C	Low	Very soluble	High	Medium	Medium
Substance D	Medium	Very soluble	High	Low	High
Substance E	Low	Very soluble	Medium	Medium	Medium
Substance F	Low	Insoluble	Low	Low	Medium
Substance G	Medium	Little soluble	High	Low	Low

Table AIV.2.1-1. Physic-chemical properties of the substances likely to cause damage to the environment. Source: Prepared by the authors.

2.2. NATURAL RESOURCES

It has been assumed that the lands adjacent to the facility are not paved, so that the soil resource would be susceptible to being damaged. In addition, there is an area occupied by a pine forest of 45 years old, which can also be affected by the hypothetical damage. On the other hand, it has been assumed that there is an aquifer in the area and that the terrain is not impermeable.

Therefore, the resources that could be affected are soil, groundwater, and habitat.

2.3. CHARACTERISTICS OF THE ENVIRONMENT

The following table shows the relevant characteristics of the environment with regard the IDM application.

Characteristics	Value
Depth of the aquifer	Shallow
Vegetation density	1.000 trees/ha
Protected natural area	No
Stony	No
Gradient	4%
Permeability	Medium (silty sands)
Average annual precipitation	1.000 mm
Average annual temperature	12,5ª
Average wind speed	4,5-5 m/s

Table AIV.2.3-1. Environmental characteristics of the installation. Source: Prepared by the authors.

3. DEVELOPMENT OF THE ENVIRONMENTAL RISK ANALYSIS (ARM FOR ITS ACRONYM IN SPANISH) FROM THE ARM APPLICATION

The ARM application is used to assist in developing the Environmental Risk Analysis in accordance with the methodology set forth in Law 26/2007, of October 23, on Environmental Liability and its Regulation for Partial Development. More specifically, it carries out the event tree analysis resulting from a basic or initiating event, following the scheme settled by UNE 150.008:2008 standard for environmental risk analysis and assessment.

In this practical example (to both the ARM module and IDM module), it has been assumed that the facility under study has different sources of danger distributed in the several zones that are shown in the following table. In addition, the initiation events associated with each of these sources of danger, are listed.

Zone	Sources of danger	Initiating event
Zone 1	Substance A	Spillage of substance A from equipment
	Substance B	Spillage of substance B from tank
	Substance C	Spillage of substance C from tank
	Substance D	Spillage of substance B from tank
	Substance G	Spillage of substance G from pipe
Zone 2	Substance E	Spillage of substance E from equipment
	Spark	Fire in zone 2
Zone 3	Substance F	Explosion/fire of substance F

Table AIV.3-1. Sources of danger and initiating events identified. Source: Prepared by the authors

It is important to highlight that in the fire in zone 2 there is not a substance associated to the initiating event, but it would be generated because of a spark, being this the source of danger that would produce the damage.

On the other hand, it has been assumed that, in the case of substance D, the consequences of an eventual accident would vary considerably whether the substance were spilled from a pipe or from a tank, since the volume released would be double in the second case. Nevertheless, this can occur by other multiple reasons, for example, because of the storage of the substance and the place in which it entries in the process are in different zones of the facility. In this case, each of them can have risks and prevention and avoidance measures sufficiently different so that their environmental consequences are also different, although the volume released into the environment was the same in both cases.

3.1. EXAMPLE OF DATA INTRODUCTION IN THE ARM MODULE

To illustrate how to use the ARM application and identify the accident scenarios that start from a source of danger, it is described below how the information is entered in the ARM module applied to a specific source of danger. In particular, it will be illustrated the source of danger: Underground Pipe-Substance G.

In the first screen of the ARM module, the general data of the report are entered: name, date of performance and user. The user will fill in the name box and click the button “Save” to continue the screen of sources of danger of the ARM report.

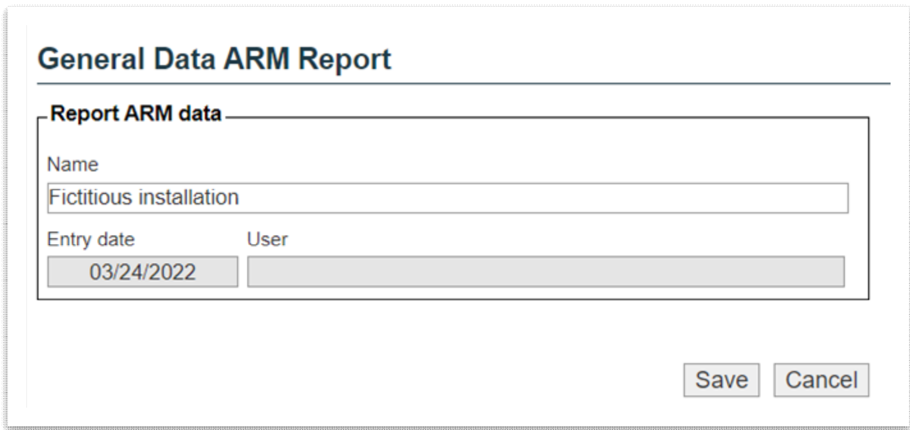


Figure AIV.3.1-1. General data of the ARM report screen. Source: SIRMA.

In the next screen, click on “Entry data of Source of danger” to enter the sources of danger for the installation in the report.

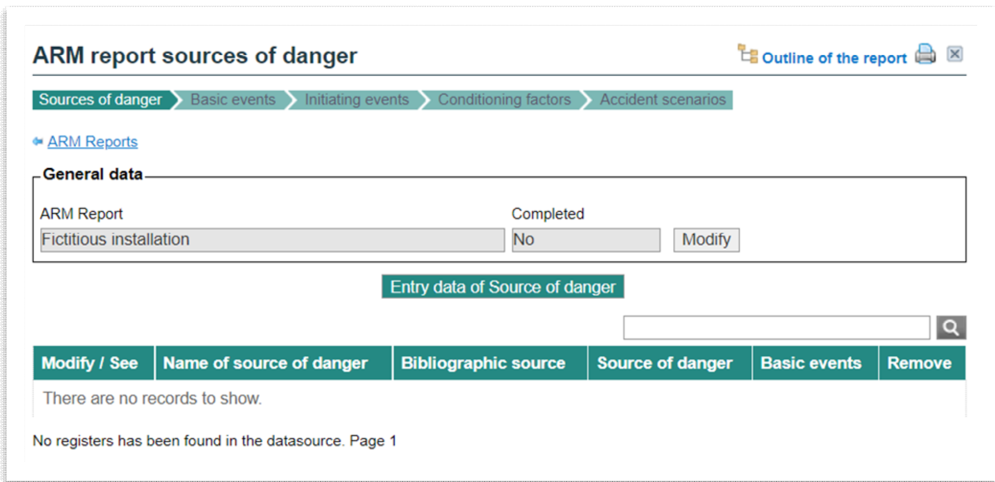


Figure AIV.3.1-2. Button of “Entry data of Source of danger” of the ARM report. Source: SIRMA.

Next, the general data of the source of danger are filled in/selected; its name, the bibliographic source you want to select to assign the probability of failure to the entered source of danger, the category to which the source of danger belongs, the source of danger (that specifies the source of danger as stated in the bibliography) and the observations that the user deems appropriate.

According to the information provided in Table AIV.3-1, the source of danger in question is "underground pipe of substance G" and the category "pipe systems". In addition, the bibliographic source Flemish Government 2009 is selected. Thus, the screen would be filled in as is shown in the following figure.

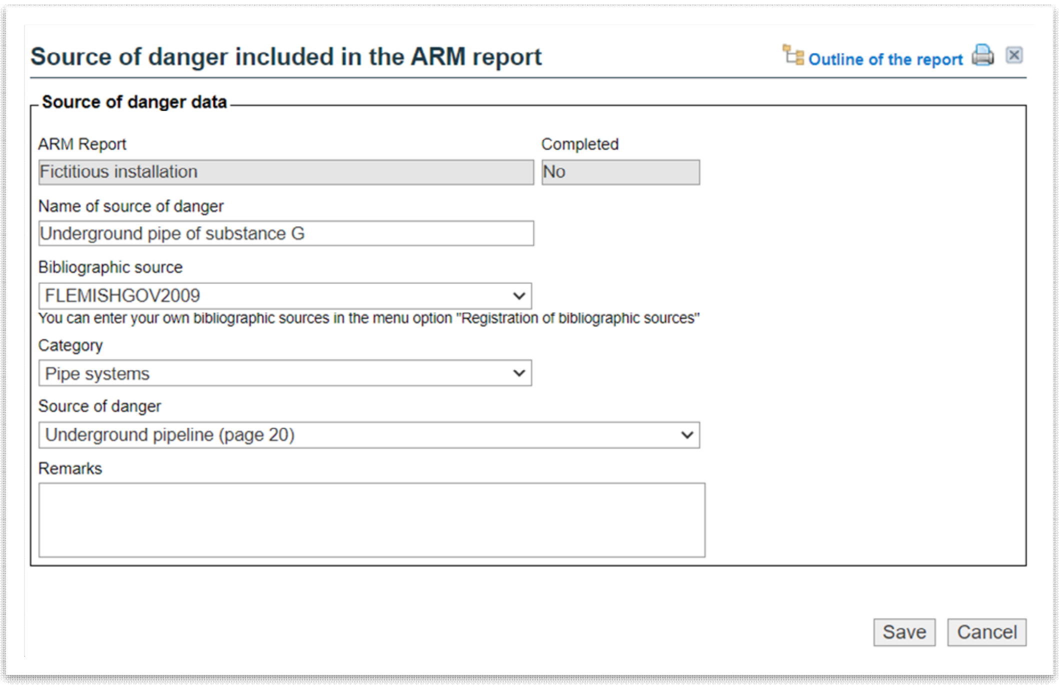


Figure AIV.3.1-3. Screen for enter the data of the source of danger associated with the ARM report. Source: SIRMA.

By pressing the "Save" button, a screen appears that shows a list of the sources of danger that the user has introduced in the report. To continue with the development of the report, they proceed to enter the basic events within the source of danger already introduced. To do this, click on the report icon (🗋) that appears under the column "Basic events" in the table.

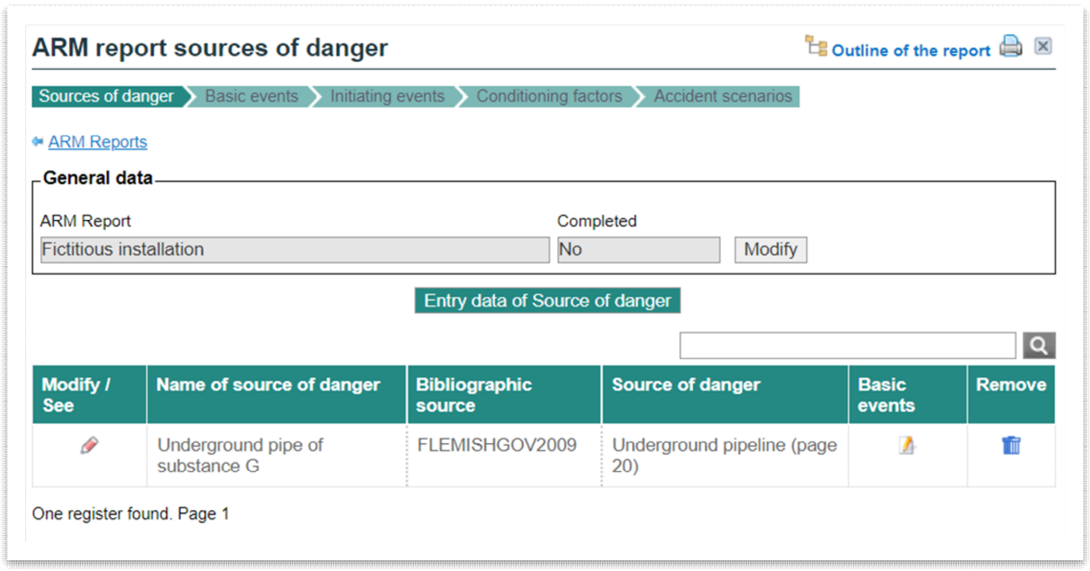


Figure AIV.3.1-4. Report button (🗋) under column "Basic events" in the table. Source: SIRMA.

To continue, click on "Entry data of Basic event" to go to the next screen.

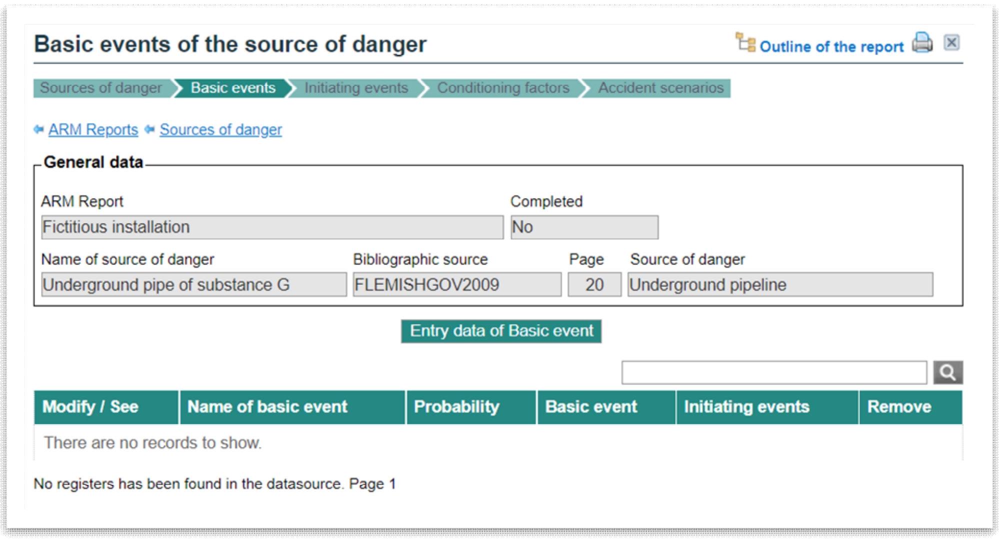


Figure AIV.3.1-5. "Entry data of Basic event" button. Source: SIRMA.

This screen includes the general data of the report, the data of the source of danger and a drop-down with the basic events associated with the selected source of danger, in this case, rupture. This basic event "rupture of the underground pipe of substance G" has an associated probability of occurrence that will be shown in the next screen.

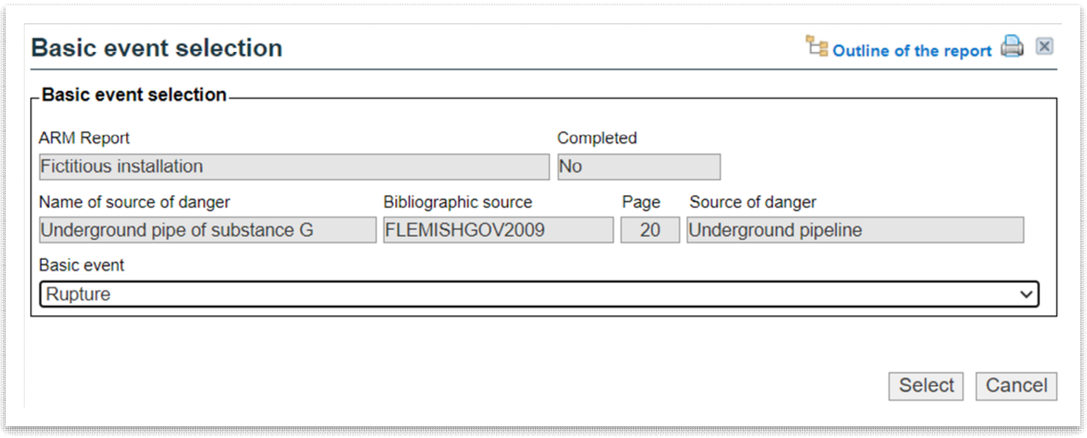


Figure AIV.3.1-6. Screen to enter the data of the basic event. Source: SIRMA.

In addition to the probability of occurrence of the basic event, in the next screen the application requests information regarding the characteristics of the source of danger to which the basic event is associated: meters, type of pollutant, type of reactivity (when applicable), type of discharge, name of the basic event and remarks on the basic event that the user considers proper (see figure below).

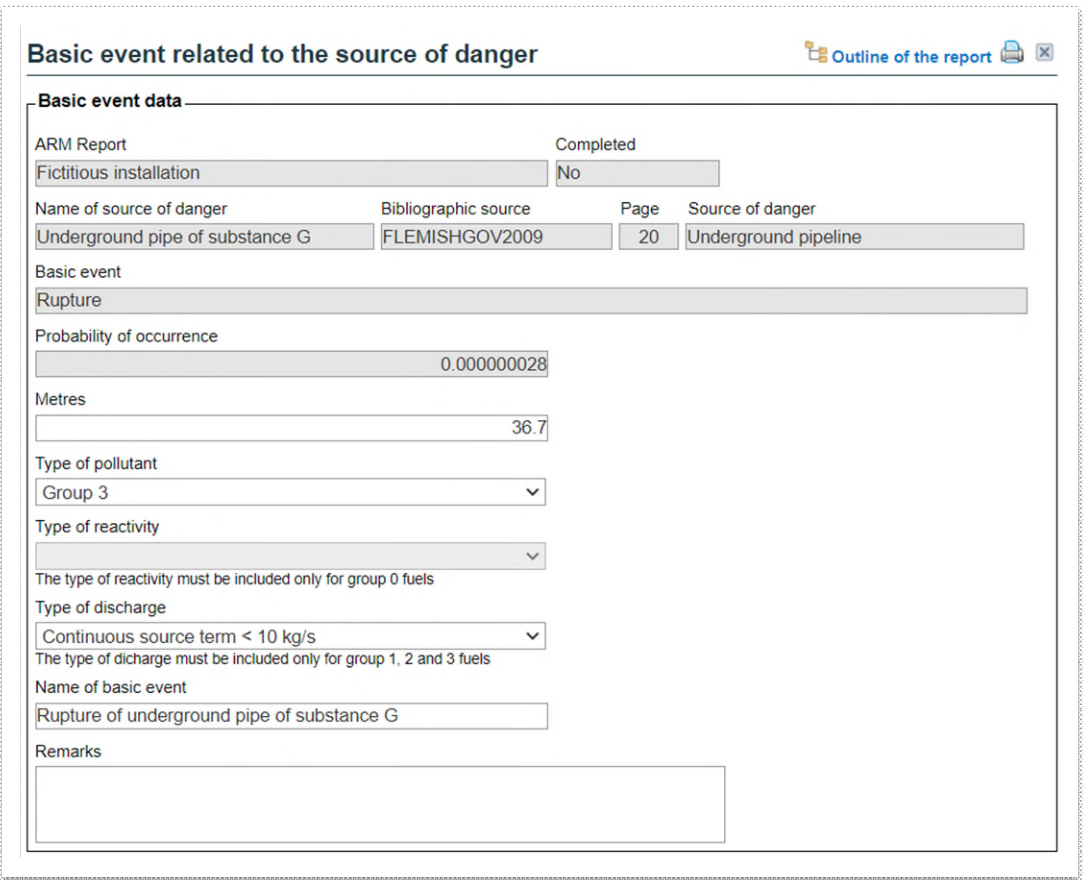


Figure AIV.3.1-7. Screen to enter data of the basic event associated with the source of danger. Source: SIRMA.

By pressing the “Save” button will return to the screen of basic events of the source of danger, which now includes the data of the basic events entered in a table, as shown in the following figure. If the user wishes to add new basic events, they must repeat the same process by pressing the “Entry data of Basic event” again.

To continue with the development of the report, the initiating events are entered within the basic event already entered. To do this, click on the report icon (🗋) that appears under the “Initiating events” column in the table.

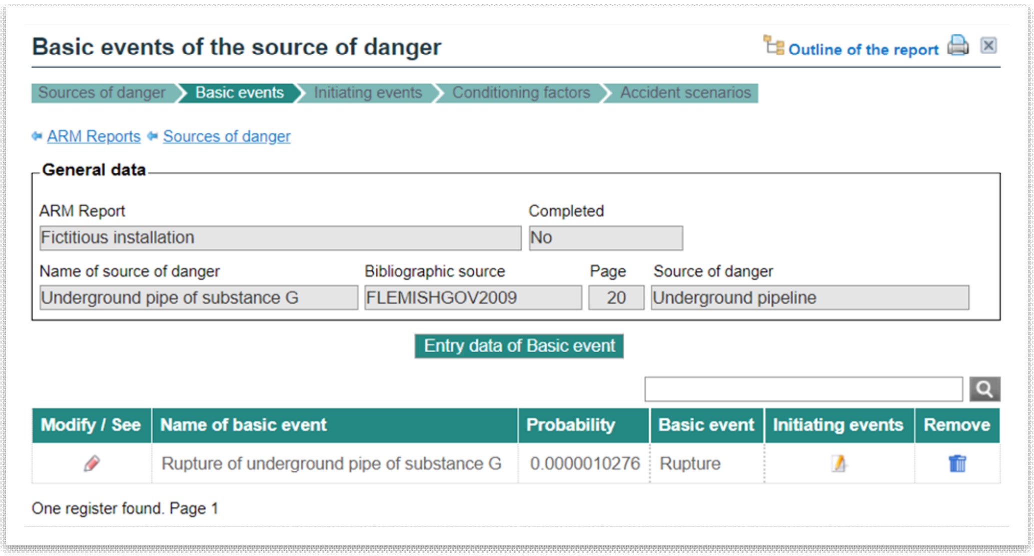


Figure AIV.3.1-8. Screen of the list of basic events of the source of danger. Source: SIRMA.

The next screen includes in the upper table the general data of the report, the data of the source of danger and the data of the basic event.

By pressing on the “Modify/see” section of each initiating event (by clicking on the “pencil” icon 🖉), the volume of pollutant associated with each of the initiating events generated is included first. This action, required to continue with the analysis and entered the conditioning factors, it is indicated in the said screen with the following warning message:

“*Data of the initiating event must be reported in order to access to the conditioning factors*”.

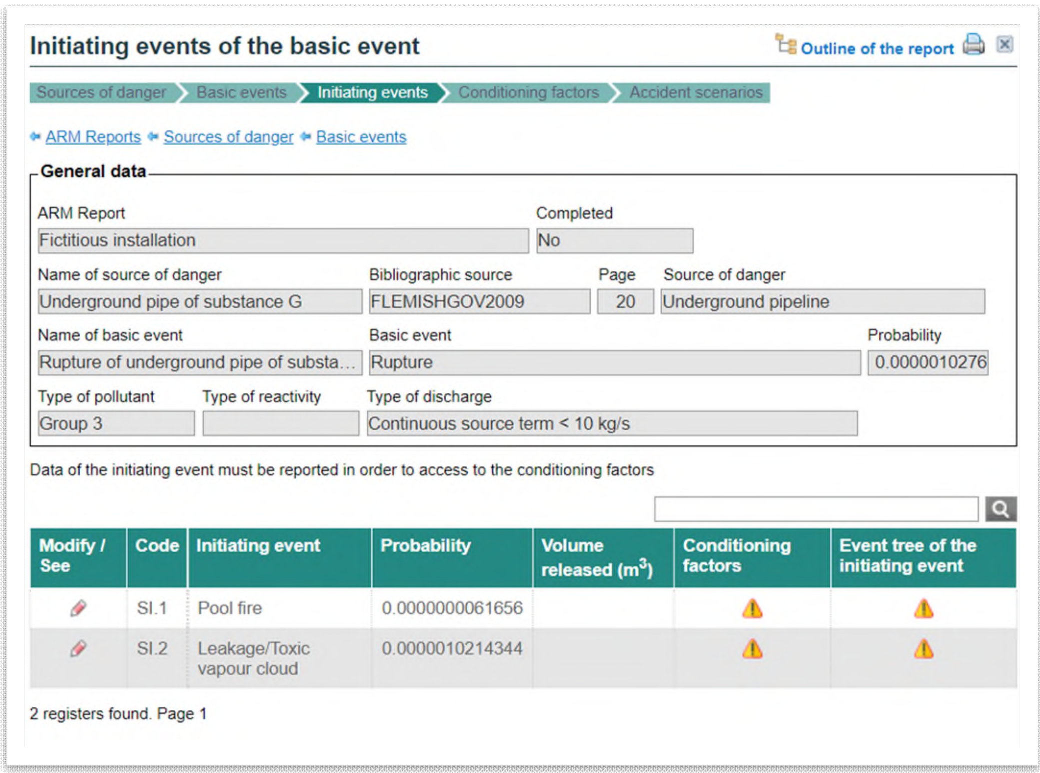
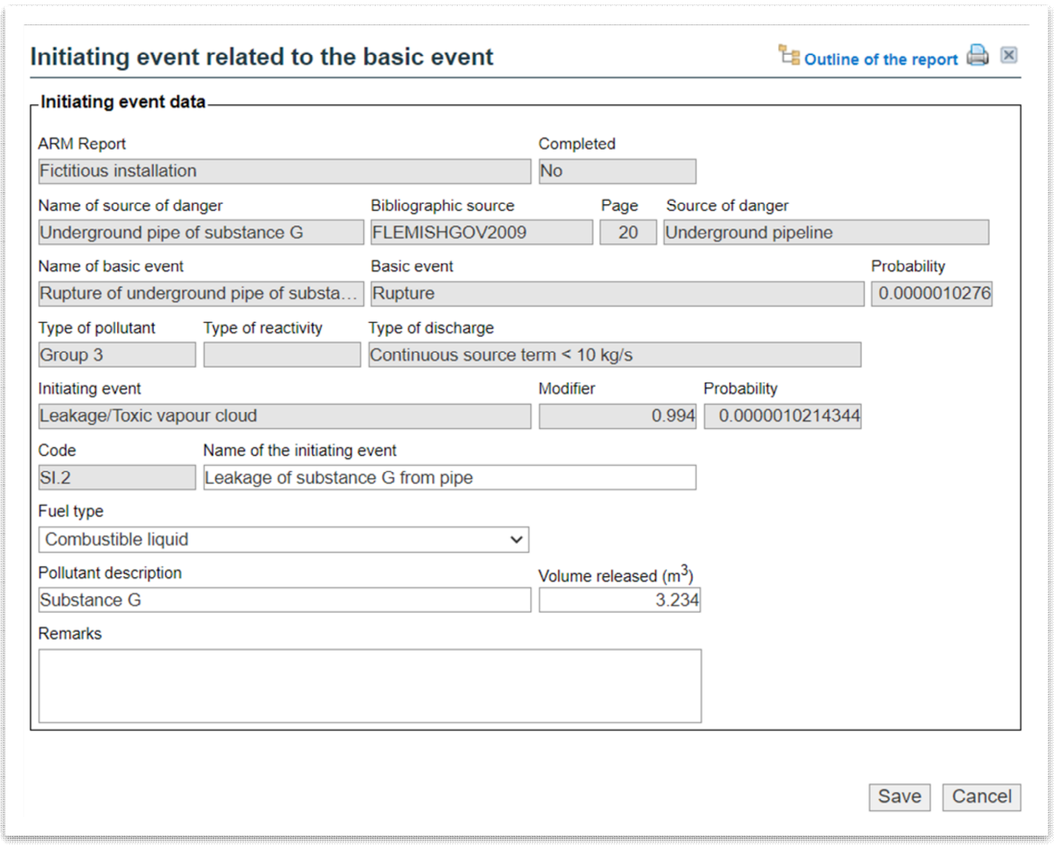


Figure AIV.3.1-9. “Modify/see” button of the initiating events of the basic event. Source: SIRMA.

Thus, by clicking on the “pencil” icon (🖉) of the “Modify/see” column it accesses to the screen of the initiating event data, called “Initiating event related to the basic event”. In this practical example, as described at the beginning of this section 3, the substance G cause the initiating event spillage and therefore the SI.2 selected is Leakage/Toxic vapour cloud.

The new fields that the user must fill in in the next screen are the name of the initiating event in question, the type of fuel, the description of the substance, the volume discharged and the remarks that the user considers appropriate.


Initiating event related to the basic event
Outline of the report

Initiating event data

ARM Report: Fictitious installation			Completed: No	
Name of source of danger: Underground pipe of substance G	Bibliographic source: FLEMISHGOV2009	Page: 20	Source of danger: Underground pipeline	
Name of basic event: Rupture of underground pipe of substa…	Basic event: Rupture			Probability: 0.0000010276
Type of pollutant: Group 3	Type of reactivity:	Type of discharge: Continuous source term < 10 kg/s		
Initiating event: Leakage/Toxic vapour cloud		Modifier: 0.994	Probability: 0.0000010214344	
Code: SI.2	Name of the initiating event: Leakage of substance G from pipe			
Fuel type: Combustible liquid				
Pollutant description: Substance G		Volume released (m^3): 3.234		
Remarks:				

Save Cancel

Figure AIV.3.1-10. Screen to fill in the data of the initiating event generated by the basic event. Source: SIRMA.

If the required information is entered and the “Save” button pressed, the application will add the amount released to the column “Volume released (m^3)” of the screen “Initiating events of the basic event” and the report icon will appear (🗋) under the column called “Conditioning factors” that will allow to continue with the environmental risk assessment (see figure below).

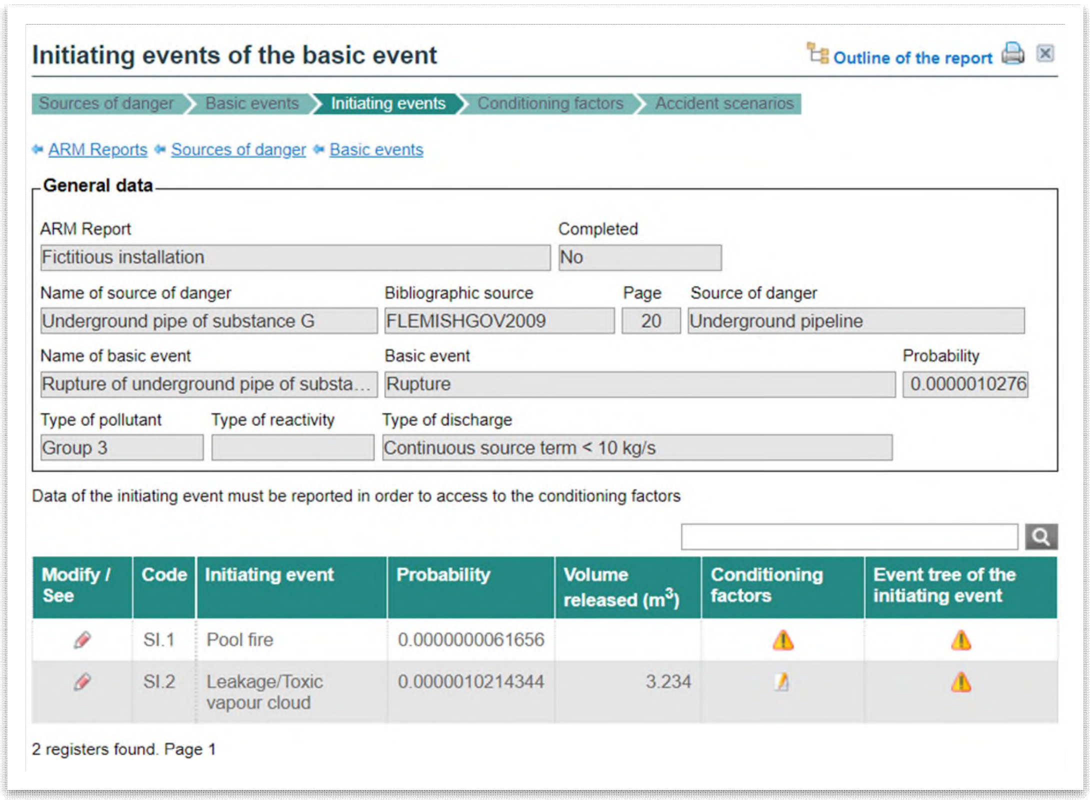


Figure AIV.3.1-1. Screen with the list of initiating events of the basic event. Source: SIRMA.

Next, the conditioning factors that apply to this initiating event are completed. To do this, if the report icon (🗋) is clicked a summary table of the general information entered so far appears under which is the button "Entry of data of conditioning factor", as shown in the following figure.

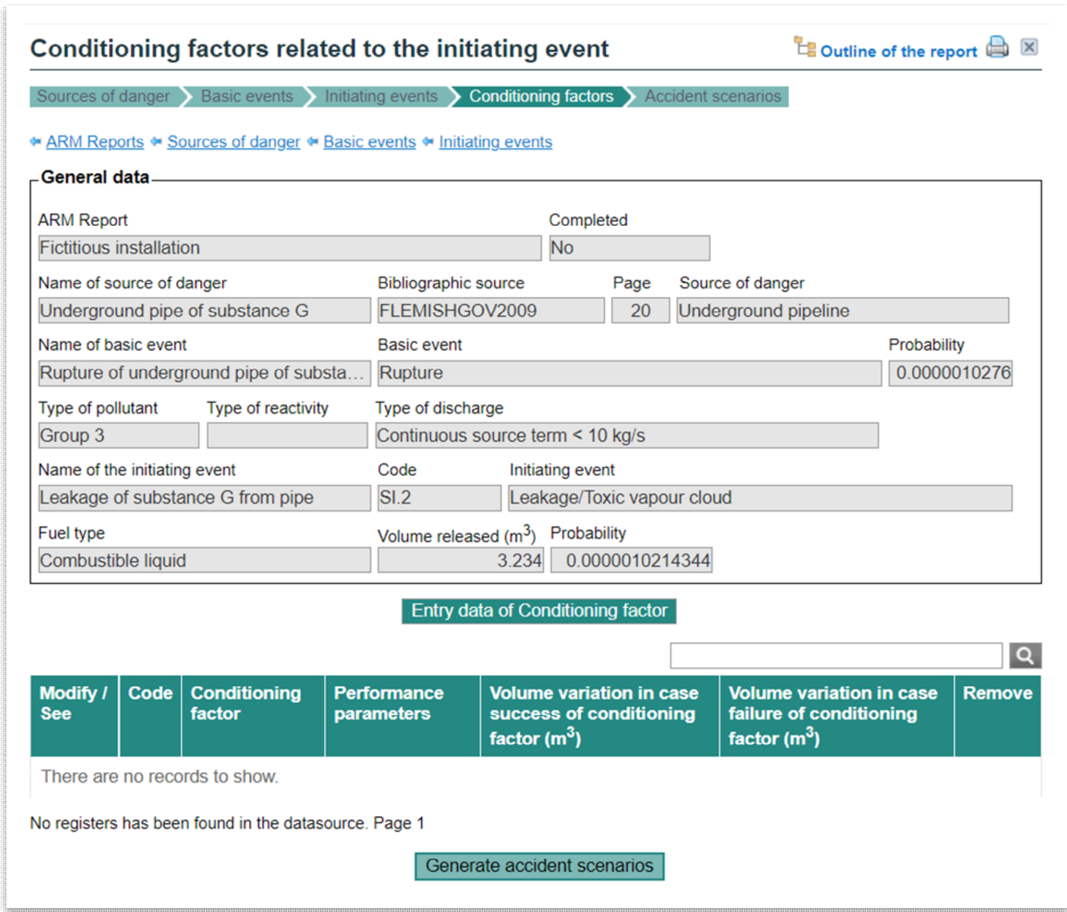
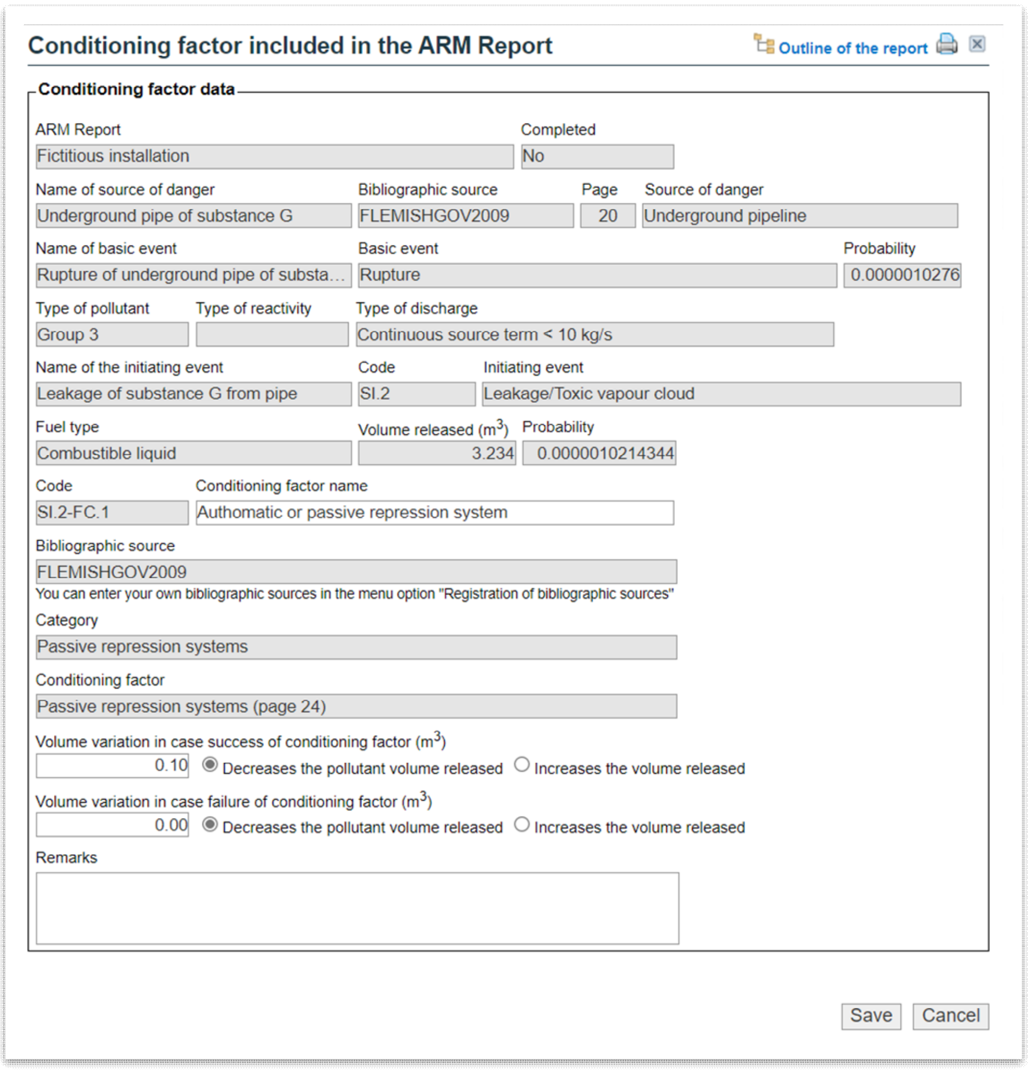


Figure AIV.3.1-12. "Entry of data of conditioning factor" button. Source: SIRMA.

Once the user has clicked on "Entry data of conditioning factor" the new screen "Conditioning factor included in the ARM Report" opens, which gathers, in addition to the data entered so far in the ARM report, an auto completed field for coding the factor and several fields that the user must fill in. These are: name of the conditioning factor, bibliographic source, category, conditioning factor, the fields "Volume variation in case success of conditioning factor (m^3)" and "Volume variation in case failure of conditioning factor (m^3)" (the instructions to fill in these changes are described in the main report of the user guide of the ARM module).

As in this practical example, the underground pipe is inside a 0.1 m^3 containment tank, this data has been entered in the variation of the released volume (see figure below).


Conditioning factor included in the ARM Report

Outline of the report

Conditioning factor data

ARM Report: Fictitious installation
Completed: No
Name of source of danger: Underground pipe of substance G
Bibliographic source: FLEMISHGOV2009
Page: 20
Source of danger: Underground pipeline
Name of basic event: Rupture of underground pipe of substa…
Basic event: Rupture
Probability: 0.0000010276
Type of pollutant: Group 3
Type of reactivity:
Type of discharge: Continuous source term < 10 kg/s
Name of the initiating event: Leakage of substance G from pipe
Code: SI.2
Initiating event: Leakage/Toxic vapour cloud
Fuel type: Combustible liquid
Volume released (m^3): 3.234
Probability: 0.0000010214344
Code: SI.2-FC.1
Conditioning factor name: Authomatic or passive repression system
Bibliographic source: FLEMISHGOV2009
You can enter your own bibliographic sources in the menu option "Registration of bibliographic sources"
Category: Passive repression systems
Conditioning factor: Passive repression systems (page 24)
Volume variation in case success of conditioning factor (m^3): 0.10 ◉ Decreases the pollutant volume released ○ Increases the volume released
Volume variation in case failure of conditioning factor (m^3): 0.00 ◉ Decreases the pollutant volume released ○ Increases the volume released
Remarks

Save | Cancel

Figure AIV.3.1-13. Screen for filling in the data of the conditioning factor associated with the ARM report. Source: SIRMA.

By pressing the "Save" button will return to the "Conditioning factors related to the initiating event" screen, which now includes a summary table of the entered conditioning factor data.

Once the only conditioning factor that applies to the initiating event (passive repression) has been entered and its action parameters have been established, it is possible to generate the accident scenario derived from it by pressing the "Generate accident scenarios" button shown in the following figure.

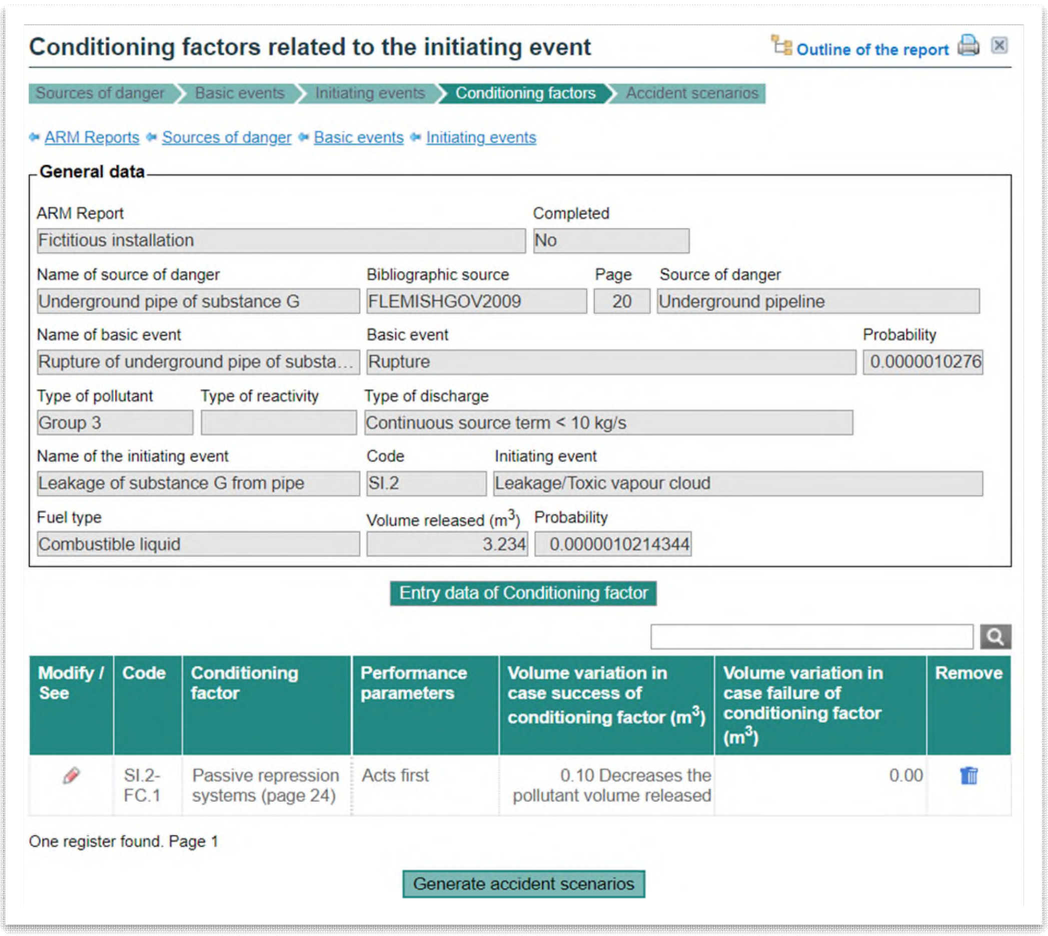


Figure AIV.3.1-14. List of conditioning factors associated with the ARM report and "Generate accident scenarios" button. Source: SIRMA.

This way, after the confirmation screen, the application generates the accident scenarios derived from applying the conditioning factors to the initiating event. Each of them is linked to the probability of occurrence and the volume released in that scenario. In addition, the "Event tree of the initiating event" button appears.

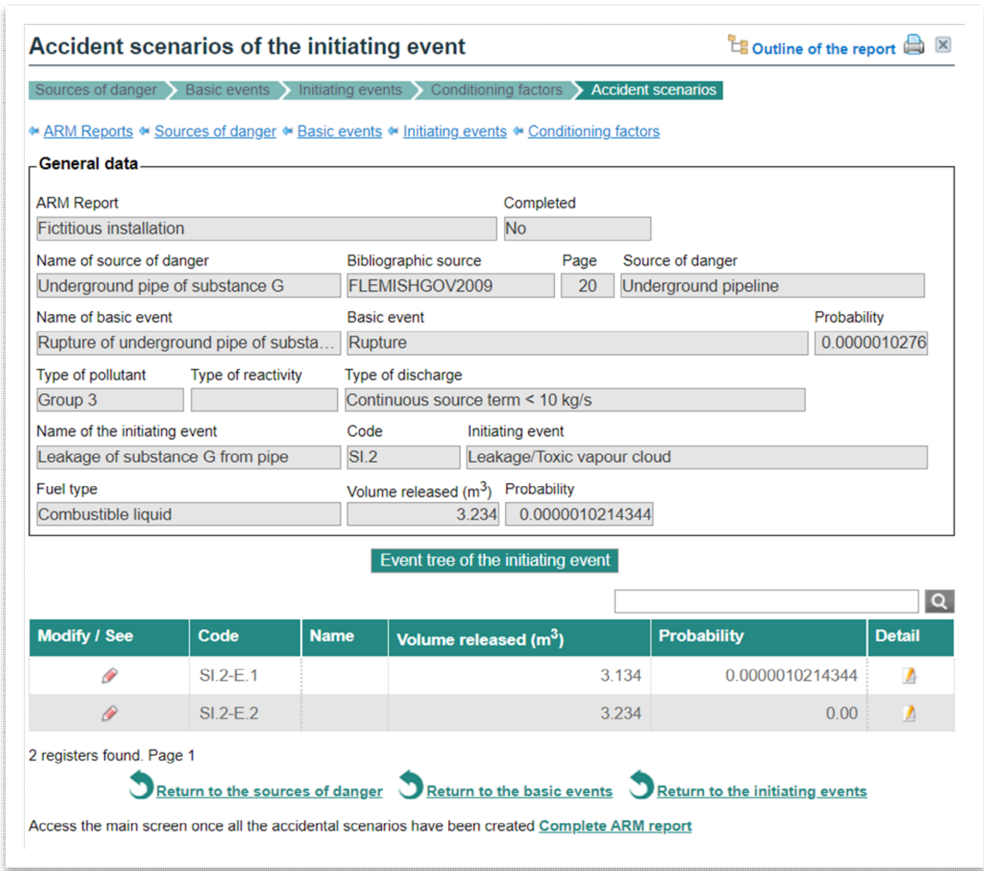


Figure AIV.3.1-15. "Event tree of the initiating event" button and list of accident scenarios of the initiating event. Source: SIRMA.

If the "Event tree of the initiating event" is pressed, the event tree of the initiating event is built that can be displayed on the screen as shown in the following figure.

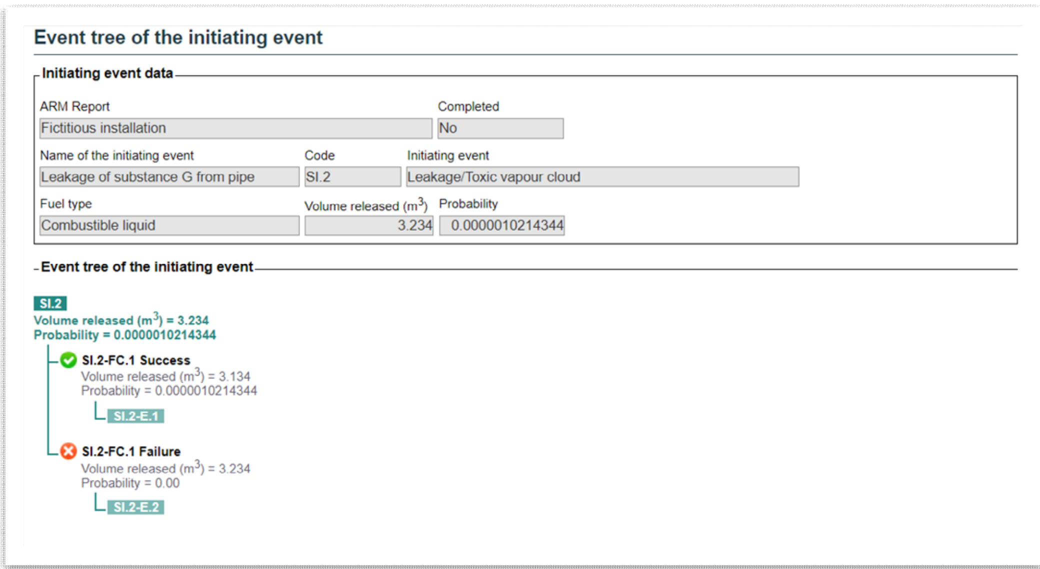


Figure AIV.3.1-15. Event tree of the initiating event screen. Source: SIRMA.

Finally, at the bottom of the screen, the following information appears: *"Access the main screen once all the accidental scenarios have been created to complete ARM report*". After this last step, the *ARM* report resulting from using the ARM module is completed.

In this practical example the event tree of the initiating event "Spillage of substance G from pipe" (see previous figure) has been generated. Using the event tree scheme, the resulting accident scenarios are obtained, as well as their probability and volume data. The "S.I.2 E.1" scenario obtained after applying the event tree scheme has the following characteristics:

–Probability of occurrence 0.0000010214344

–Volume released (m^3): 3.134

It will be necessary to replicate this process as many times as sources of danger exist in the installation that is the object of the Environmental Risk Analysis. Thus, in this practical example it should be carried out for each of the eight sources of danger described at the beginning of section 3 of this document (Table AIV.3-1). Next, possible accident scenarios that could result from the eight sources of danger identified are included. The following table shows the hypothetical probability associated with each accident scenario, including the probability of scenario 4, which calculation has been carried out and described step by step in this practical example.

Scenario		
Code	**Description**	**Probability**
E.1	Spillage of substance A from equipment. Affect: soil and groundwater	2.01E-02
E.2	Spillage of substance B from tank. Affect: soil and groundwater	2.12E-02
E.3	Spillage of substance C from tank. Affect: soil and groundwater	5.91E-04
E.4	Spillage of substance G from pipe. Affect: soil and groundwater	1.02E-06
E.5	Spillage of substance D from tank. Affect: soil and groundwater	1.03E-03
E.6	Spillage of substance E from equipment. Affect: soil and groundwater	1.09E-03
E.7	Discharge of fire attempt extinguishing water with substance E dissolved. Affect: soil and groundwater	3,11E-04
E.8	Fire affecting the entire facility and discharge of fire extinguishing water that goes outside with substance C dissolved. Affect: soil, habitat and groundwater.	3.23E-06
E.9	Fire contained in the starting sector and discharge of fire extinguishing water with substance E dissolved. Affect: soil and groundwater	2.15E-05
E.10	Fire affecting the entire facility and discharge of fire extinguishing water that does not go outside with substance F dissolved. Affect: soil and groundwater	7.75E-04

Table AIV.3.1-16. Accident scenarios and probability assigned to each of them. Source: Prepared by the authors

The values of probability obtained in the ARM application will be necessary to calculate the risk associated with each scenario, from which the selection of the reference scenario procedure will be carried out. In addition to the value of the probability of occurrence, it is necessary to know the value of the IDM associated with each accident scenario. The practical example of estimating the IDM associated with each scenario using the IDM application is developed in the following section.

3.2. EXAMPLE OF THE USER'S BIBLIOGRAPHICAL SOURCES FUNCTIONALITY

Through the "user's bibliographical sources" functionality, it is possible to enter sources of danger or conditioning factors not included in the application's own bibliography.

The following is an example of the inclusion of a bibliographic source with the source of danger "Electrical transformer" with its respective initiating events.

The first step is to create a new bibliographic source and then add the information about the source of danger using the "Add bibliographic source" link.

In the "Bibliographic source general data" screen, the following fields should be completed: Code, Full name and Remarks, as shown in the following image.

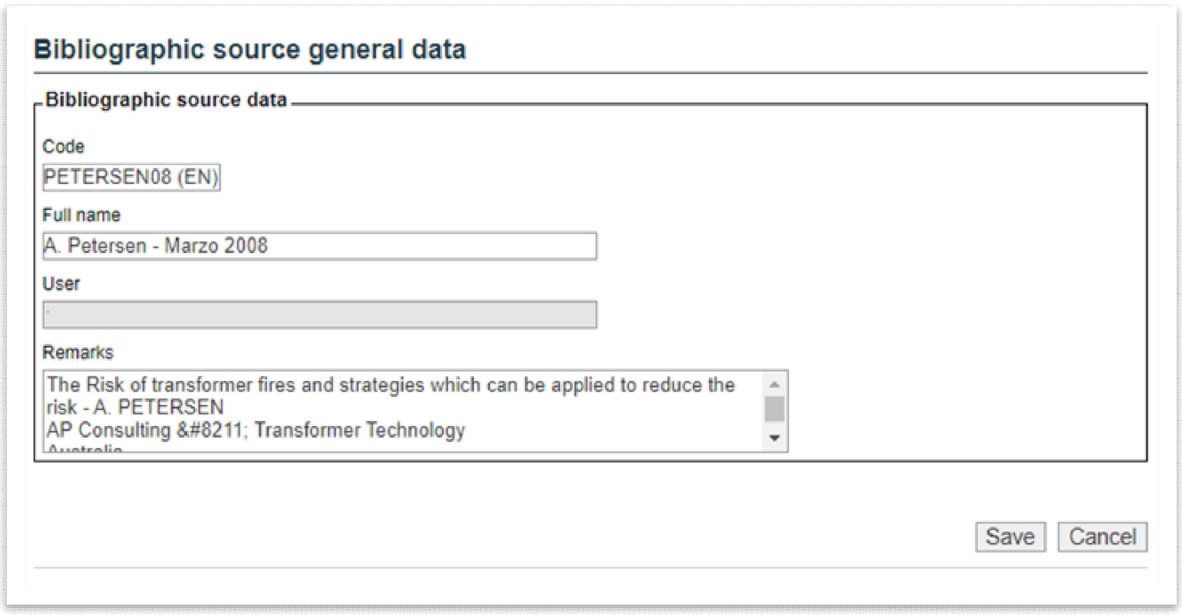


Figure AIV.3.2-1. General data of the bibliographic source. Source: SIRMA.

Once the bibliographic source has been registered, it is possible to add the "Source of danger category".

In the "Source of danger Category" screen, the new category "Transformers" would be entered, which would appear at this point reflected in the "Source of danger Categories" table as it is shown in the following figures.

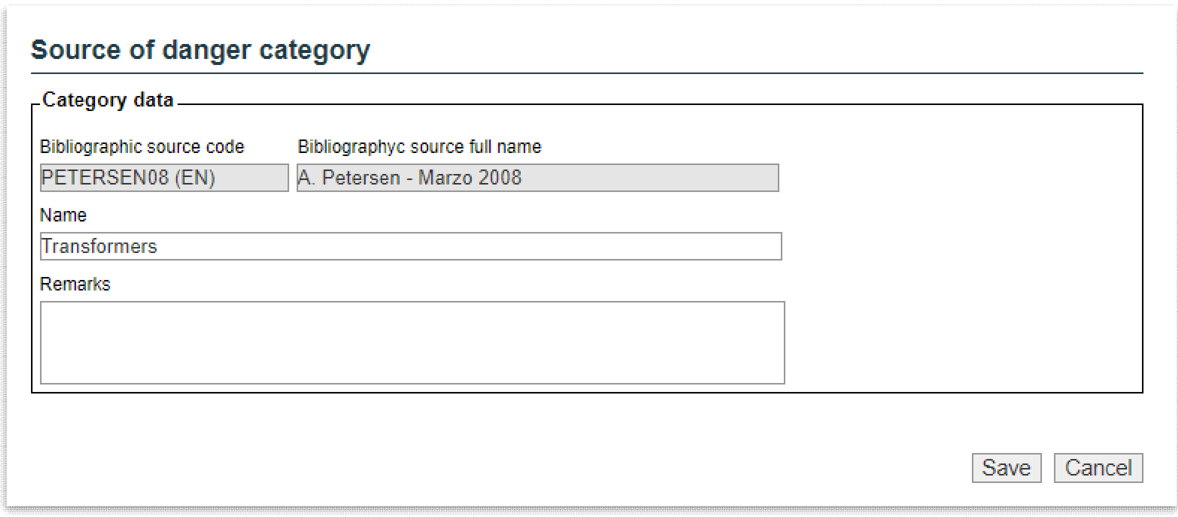


Figura AIV.3.2-2. Source of danger category. Source: SIRMA.

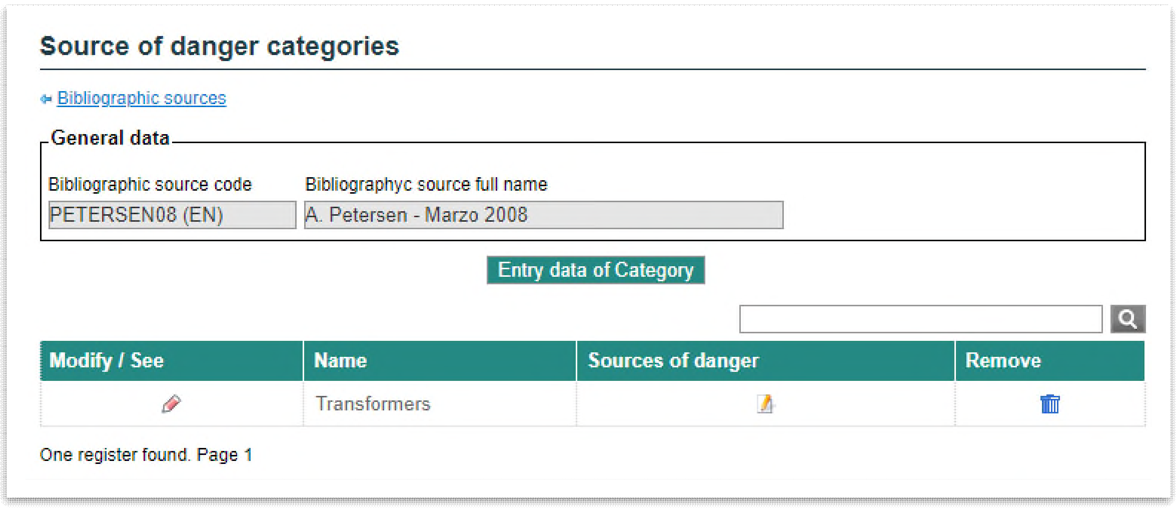


Figura AIV.3.2-3. Source of danger categories. Source: SIRMA.

Through the "Report" icon of the table, the display of sources of danger within that category can be accessed. In addition, with the "Entry data of Source of danger" button, "Electrical Transformer" would be added. To do this, it will be necessary to complete the Name, Page and Description fields – optionally – optionally, it is also possible to add information in the Remarks section–.

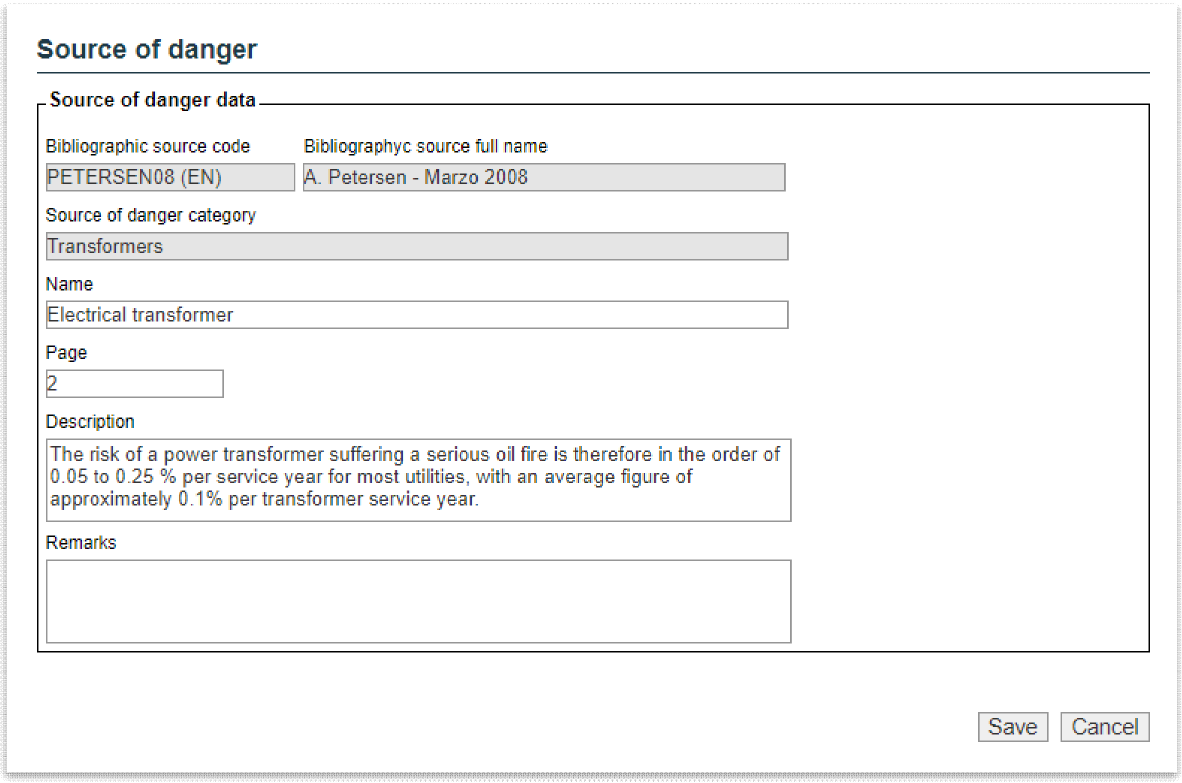


Figure AIV.3.2-4. Source of danger. Source: SIRMA.

Once the source of danger has been registered, it is shown in the source of danger table and the corresponding basic events can be added to it by clicking on the "report" icon in the "Basic events" column.

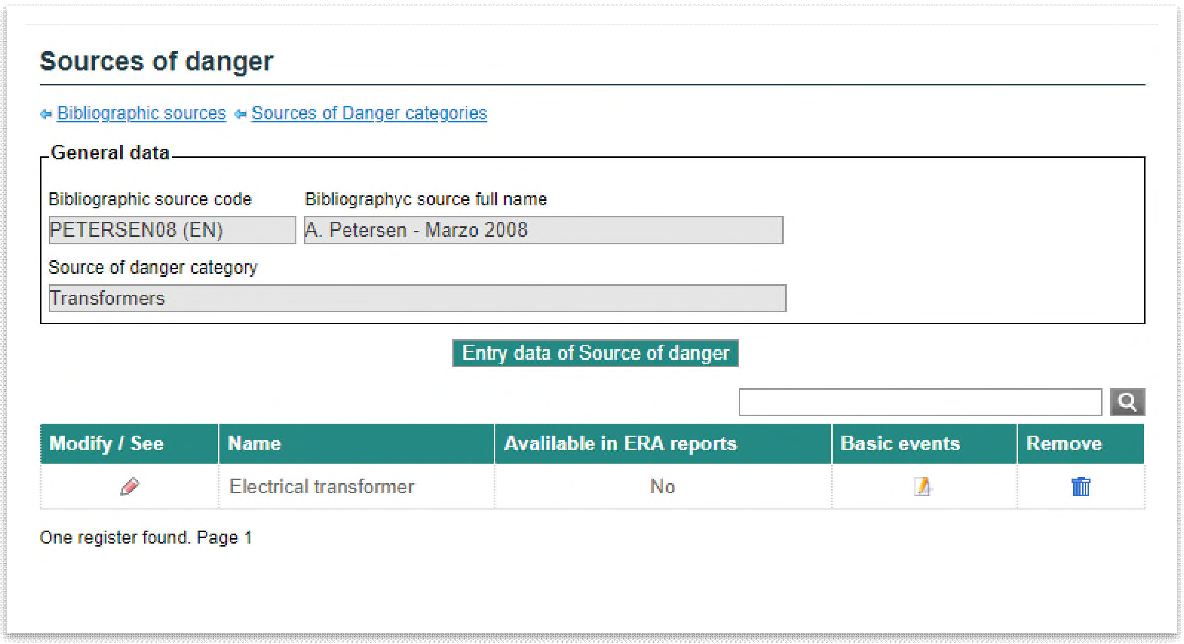


Figure AIV.3.2-5. Sources of danger. Source: SIRMA.

Through the "Entry data of Basic Event" icon, the user can complete the information requested. It is necessary to complete: Name, Possible ignition with an associated combustible substance/ Possible ignition without an associated combustible substance, Description and Remarks.

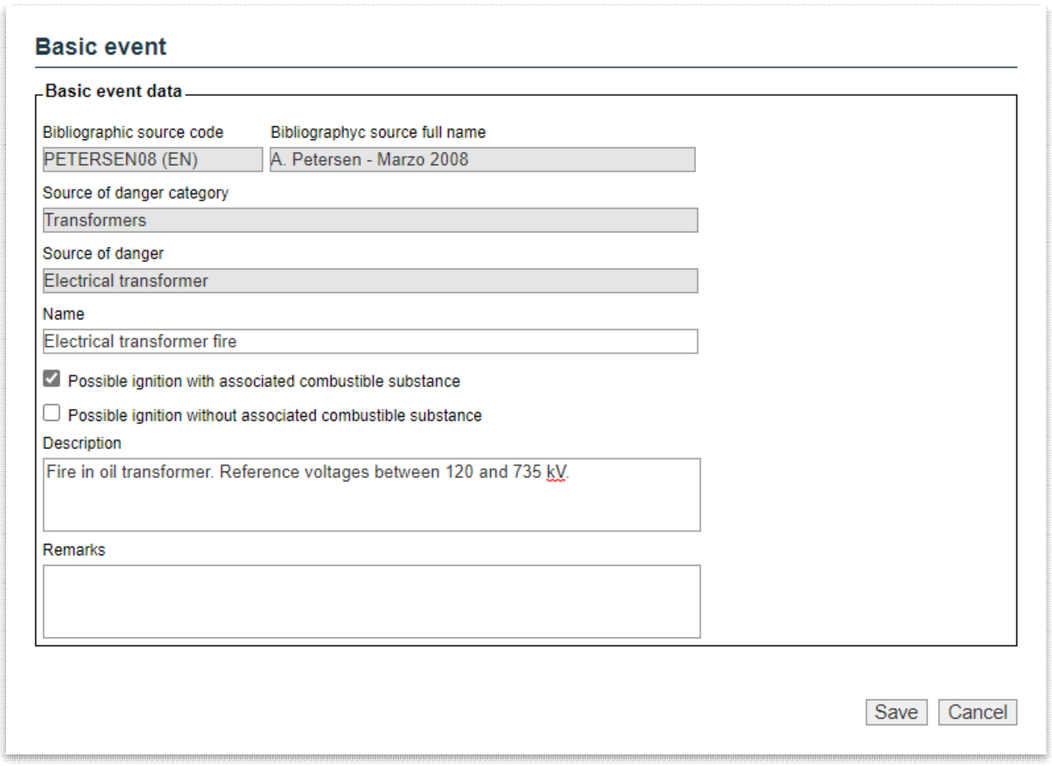


Figure AIV.3.2-6. Basic event data. Source: SIRMA.

When a basic event has been registered, it is possible to add the probability of occurrence by clicking on the "report" icon in the "Probability" column.

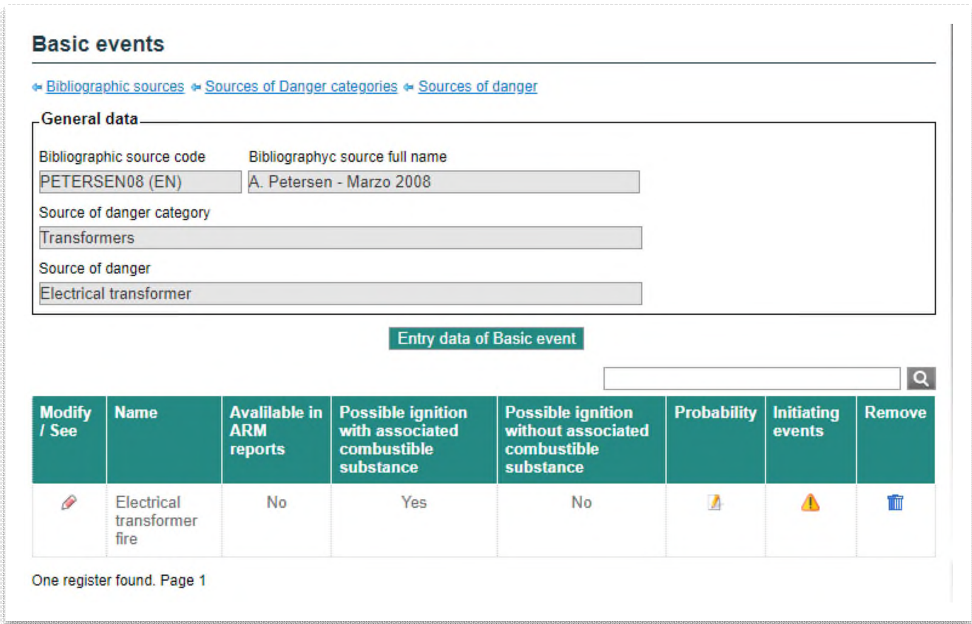


Figure AIV.3.2-7. Basic events. Source: SIRMA.

The data extracted from the reference literature that will be necessary to enter in the "Probability related to the basic event" screen are: Units of the basic event, Probability (numerical probability), Description and Remarks (this is a non-mandatory field). In the example, the probability would be 0.0001 failures per transformer per year as shown in the following figure.

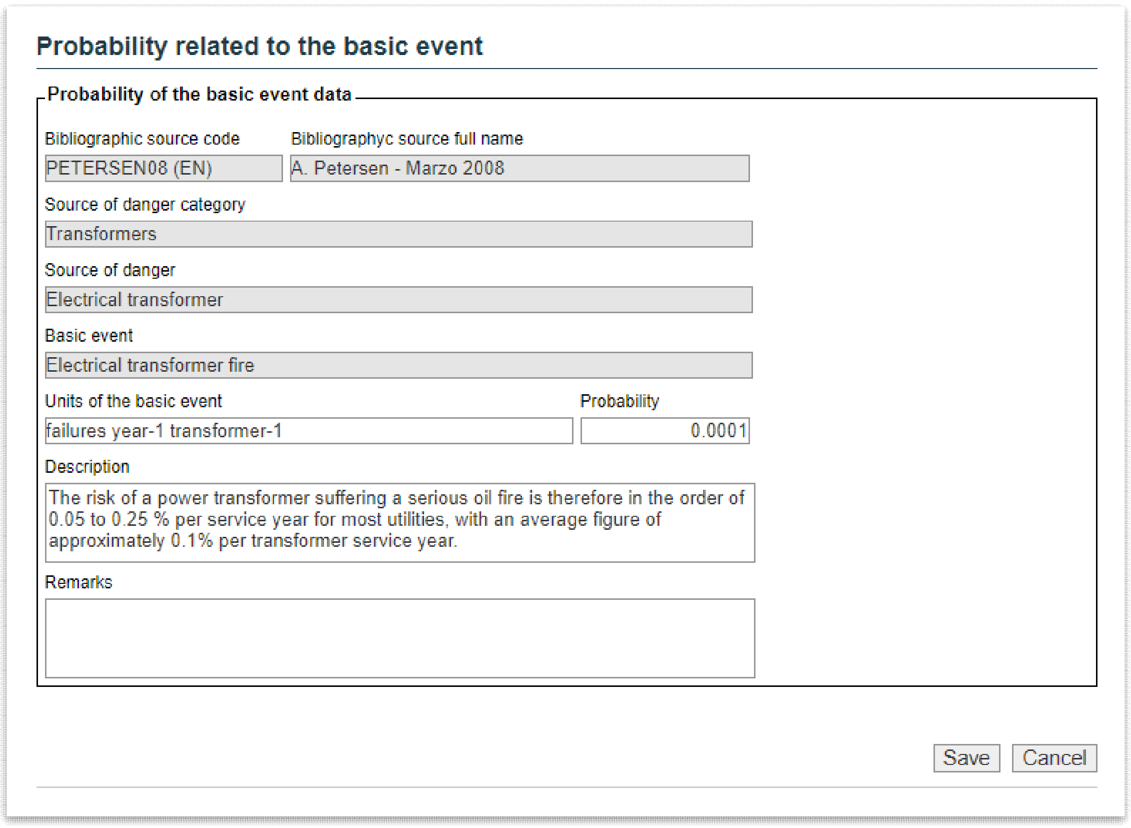


Figure AIV.3.2-8. Probability related to the basic event. Source: SIRMA.

Once the probability of occurrence of the basic event has been entered, the fields on which this probability will depend must be entered –those concepts involved in the units in which the probability is measured–. To add these fields, click on the "report" icon in the "Fields" column and add the necessary fields by clicking on the "Entry data of Field" button.

Figure AIV.3.2-9. Probability of the basic event. Source: SIRMA.

The Application offers a drop-down list to choose the fields needed to calculate the probability of the basic event. In the example, the unit offered in the bibliography refers to failures per year per transformer so, in line with the above, the field to be entered will be the number of transformers. Thus, the generic field "Number of devices" is chosen from those offered by the tool.

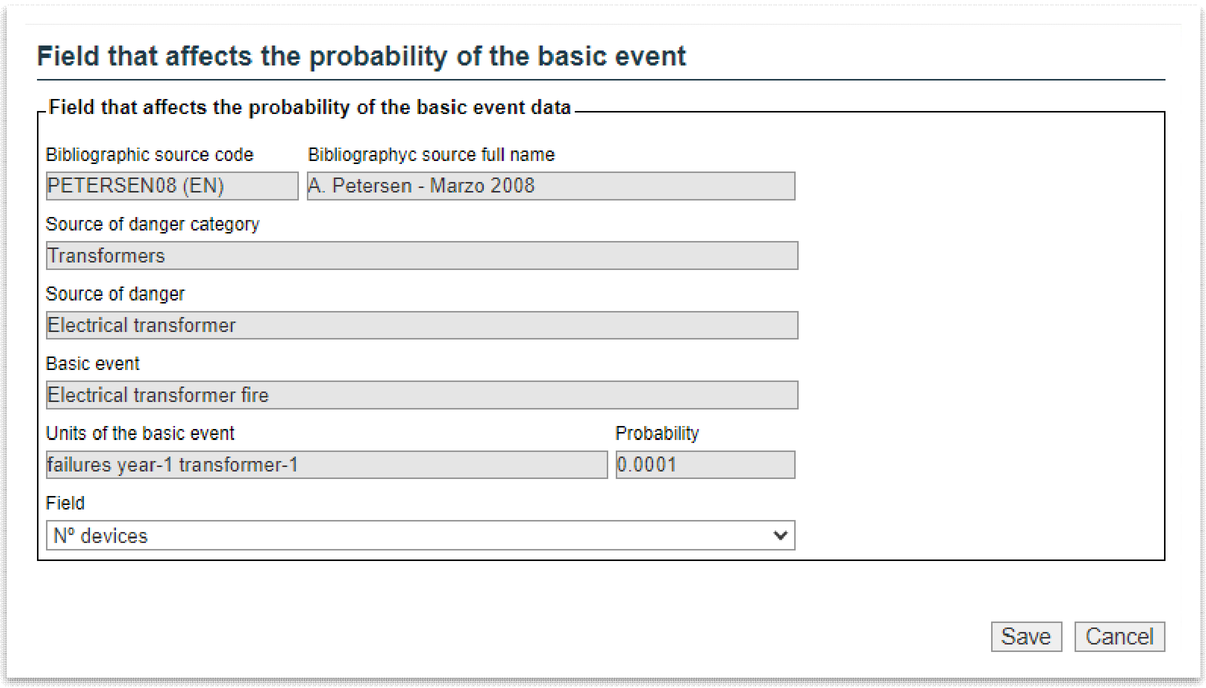


Figure AIV.3.2-10. Field that affects basic event probability. Source: SIRMA.

By clicking on the "Save" button, the field will be available in the "Fields that affect the probability of the basic event" table as shown in the following figure.

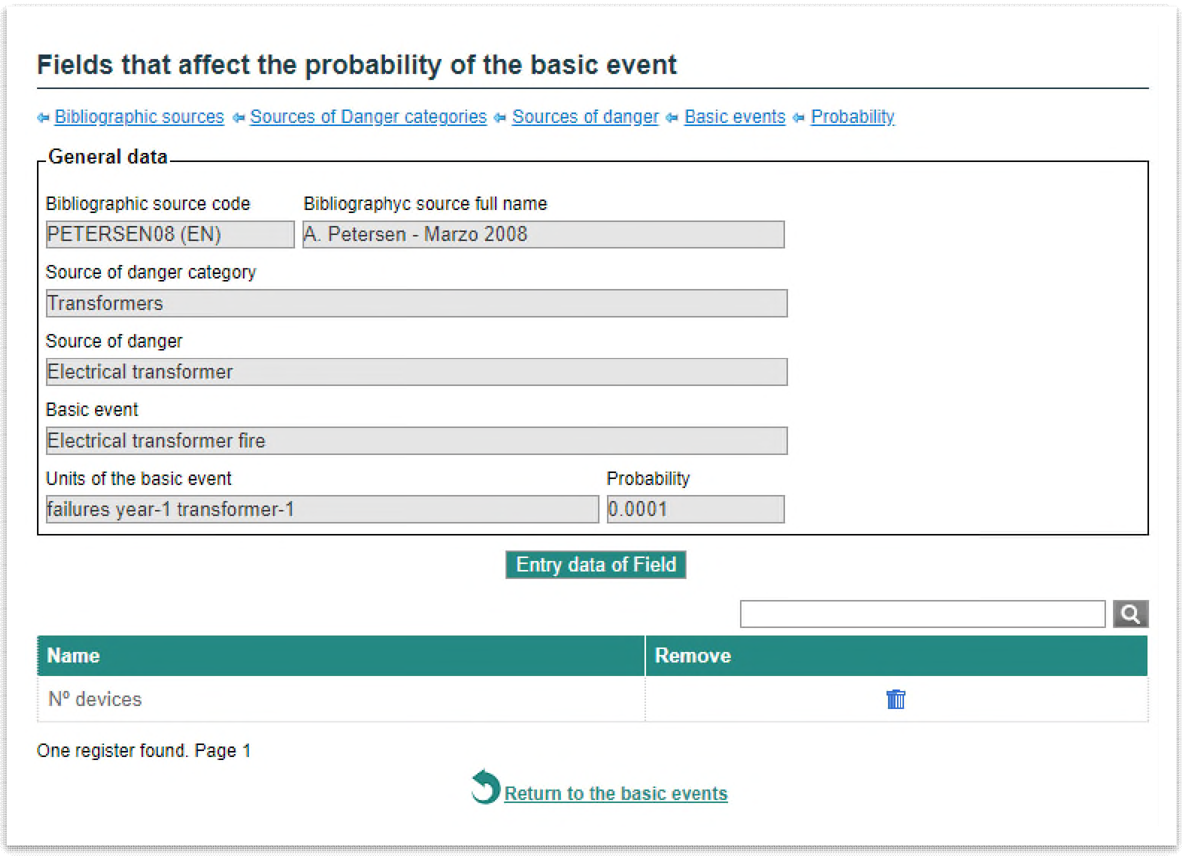


Figure AIV.3.2-11. Fields that affect basic event probability. Source: SIRMA.

In this case it is not necessary to include more fields. By clicking on the "Return to the basic events" link the tool returns us to the "Basic events" screen where the "report" icon has been enabled in the initiating events column. The information at this point is completed.

The data requested in the "Initiating event related to the basic event" screen are Initiating event - this is a general description of the type of initiating event generated to be chosen from a drop-down list -, probability Modifier of the basic event and Remarks (optional field). Remember that the sum of the modifiers of the initiating events derived from the same basic event must be unity. In the example, the initiating event derived from the basic event "Transformer fire" will be "Fire" and, since it is a single initiating event associated with the basic event, the value of the probability modifier will be 1.

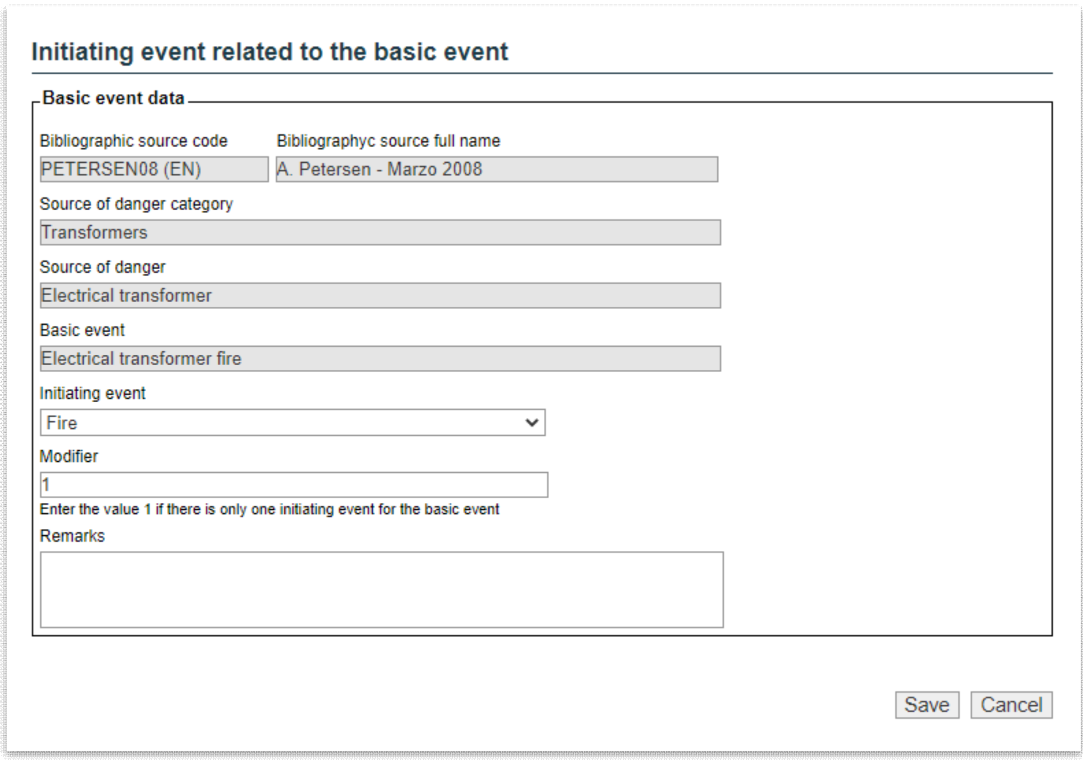


Figure AIV.3.2-12. Initiating event related to the basic event. Source: SIRMA.

With this completed information, the initiating event is already listed in the "Initiating events generated by the basic event" table.

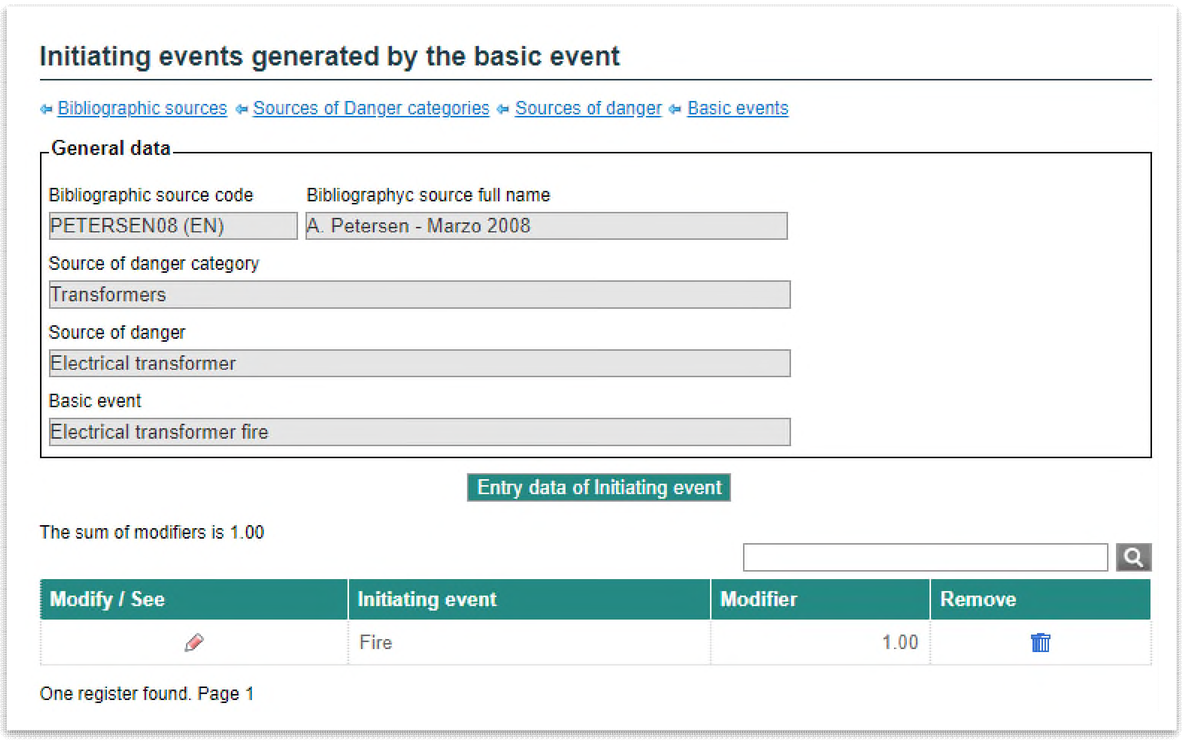


Figure AIV.3.2-13. Initiating event related to the basic event. Source: SIRMA.

The input data for the Source of danger "Electrical Transformer", the Basic Event "Transformer Fire" and the Initiating Event "Fire" have now been completed and are finally listed in the Sources of Danger Table as "Available in ARM Reports".

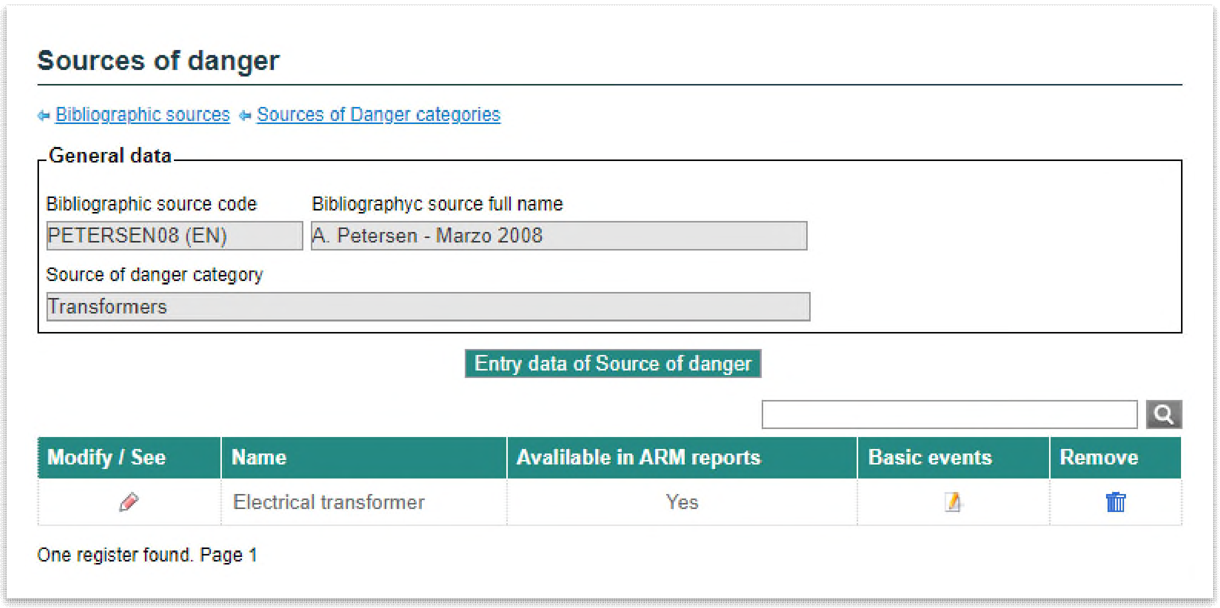


Figure AIV.3.2-14. Sources of danger. Source: SIRMA.

4. ENVIRONMENTAL DAMAGE INDEX ESTIMATION

Once the environmental risk analysis has been carried out and the possible natural resources that could be affected by each accident scenario have been analysed, the IDM is estimated. To do this, the different accident scenarios for which the IDM must be calculated are extracted from the ARM.

First, the agent-resource groups that apply in each accident scenario have been identified, as well as the type of agent involved. As it is shown in the following table, since in all the cases the natural resources that could be affected by the damage are soil, groundwater and habitat, the agent-resource groups of the table 1 of the Annex III of the Regulation for Partial Development that are involved in the different accident scenario set out in this practical example are 5 (damage to groundwater by chemicals), 9 (damage to soil by chemicals) and 14 (damage to plant species by fire).

It is worth noting that, apart from substance D, which is an inorganic substance, it has been assumed that the rest of the substances involved in the different accident scenarios are organic substances (all non-halogenated except for substance A), therefore the agent causing the damage would be classified in the groups of VOCs, SVOCs and NVOCs[1].

Finally, it is important keep in mind that in the case of group 14 (damage to habitat by fire) it has been necessary to classify — according to the categories set out by Annex II of the Regulation for this group — the type of resource that would be affected. In this way, and as it is a 45-year-old pine forest without protected plant species, the resource has been classified as a mature woodland habitat with a diameter greater than 20 cm.

[1] VOCs: Volatile Organic Compounds.
SVOCs: Semi-volatile Organic Compounds.
NVOCs: Non Volatile Organic Compounds.

Scenario		Type of agent	Resource	Group table 1
Code	Description			
E.1	Spillage of substance A from equipment. Affect: soil and groundwater	Halogenated VOCs	Groundwater	5
			Soil	9
E.2	Spillage of substance B from tank. Affect: soil and groundwater	Non-halogenated SVOCs	Groundwater	5
			Soil	9
E.3	Spillage of substance C from tank. Affect: soil and groundwater	Non-halogenated VOCs	Groundwater	5
			Soil	9
E.4	Spillage of substance G from pipe. Affect: soil and groundwater	Fuels and NVOCs	Groundwater	5
			Soil	9
E.5	Spillage of substance D from tank. Affect: soil and groundwater	Inorganic	Groundwater	5
			Soil	9
E.6	Spillage of substance E from equipment. Affect: soil and groundwater	Non-halogenated VOCs	Groundwater	5
			Soil	9
E.7	Discharge of fire attempt extinguishing water with substance E dissolved. Affect: soil and groundwater	Non-halogenated SVOCs	Groundwater	5
			Soil	9
E.8	Fire affecting the entire facility and discharge of fire extinguishing water that goes outside with substance C dissolved. Affect: soil, habitat and groundwater.	Non-halogenated VOCs	Groundwater	5
			Soil	8
			Habitat	14
E.9	Fire contained in the starting sector and discharge of fire extinguishing water with substance E dissolved. Affect: soil and groundwater	Non-halogenated VOCs	Groundwater	5
			Soil	9
E.10	Fire affecting the entire facility and discharge of fire extinguishing water that does not go outside with substance F dissolved. Affect: soil and groundwater	Non-halogenated SVOCs	Groundwater	5
			Soil	9

Table AIV.4-1. Groups of agent-resource assigned to each accident scenario. Source: Prepared by the authors.

After identifying the different agent-resource combinations (groups) that correspond to each accident scenario, as well as the type of agent causing the damage for each group, the IDM estimation module is used for each of the identified accidental scenarios.

4.1. EXAMPLE OF ENTERING DATA IN THE IDM APPLICATION

In the first screen of the IDM estimation module, the general data of the report are entered: name, date of performance and user. The user will fill in the name field and press the "save" button to continue the screen of Consultation of scenarios included in the IDM report.

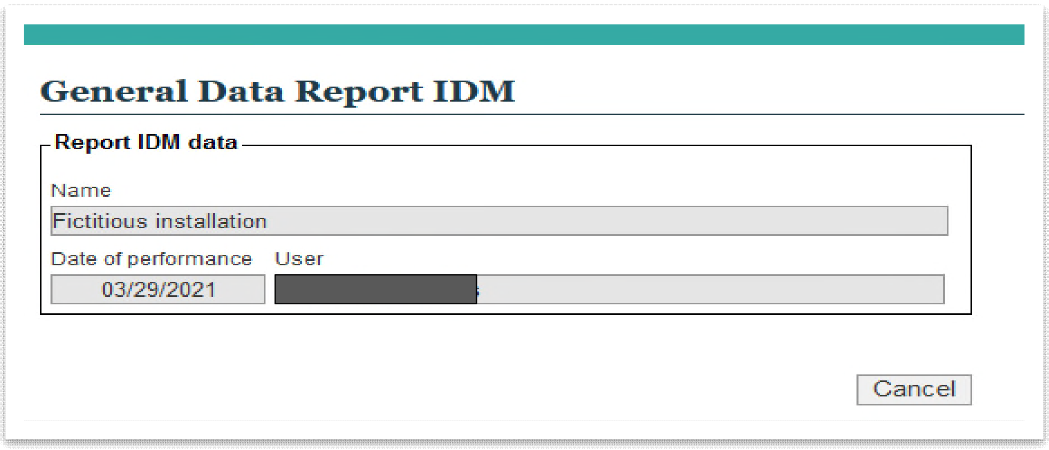


Figure AIV.4.1-1. General data of the IDM report screen. Source: SIRMA.

On the next screen, click on "Entry data of scenario" to enter the accident scenarios in the report. In this case, the process of estimating the IDM of scenario 1 will be carried out (Spillage of substance A from equipment, affecting to the natural resources soil and groundwater).

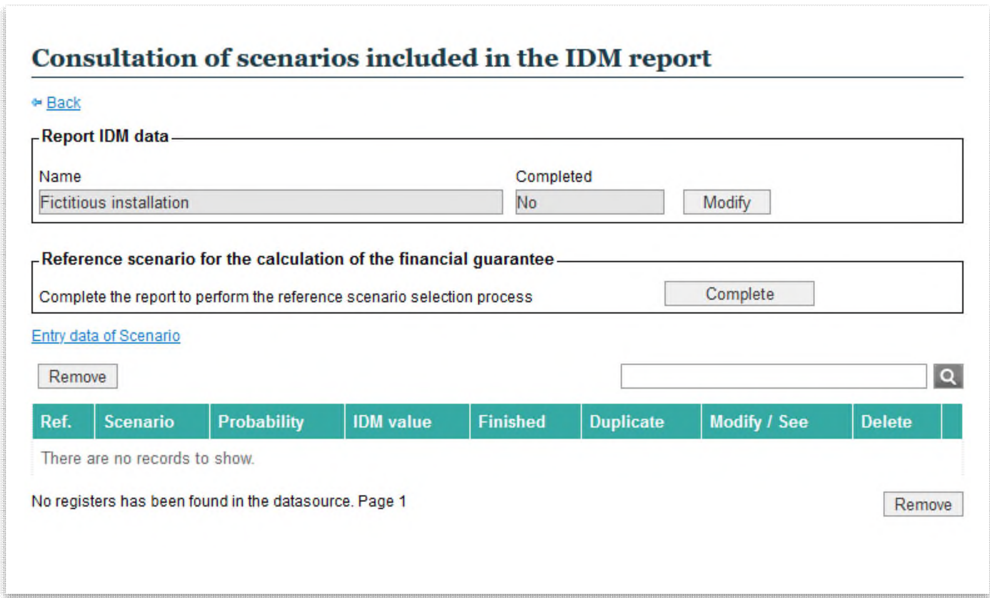


Figure AIV.4.1-2. Screen of scenarios included in the IDM report. Source: SIRMA.

Next the general data of the scenario are entered, its name and probability of occurrence and the "Next" button is clicked on.

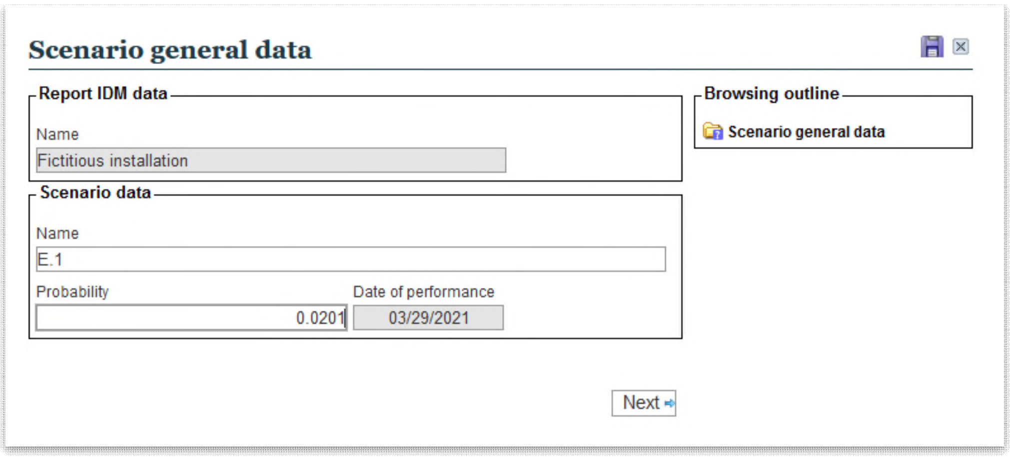


Figure AIV.4.1-3. General data of the scenario. Source: SIRMA.

By pressing the "Next" button, a screen appears that provides a list of different agents causing the damage so that the user can select one or more of the elements of the model that could cause a significant effect on natural resources. In this case, the "halogenated VOCs" agent is selected.

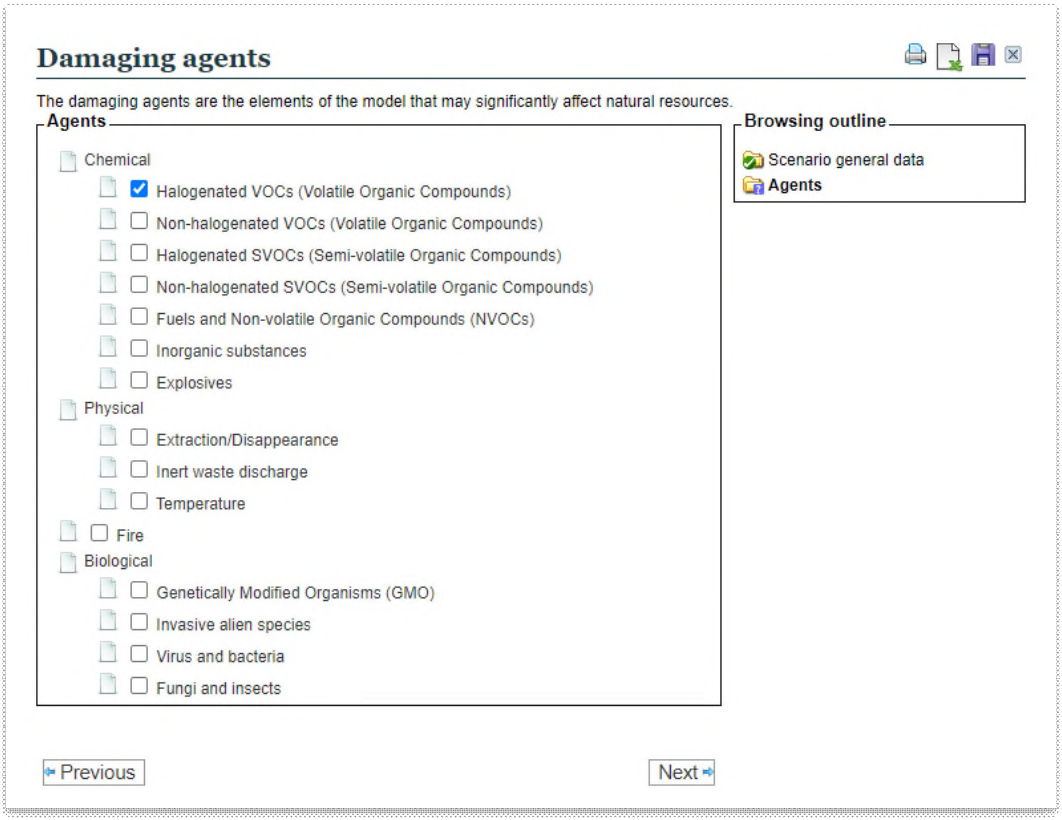


Figure AIV.4.1-4. Selection of the agent causing the damage for scenario E.1. Source: SIRMA.

In the following step, the user will click on the "Next" button and go to the selection screen of the resources that could be damaged by the accident that, for this first scenario, as indicated in Table AIV.4-1, are the resources soil and groundwater.

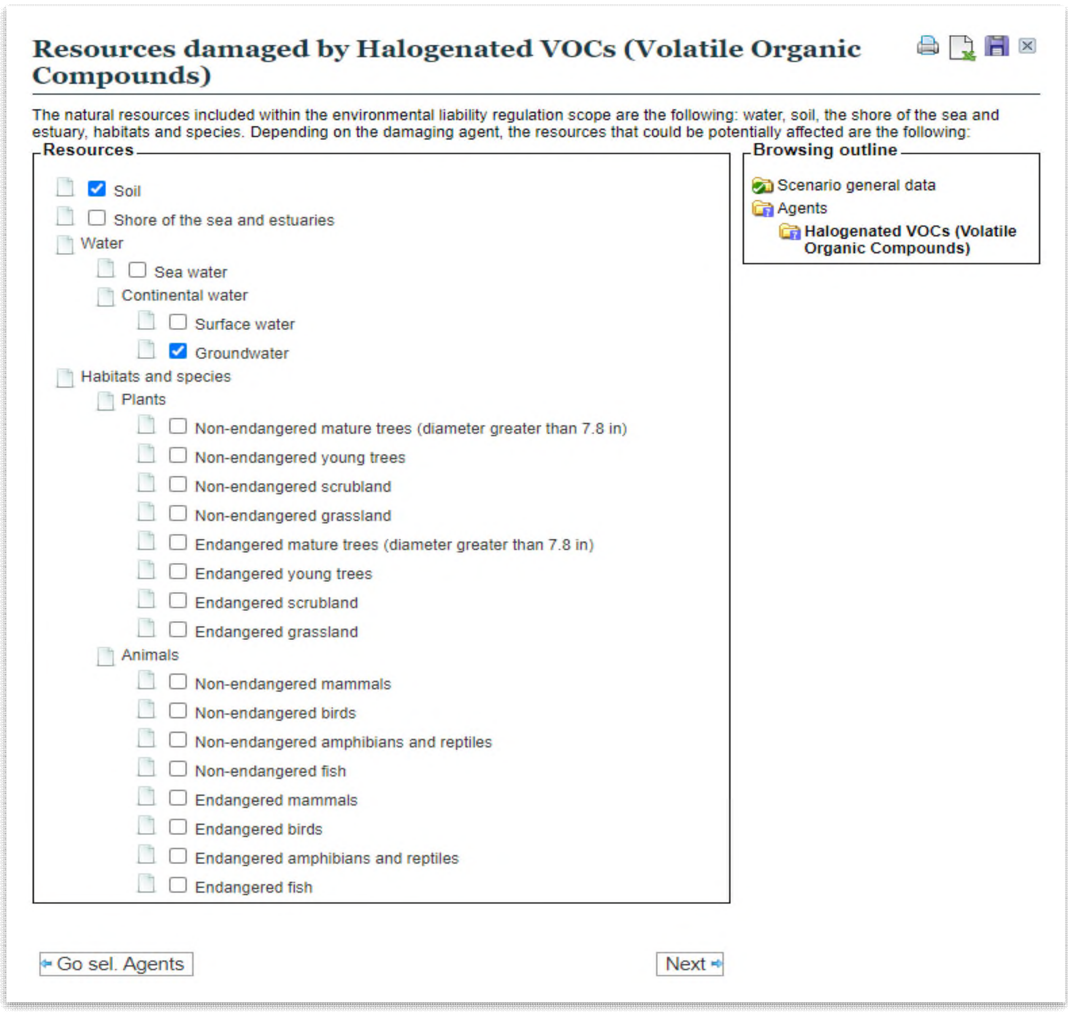


Figure AIV.4.1-5. Selection screen of the resources damaged by the scenario E.1. Source: SIRMA.

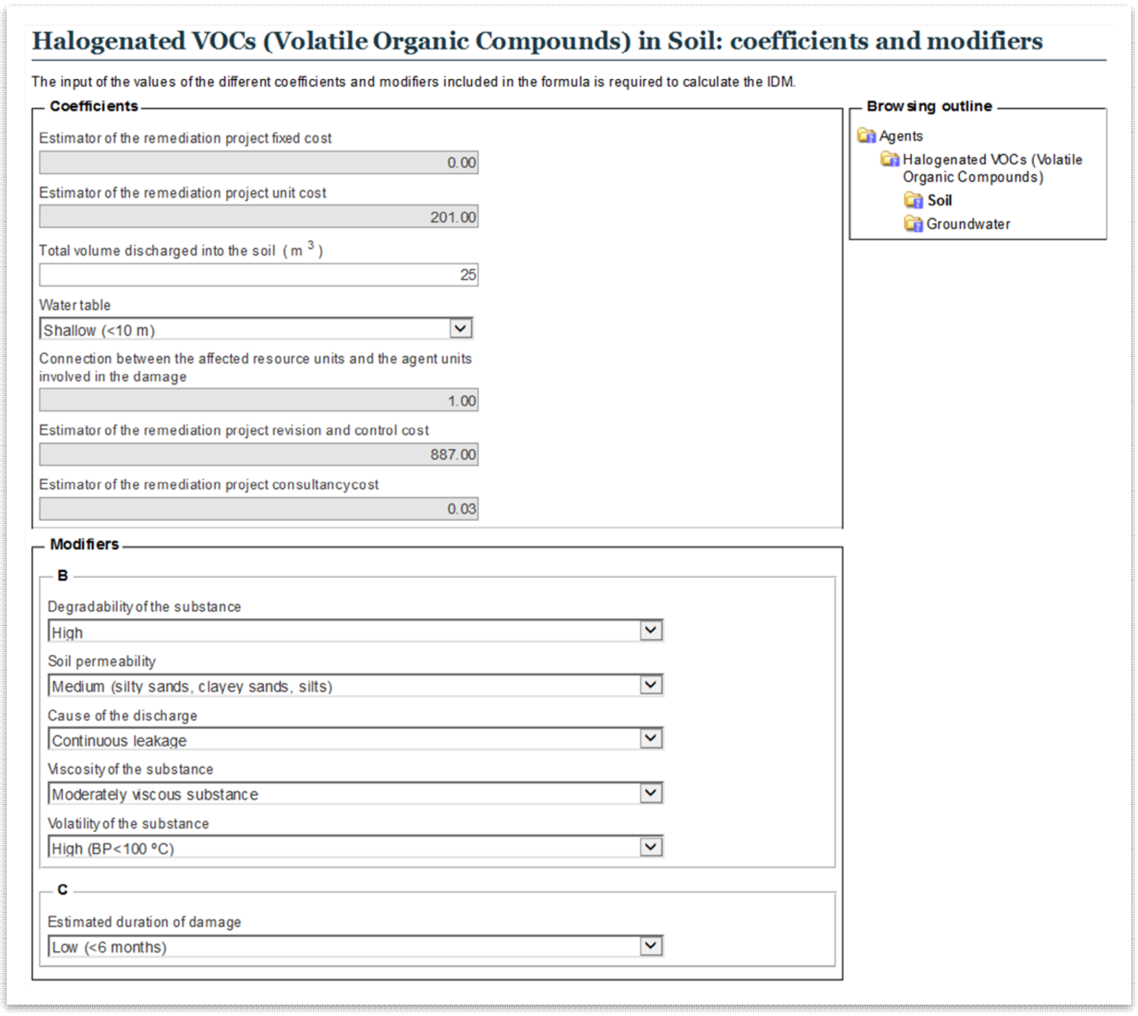
The following screens will show for each combination agent-resource (in this specific scenario halogenated VOCs-soil and halogenated VOCs-groundwater) the coefficients and modifiers that will apply.

As has been previously explained, the coefficients are fixed for each agent-resource combination. Therefore, the user will only have to complete the category that corresponds to each of the modifiers for this scenario, as well as the information regarding the total volume discharged into the soil and the depth of the water table. These last two data are used by the IDM application, in accordance with the equation indicated in section III of Annex III of the Regulation, to establish the distribution of the volume discharged between the natural resources, soil and groundwater.

That section indicates that in the case of combined damage to the soil and groundwater, the distribution of the volume that affects each resource will be carried out in terms of the aquifer depth. This way, from the total volume discharged into the soil, it is considered that a part will remain in the soil, while the rest will seep and end affecting the groundwater. The greater or lesser impact on each of these resources will depend on the depth of the aquifer, in such a way that if the aquifer is shallow, the groundwater will be more affected; on the contrary, if it is deep, the most affected resource will be the soil.

In the case of the accident scenario that is being analysed it is supposed that the total amount discharged into the soil has been 25 m^3, therefore, since the aquifer is shallow (see Table AIV. 2.3-1), most of the damage will affect groundwater.

Additionally, according to the data indicated in the tables Table AIV. 2.1-1 (data of the substance involved in the accident scenarios) and Table AIV. 2.3-1 (environmental data such as, for example, soil permeability), and assuming that it is a continuous leakage and that the estimated duration of the damage is less than 6 months, the screen for the case of soil damage would fill in as indicated in the figure below.



Halogenated VOCs (Volatile Organic Compounds) in Soil: coefficients and modifiers

The input of the values of the different coefficients and modifiers included in the formula is required to calculate the IDM.

Coefficients

Estimator of the remediation project fixed cost: 0.00

Estimator of the remediation project unit cost: 201.00

Total volume discharged into the soil (m^3): 25

Water table: Shallow (<10 m)

Connection between the affected resource units and the agent units involved in the damage: 1.00

Estimator of the remediation project revision and control cost: 887.00

Estimator of the remediation project consultancycost: 0.03

Modifiers

B

Degradability of the substance: High

Soil permeability: Medium (silty sands, clayey sands, silts)

Cause of the discharge: Continuous leakage

Viscosity of the substance: Moderately viscous substance

Volatility of the substance: High (BP<100 °C)

C

Estimated duration of damage: Low (<6 months)

Browsing outline

- Agents
  - Halogenated VOCs (Volatile Organic Compounds)
    - Soil
    - Groundwater

Figure AIV.4.1-6. Screen of coefficients and modifiers in damage to soil for accident scenario E.1. “Spillage of substance A from equipment”. Source: SIRMA.

Similarly, the data for the case of damage to groundwater would be completed. To this end, the data in tables AIV. 2.1-1 and AIV. 2.3-1 has also been taken and it has been estimated that the duration of the damage would be less than three years.

It is worth pointing that both in the case of soil damage as well as in the case of damage to groundwater, the user must enter the total amount discharged into the soil (25 m^3), because it is the IDM estimation module that will internally allocate the amount to both resources, depending on the part that remains in the soil and the part that would percolate in the ground, affecting groundwater.

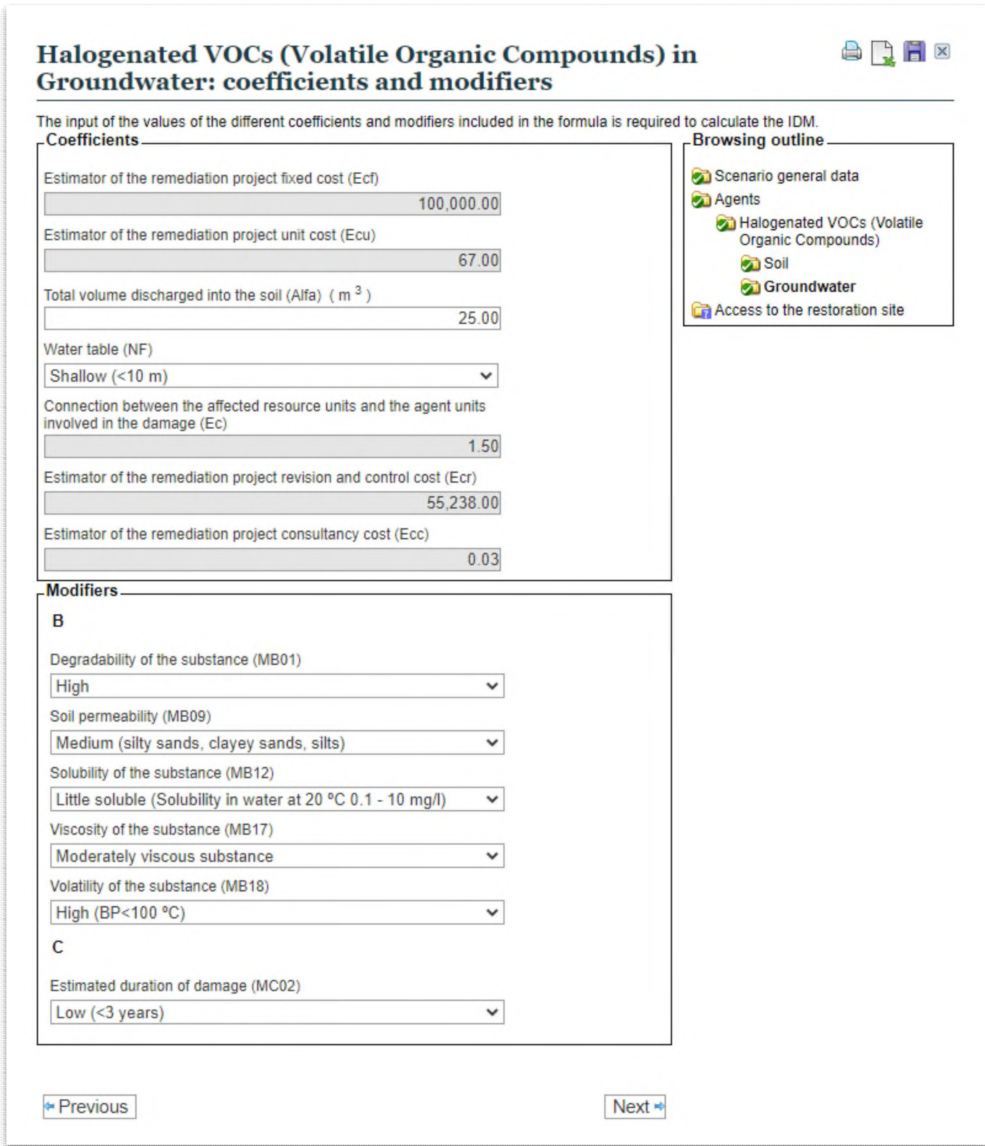


Figure AIV.4.1-7. Screen of coefficients and modifiers in damage to groundwater for accident scenario E.1. “Spillage of substance A from equipment”. Source: SIRMA.

Finally, the user must enter the distance to the nearest track so that the IDM application can estimate the cost of access to the damaged site. This is because in the event that it is not possible to access by a road to the damaged site, the estimation of the remediation cost should consider the cost of building a road to the affected site. In this case, it has been assumed that it would not be necessary to build any road when reaching the closest road to the place affected by the damage, so the screen for this estimate would be completed as shown in the following figure.

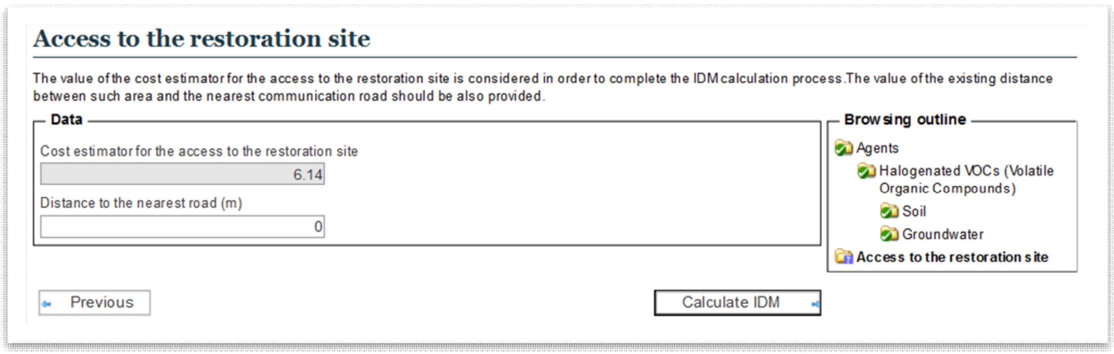


Figure AIV.4.1-8. Screen for estimating the access costs for scenario S.1 "Spillage of substance A from equipment". Source: SIRMA.

Once all the data relating to this first scenario has been entered, the user would get the value of the IDM for the analysed scenario.

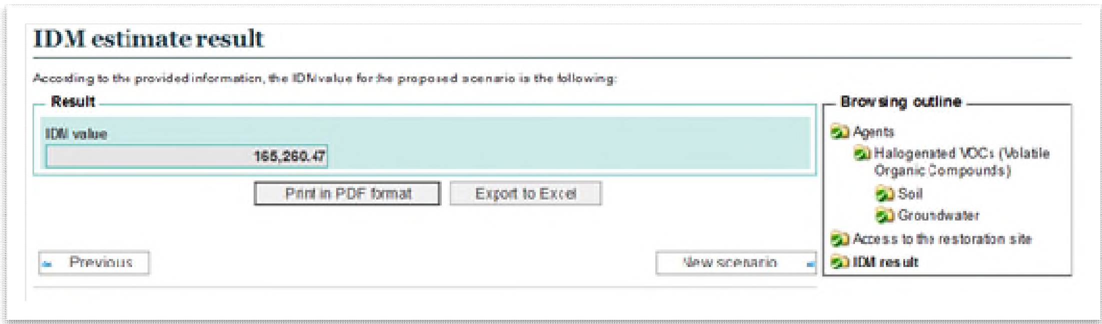


Figure AIV.4.1-9. Result of the IDM estimation for scenario S.1 "Spillage of substance A from equipment". Source: SIRMA.

The "Complete" button allows you to close and end the scenario, so that it can be considered when determining the accidental reference scenario. By pressing this button, the user is led to the screen for "Consultation of scenarios included in the IDM report" where they can enter all the scenarios of the installation by repeating the previous process as many times as accident scenarios have.

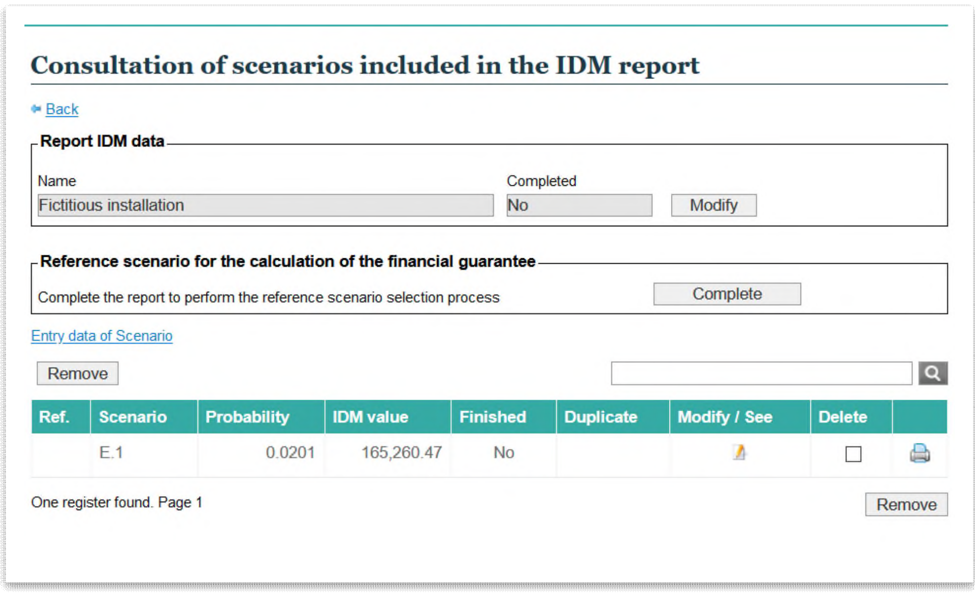


Figure AIV.4.1-10. Screen for “Consultation of scenarios included in the IDM report” after having introduced the scenario E.1 "Spillage of substance A from equipment” in the report. Source: SIRMA.

Thus, considering the scenarios of this practical example, the screen of scenarios included in the report is the one shown in the following figure.

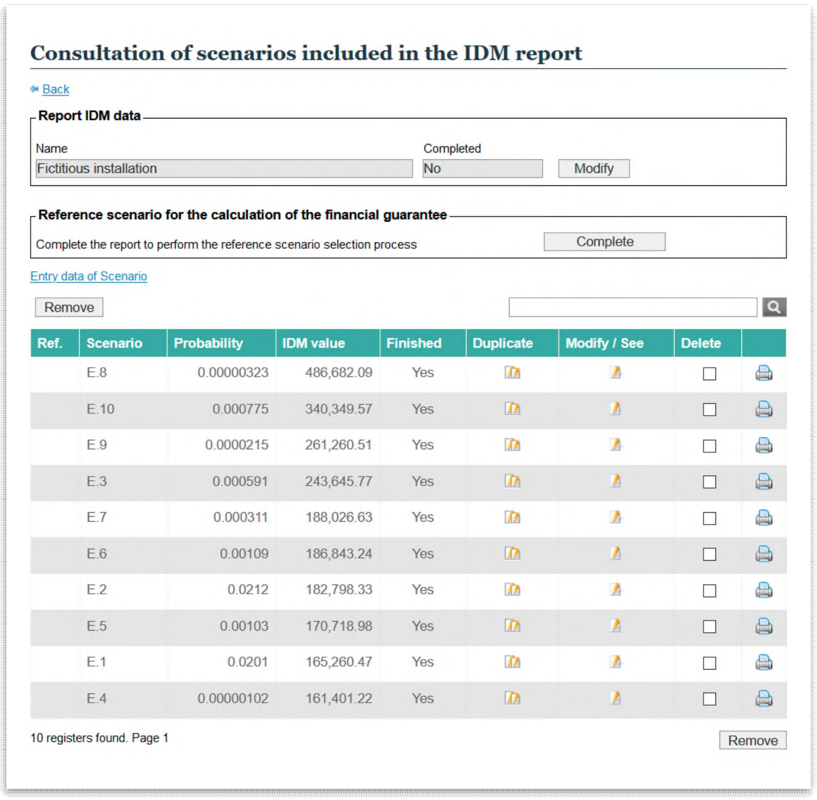


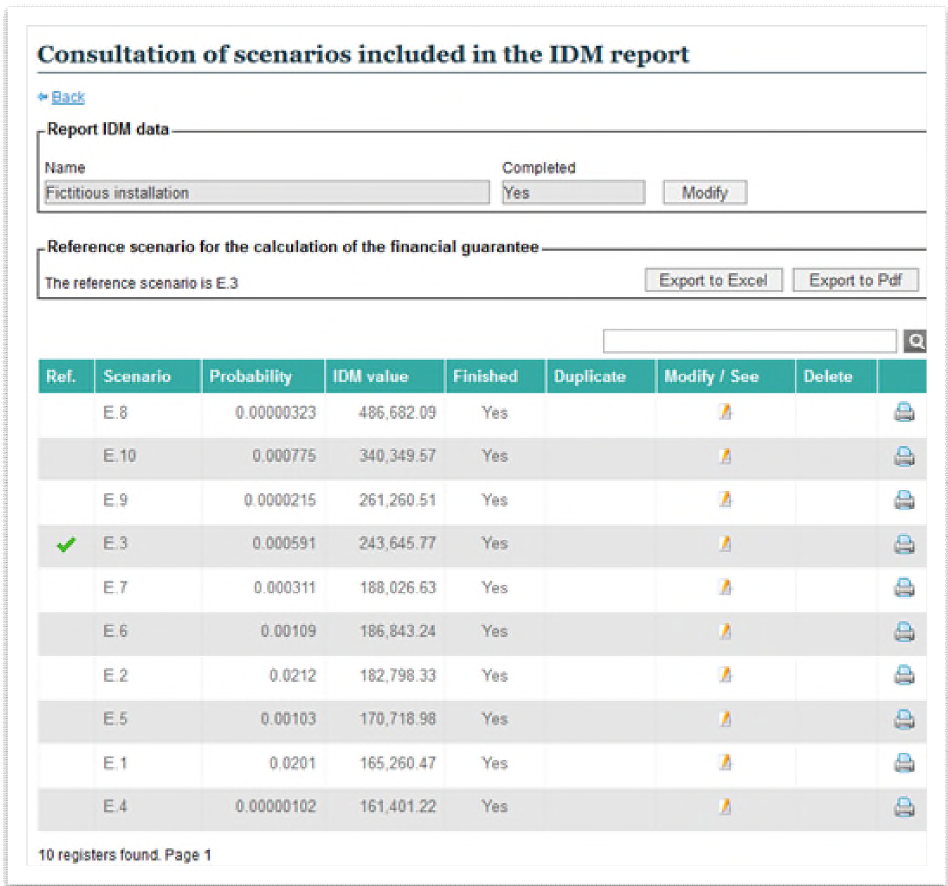
Figure AIV.4.1-11. Screen for “Consultation of scenarios included in the IDM report” after having entered all the scenarios that are part of the report. Source: SIRMA.

5. SELECTION OF THE REFERENCE ACCIDENT SCENARIO

Once the IDM has been estimated for each of the ten scenarios proposed for this example, estimated, the reference scenario would be selected. How the reference scenario should be selected to determine the amount of the financial security is as set out in the wording of article 33 of the Regulation for Partial Development of Law 26/2007, of October 23.

To do this, and once the user has entered and completed all their relevant scenarios in the IDM module, will press “complete” the report and the “confirm” button that appears next. When confirming the completion of the report, the screen “Consultation of scenarios included in the IDM report” shows the report as completed and provides by default the reference accident scenario selected for the calculation of the financial security. This scenario appears with a green mark in the column "Ref." from the list of scenarios.

The reference accident scenario in this practical exercise is scenario E.3 as indicated by the IDM module in the next screen. The scenario refers to the discharge of substance C generated by the spillage of that substance from a tank located in zone 1. The accident scenario to be assessed could cause damage to the soil and groundwater.


Consultation of scenarios included in the IDM report

Back

Report IDM data

Name: Fictitious installation — Completed: Yes — Modify

Reference scenario for the calculation of the financial guarantee

The reference scenario is E.3 — Export to Excel — Export to Pdf

Ref.	Scenario	Probability	IDM value	Finished	Duplicate	Modify / See	Delete	
	E.8	0.00000323	486,682.09	Yes				
	E.10	0.000775	340,349.57	Yes				
	E.9	0.0000215	261,260.51	Yes				
✓	E.3	0.000591	243,645.77	Yes				
	E.7	0.000311	188,026.63	Yes				
	E.6	0.00109	186,843.24	Yes				
	E.2	0.0212	182,798.33	Yes				
	E.5	0.00103	170,718.98	Yes				
	E.1	0.0201	165,260.47	Yes				
	E.4	0.00000102	161,401.22	Yes				

10 registers found. Page 1

Figure AIV.5-1. Screen for “Consultation of scenarios included in the IDM report” after the report has been completed and the accidental reference scenario selected. Source: SIRMA.

In addition, the IDM module offers the option of "Export to Excel" and "Export to Pdf" which contents are provided bellow:

- The Excel File is made up of two results sheets that provide the main results of the IDM module: specifically, a graph and a table. Note that the results sheets obtained can be managed and modified by the user as they consider most appropriate to their specific needs and circumstances. The results obtained in this practical example are the following:

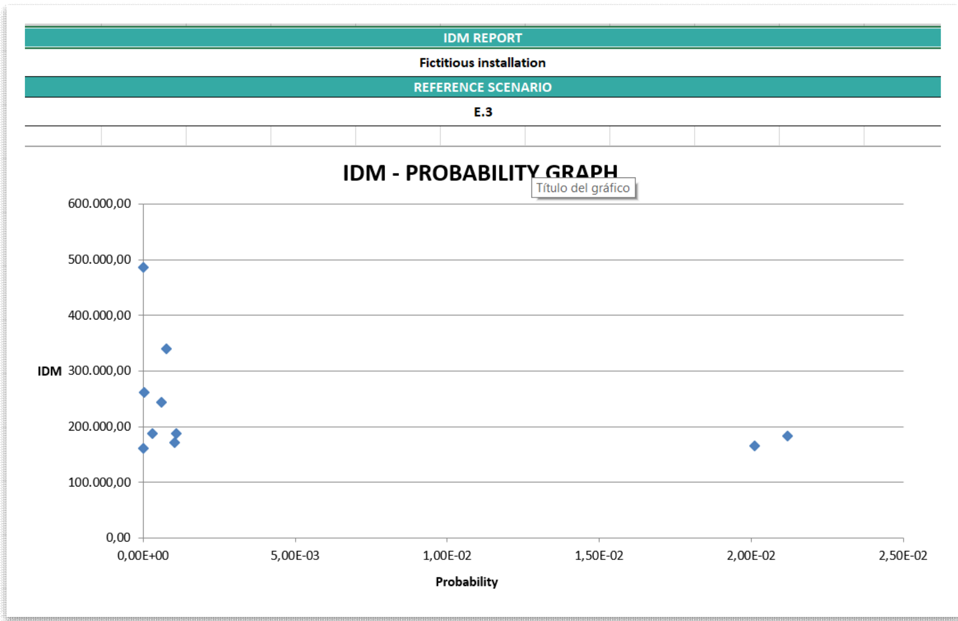


Figure AIV.5-2. IDM-Probability graph of the fictitious installation from the Excel file. Source: SIRMA.

IDM REPORT					
Fictitious installation					
REFERENCE SCENARIO					
E.3					
REFERENCE SCENARIO SELECTION PROCESS					
Accident scenario	Probability	IDM	Risk	Relative risk (%)	Accumulated relative risk (%)
E.8	3,23E-06	486.682,09	1,57198315070000000000	0,02	100,00
E.10	7,75E-04	340.349,57	263,77091675000000000000	3,28	99,98
E.9	2,15E-05	261.260,51	5,61710096500000000000	0,07	96,70
E.3	5,91E-04	243.645,77	143,99465007000000000000	1,79	96,63
E.7	3,11E-04	188.026,63	58,47628193000000000000	0,73	94,85
E.6	1,09E-03	186.843,24	203,65913160000000000000	2,53	94,12
E.2	2,12E-02	182.798,33	3.875,32459600000000000000	48,14	91,59
E.5	1,03E-03	170.718,98	175,84054940000000000000	2,18	43,45
E.1	2,01E-02	165.260,47	3.321,73544700000000000000	41,26	41,27
E.4	1,02E-06	161.401,22	0,16462924440000000000	0,00	0,00

Figure AIV.5-3. Data for the selection of the accident reference scenario from the Excel file of the fictitious installation. Source: SIRMA.

- The Pdf File captures the table obtained in the Excel file in a protected format, so unlike the previous one, it cannot be modified.

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

Comisión Técnica de Prevención y Reparación de Daños Medioambientales

IDM Índice de Daño Medioambiental

DETERMINATION OF THE REFERENCE SCENARIO FOR THE CALCULATION OF THE FINANCIAL GUARANTEE FOR ENVIROMENTAL LIABILITY

IDM REPORT
Fictitious installation
REFERENCE SCENARIO
E.3

REFERENCE SCENARIO SELECTION PROCESS					
Accidental scenario	Probability	IDM	Risk	Relative risk (%)	Accumulated relative risk (%)
E.8	0.00000323000000000000	486,682.09	1.57198315070000000000	0.02	100.00
E.10	0.00077500000000000000	340,349.57	263.77091675000000000000	3.28	99.98
E.9	0.00002150000000000000	261,260.51	5.61710096500000000000	0.07	96.70
E.3	0.00059100000000000000	243,645.77	143.99465007000000000000	1.79	96.63
E.7	0.00031100000000000000	188,026.63	58.47628193000000000000	0.73	94.85
E.6	0.00109000000000000000	186,843.24	203.65913160000000000000	2.53	94.12
E.2	0.02120000000000000000	182,798.33	3,875.32459600000000000000	48.14	91.59
E.5	0.00103000000000000000	170,718.98	175.84054940000000000000	2.18	43.45
E.1	0.02010000000000000000	165,260.47	3,321.73544700000000000000	41.26	41.27
E.4	0.00000102000000000000	161,401.22	0.16462924440000000000	0.00	0.00

Figure AIV.5-4. Data for the selection of the reference scenario from the Pdf File of the fictitious installation. Source: SIRMA.

6. QUANTIFICATION AND MONETIZATION OF THE REFERENCE SCENARIO

Once the reference scenario for determining the amount of the financial security of the facility under analysis has been selected, it is necessary to quantify and monetize this scenario later.

The natural resources likely to be damaged in the accident reference scenario (E.3) would be soil and groundwater. Specifically, 350 m^3 of substance C would be discharged, affecting these natural resources.

Since the purpose of this practical exercise is not to explain how the reference scenario should be quantified, only the results assumed for the damage quantification process are provided below.

6.1. EXTENT OF DAMAGE

As indicated, it is assumed that the only natural resources potentially affected by environmental damage would be soil and groundwater. Applying a contaminant dispersion model, it is obtained that the damage would affect 808,31 m^3 of soil (applying its density value they are equivalent to 1.333,72 t) and 27.191,78 m^3 of groundwater.

6.2. INTENSITY OF DAMAGE

According to the precautionary principle, it is assumed that the damage would have a lethal intensity that would involve the complete loss of the populations reached by the agent causing the damage.

6.3. TEMPORAL SCALE

The temporal scale of damage is evaluated in terms of duration, frequency, and reversibility.

The duration of the damage is estimated by carrying out the MORA assessment report since one of the results of the same is, precisely, the time that it is estimated that it would be necessary to recover the baseline condition of the natural resources. As set out in the following paragraphs, the duration is estimated at:

- 6 months of waiting time and 9 months of recovery time for the soil, which implies a total duration of damage to the soil of 15 months.
- 6 months of waiting time and 18 months of recovery time for groundwater, which implies a total duration of damage to groundwater of 24 months.

Therefore, the duration of the damage caused by the accident reference scenario would be 24 months if both repairs can be carried out at the same time, and at least 39 months if the works must be carried out sequentially.

The estimated frequency for the reference scenario coincides with the probability assigned to it, being 5,91 10^{-4}.

Finally, considering the characteristics of the accident scenario, it is assumed that the damage is reversible and that, therefore, the natural resources affected could return to their baseline condition within a reasonable period.

7. ECONOMIC VALUATION OF THE REFERENCE SCENARIO (MORA)

7.1. DATA COLLECTION FOR ECONOMIC VALUATION

The following table collects the data of interest for economic assessment of environmental damage using the MORA module. It is assumed that such data must either be collected in the environmental risk analysis of the operator or be consulted in the cartographic viewer of the MORA application.

Parametre	Value	Unit	Source
Type of agent	Biodegradable Non halogenated VOC	-	ARM
Coordinates	-	-	ARM
Amount of damaged soil	1,334	t	ARM
Amount of damaged groundwater	27,192	m^3	ARM
Accesibility	Yes	-	ARM /MORA viewer
Distance to the nearest road	0	m	ARM /MORA viewer
Slope	Very low	-	ARM /MORA viewer
Permeability	Medium	-	ARM /MORA viewer
Protected area	No	-	ARM /MORA viewer

ARM: Environmental risk analysis of the operator
MORA viewer: cartographic viewer of the MORA module

Table AIV. 7.1-1. Data collection for the use of the MORA module. Source: Prepared by the authors.

- The type of agent selected is a biodegradable non-halogenated VOC consistent with the treatment given to "Substance C" in the IDM module.
- Regarding the location of the damage, some random coordinates have been entered in the MORA cartographic viewer that respond to the characteristics of the environment that are being assumed. Such coordinates are not shown in the document as they are of no interest as they are a fictitious case.
- The amount of damaged natural resources has been rounded up, thus being 1,334 t of soil and 27,192 m^3 of groundwater.
- The area is considered accessible with an adjacent road and a very low slope, a medium permeability and without any specific protection figure.

7.2. ACCESS TO THE MORA APPLICATION

The MORA report can be started by pressing on the "create a new report" button within the MORA section of the navigation menu of the tool.

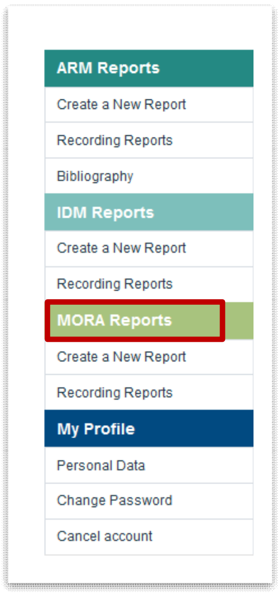


Figure AIV. 7.2-1. Access to the MORA module. Source: SIRMA.

7.3. GENERAL DATA

Once the user clicks on the "Create a new report" button they access the general data screen where they must fill in the name of the report, the name or company name of the operator, the type of company and its CNAE code.

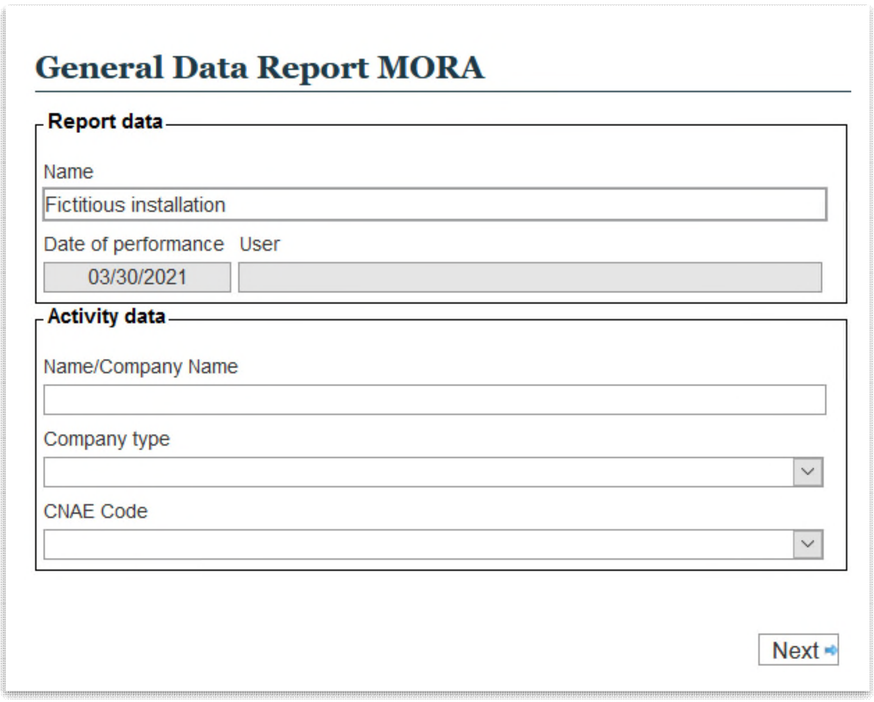


Figure AIV. 7.3-1. General data of the report. Source: SIRMA.

When such data has been completed, the "Next" button will be pressed to proceed with the location of the environmental damage.

7.4. LOCATION OF THE DAMAGE

In the damage location screen, the user can either directly enter the coordinates of the affected site or select the point on the MORA cartographic viewer by pressing on the "browse" button. As indicated, this document does not specify these data since the practical example has been directed to an hypothetical facility.

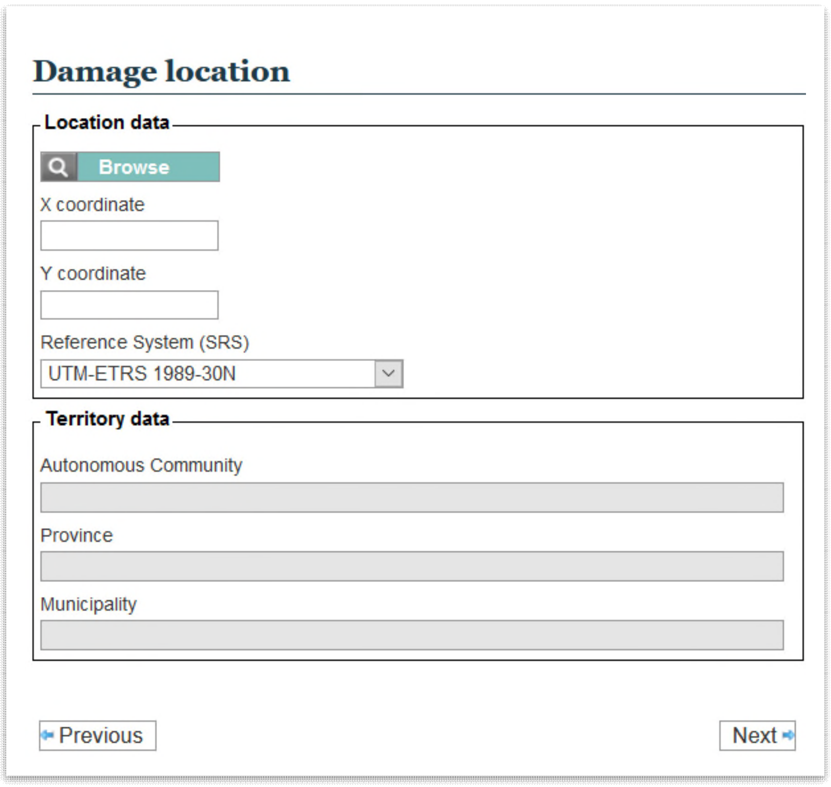


Figure AIV. 7.4-1. Location of the damage. Source: SIRMA.

From the location entered by the user, the MORA application loads the territory parameters predefined by its digital maps.

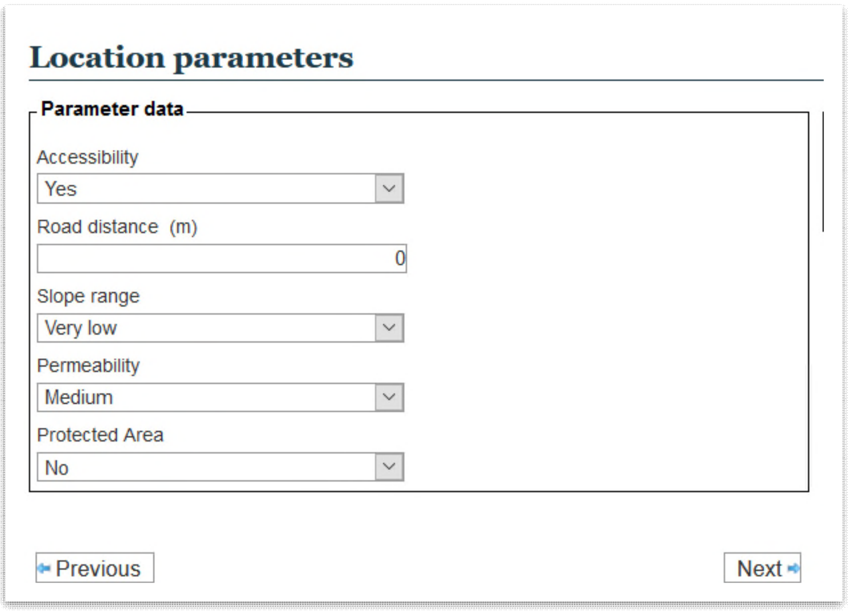


Figure AIV. 7.4-2. Damage location parameters. Source: SIRMA.

In the present practical case, all the default values have been maintained, except for the distance to the closest communication route, which has been set to zero, considering that the area affected by the damage has an adjacent road.

.

7.5. AGENTS SELECTION

A biodegradable non-halogenated VOC is marked as the damaging agent on the damaging agents screen.

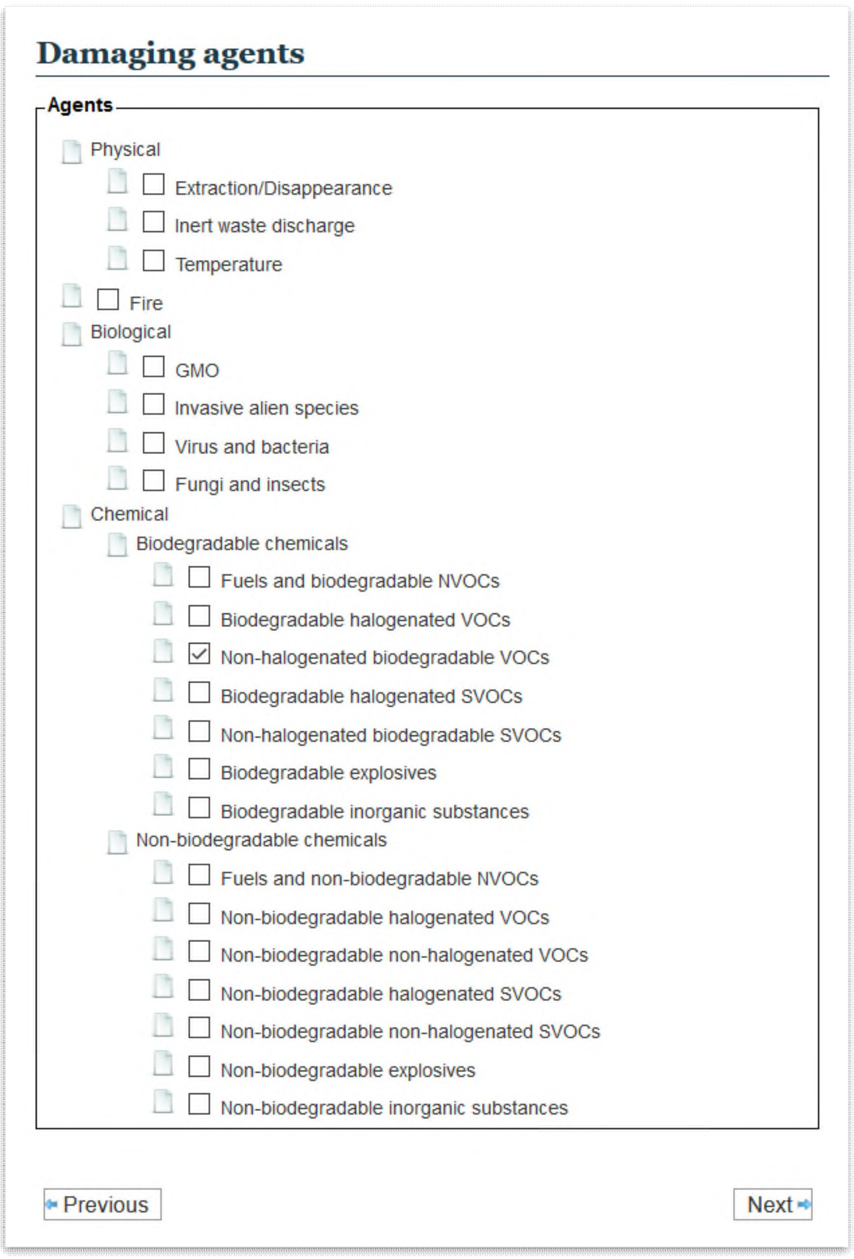


Figure AIV. 7.5-1. Selection of the damaging agents. Source: SIRMA.

Clicking on the "Next" button it accesses to the natural resources screen.

7.6. NATURAL RESOURCES AFFECTED BY THE AGENT

The user would select as damaged resources the soil and groundwater.

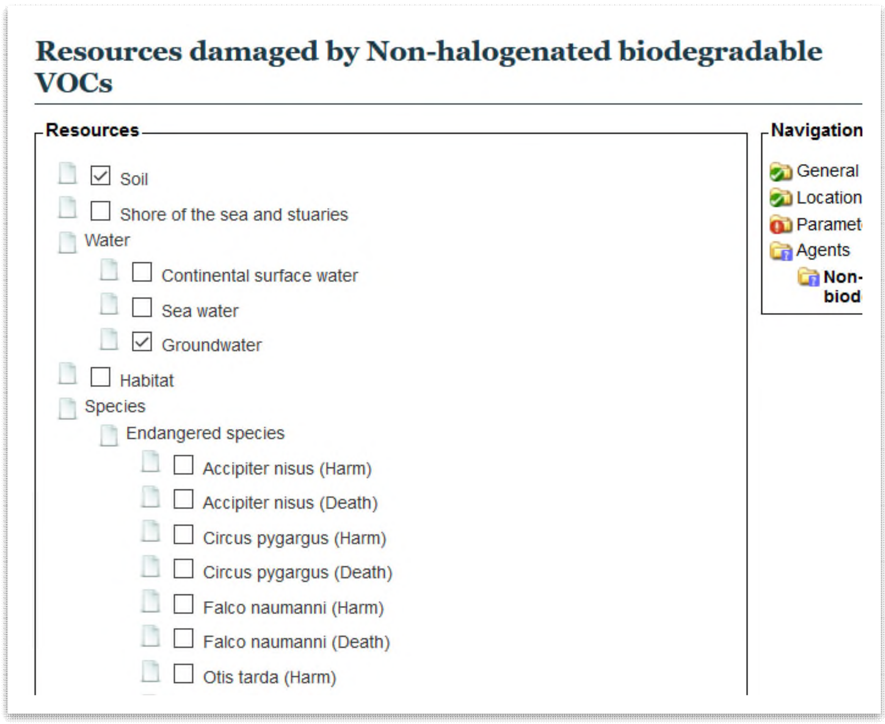


Figure AIV. 7.6-1. Selection of the resources affected by the agent. Source: SIRMA.

By clicking on the "Next" button it starts the specific assessment process of valuation of each combination damaging agent-damaged natural resource.

7.7. COMBINATION AGENT-RESOURCE: DAMAGE DATA

Since the practical example presents two agent-resource combinations (damage by VOC to soil and damage by VOC to groundwater), the reference scenario is made up of these two combinations; that is why the MORA application will request each of these two combinations separately.

The following sections show only, as an illustration, the screens and the process followed for the first combination (biodegradable non-halogenated VOC damage to the soil) since the process for the other combination is similar.

The first screen of each combination refers to the amount of resource that would be affected by the damage and the reversibility of the damage. In the following screens it will proceed to the economic valuation of the environmental damage.

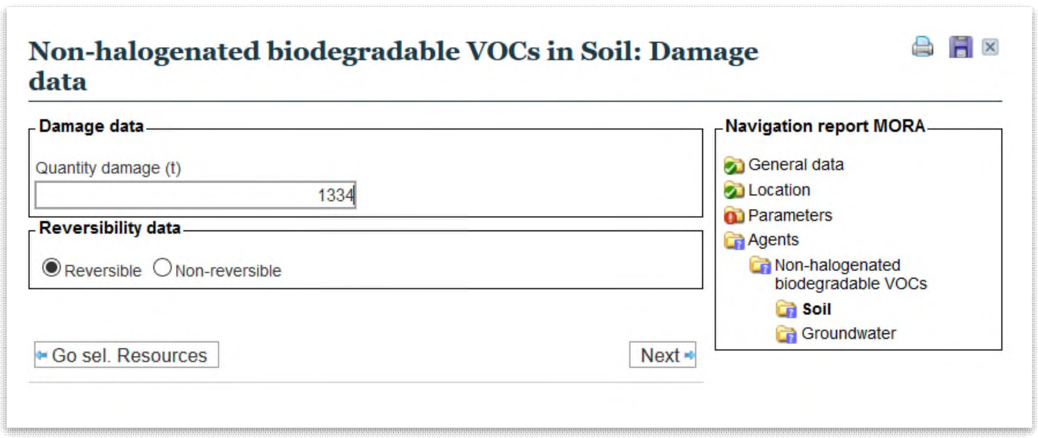


Figure AIV. 7.7-1. Request for damage data. Source: SIRMA.

7.8. ECONOMIC VALUATION OF THE ENVIRONMENTAL DAMAGE

The reference scenario in the practical example has been considered as reversible so the MORA application proceeds to calculate the primary remediation and the compensatory remediation. It is recalled that if the damage had been described as irreversible the module would only proceed to the valuation of the complementary remediation.

a) Agent-resource combination: Primary remediation technique

MORA recommends a single technique for repairing each agent-resource combination. In this case, the selected technique for the primary remediation is biopiles. However, those operators who wish to modify this selection given by default can do so by selecting one of the techniques listed in the "Recommended Techniques" or "Available Techniques" catalog. Alternatively, the operator could enter its own repair technique in the "Own technique" section.

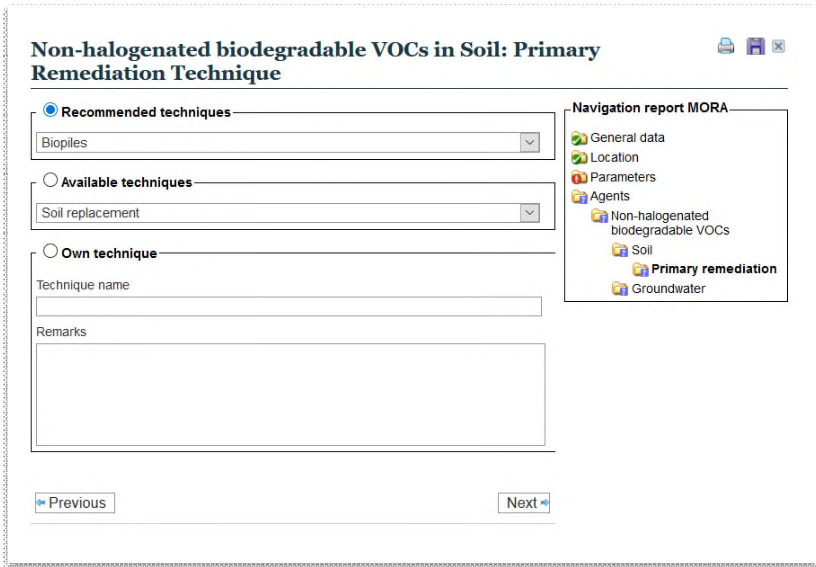


Figure AIV. 7.8-1. Screen for the selection of the primary remediation technique. Source: SIRMA.

b) Agent-resource combination: Data of the primary remediation

The next screen shows the cost and recovery time data for the primary remediation.

If the analyst has opted for an own repair technique, they must fill in this screen with the appropriate cost information.

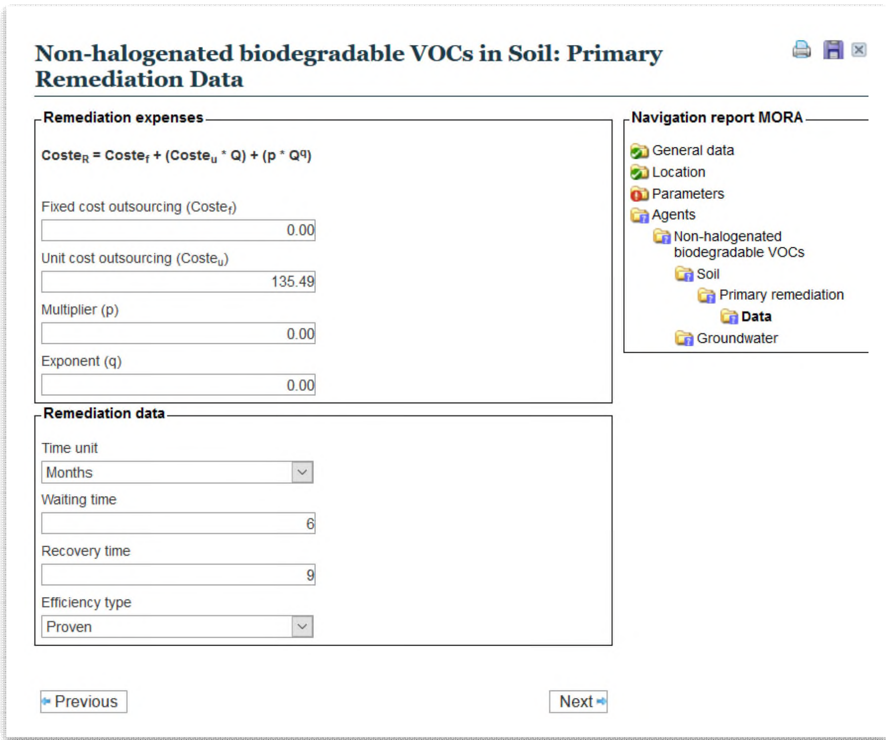
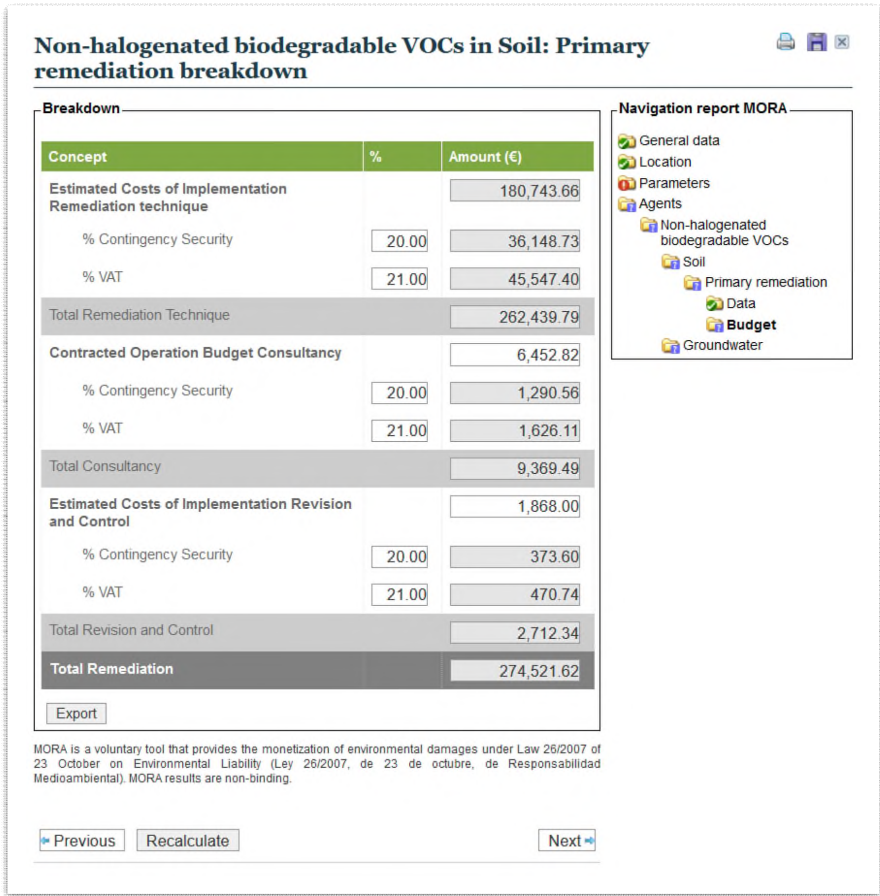


Figure AIV. 7.8-2. Screen of primary remediation data. Source: SIRMA.

c) Agent-resource combination: Budget for the primary remediation

With the initial data above, the application builds the budget for the primary remediation so that the valuation of this measure is completed.



Non-halogenated biodegradable VOCs in Soil: Primary remediation breakdown

Breakdown

Concept	%	Amount (€)
Estimated Costs of Implementation Remediation technique		180,743.66
% Contingency Security	20.00	36,148.73
% VAT	21.00	45,547.40
Total Remediation Technique		262,439.79
Contracted Operation Budget Consultancy		6,452.82
% Contingency Security	20.00	1,290.56
% VAT	21.00	1,626.11
Total Consultancy		9,369.49
Estimated Costs of Implementation Revision and Control		1,868.00
% Contingency Security	20.00	373.60
% VAT	21.00	470.74
Total Revision and Control		2,712.34
Total Remediation		274,521.62

Export

Navigation report MORA
- General data
- Location
- Parameters
- Agents
  - Non-halogenated biodegradable VOCs
    - Soil
      - Primary remediation
        - Data
        - **Budget**
    - Groundwater

MORA is a voluntary tool that provides the monetization of environmental damages under Law 26/2007 of 23 October on Environmental Liability (Ley 26/2007, de 23 de octubre, de Responsabilidad Medioambiental). MORA results are non-binding.

Previous | Recalculate | Next

Figure AIV. 7.8-3. Budget for the primary remediation. Source**:** SIRMA.

d) Agent-resource combination: Compensatory remediation technique

The procedure for the valuation of the compensatory remedial measure is like that performed for the assessment of the primary remedial measure. In this way, it starts from the identification of the technique to be applied.

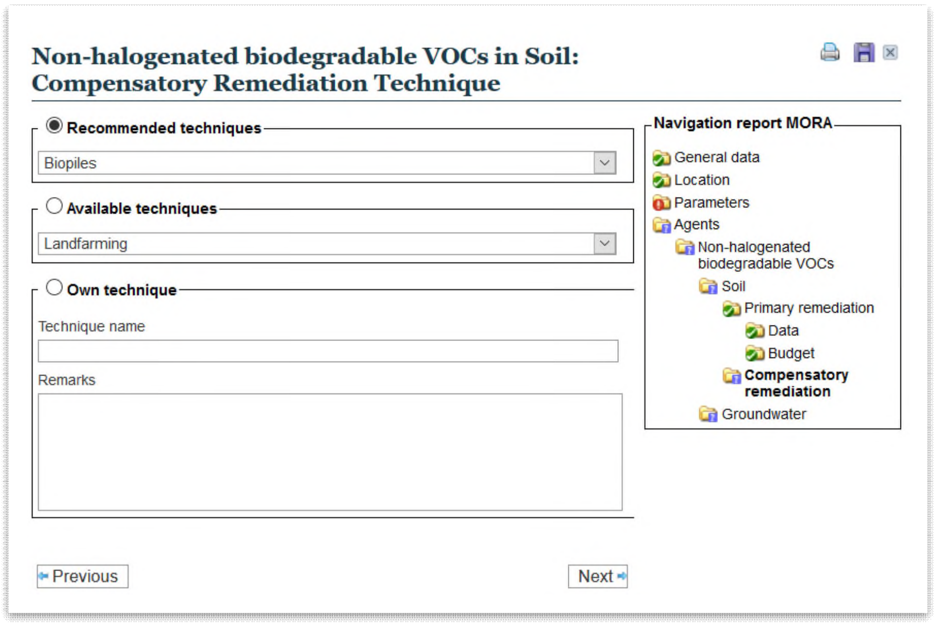


Figure AIV. 7.8-4. Screen for the selection of the compensatory remediation technique. Source: SIRMA.

e) Agent-resource combination: Data of the compensatory remediation

The next screen shows the cost and recovery time data, in this case, for the compensatory remediation.

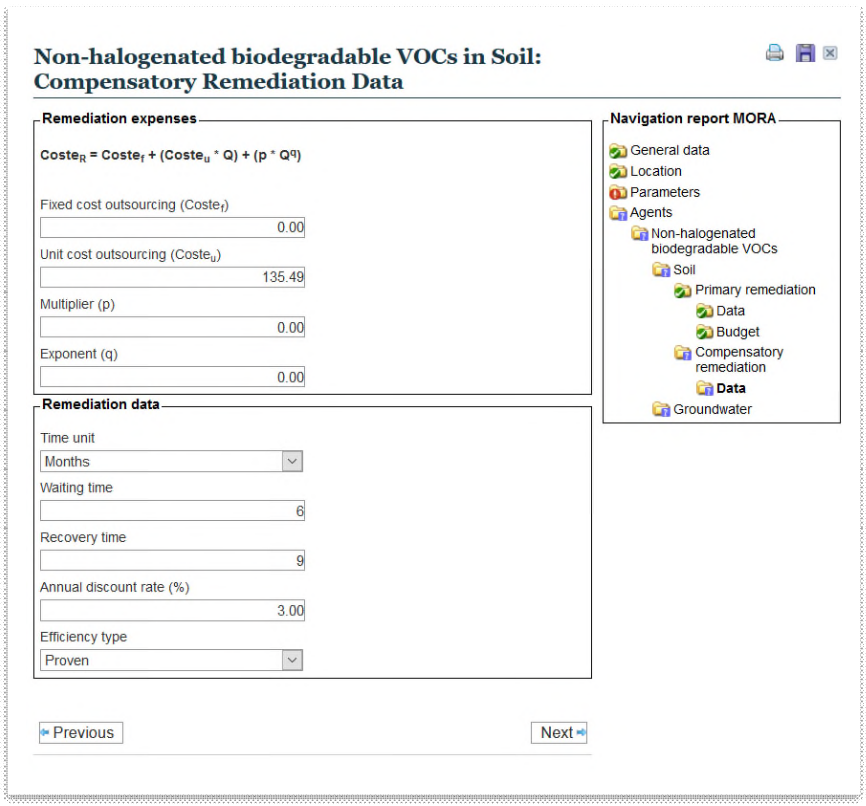


Figure AIV. 7.8-5. Screen of compensatory remediation data. Source: SIRMA.

f) Agent-resource combination: Compensatory remediation diagram

The following screen represents a difference with respect to the design procedure of the primary remediation since it shows the chart of the Resource Equivalency Analysis (REA) that is carried out to know the additional resource units that should be repaired in compensatory measure concept. In other words, the REA result is always expressed in units of affected natural resources (environmental debit) and generated by remediation (environmental credit). Subsequently, these units are object of economic valuation using the methodology and data collected in MORA.

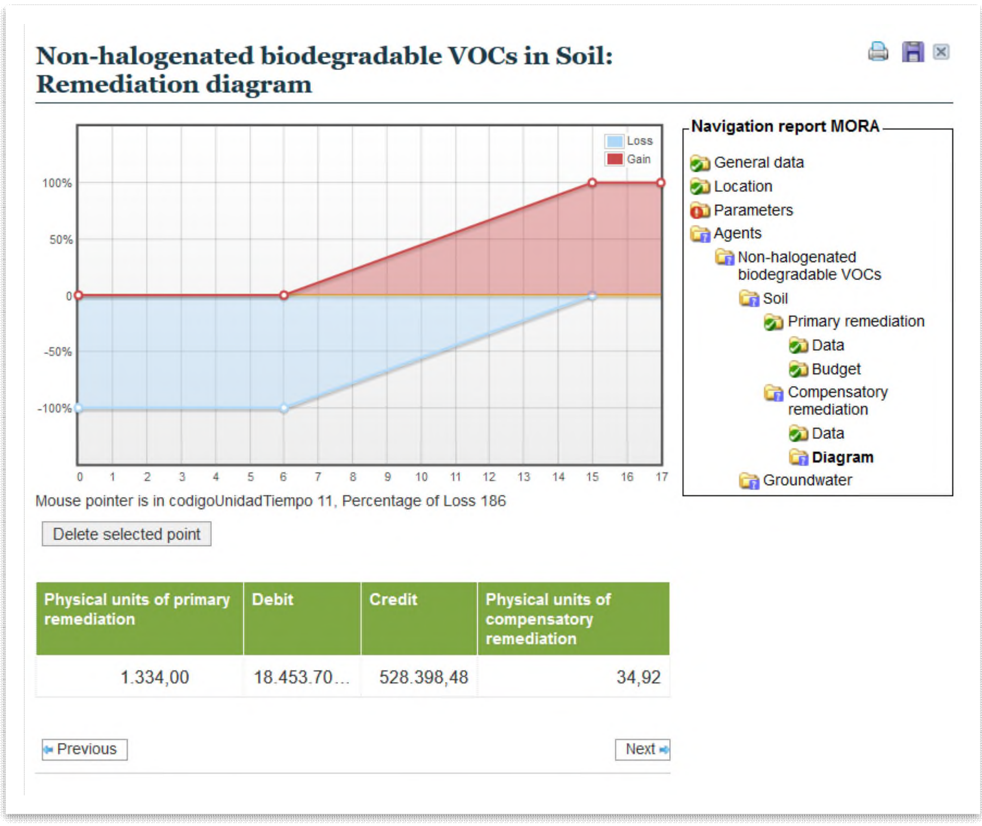


Figure AIV. 7.8-6. REA chart of the compensatory remediation. Source: SIRMA.

In the case used in this practical example in the REA, a result of 34.92 would be obtained. That is, an additional 34.92 t of soil should be repaired to compensate society for the time elapsed from when the damage occurred until it is repaired.

g) Agent-resource combination: Budget for the compensatory remediation

Once the units to be repaired are known, they are monetized, constructing the budget for the compensatory remediation.

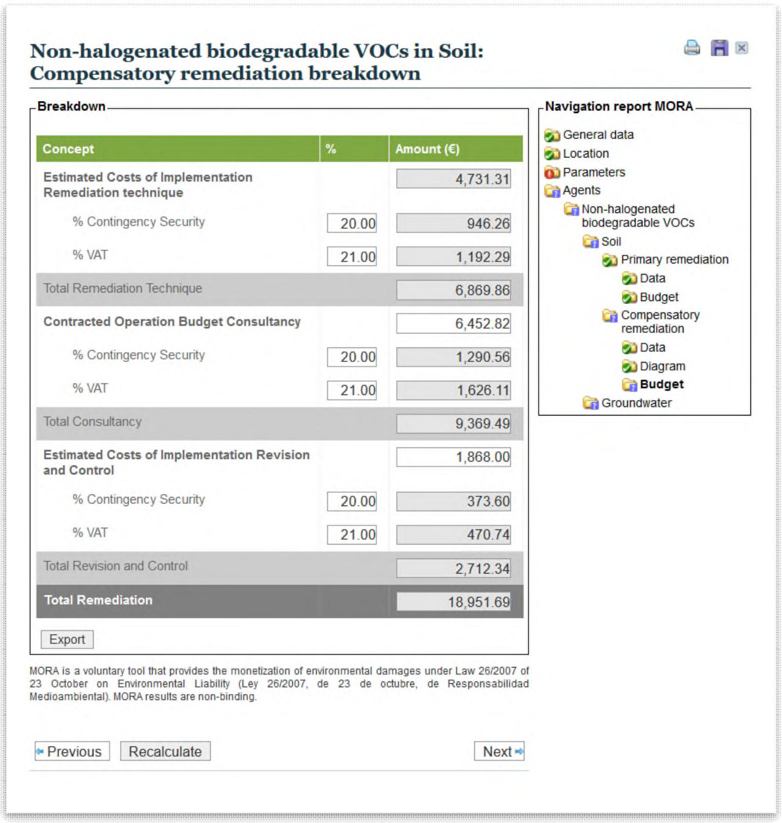


Figure AIV. 7.8-7. Budget for the compensatory remediation. Source: SIRMA.

h) Agent-resource combination: Total breakdown of damage

Once the valuation of the remedial measures (primary and compensatory, in this case) has been concluded, the application returns a summary table with the total cost of damage associated with the agent-resource combination that has been entered.

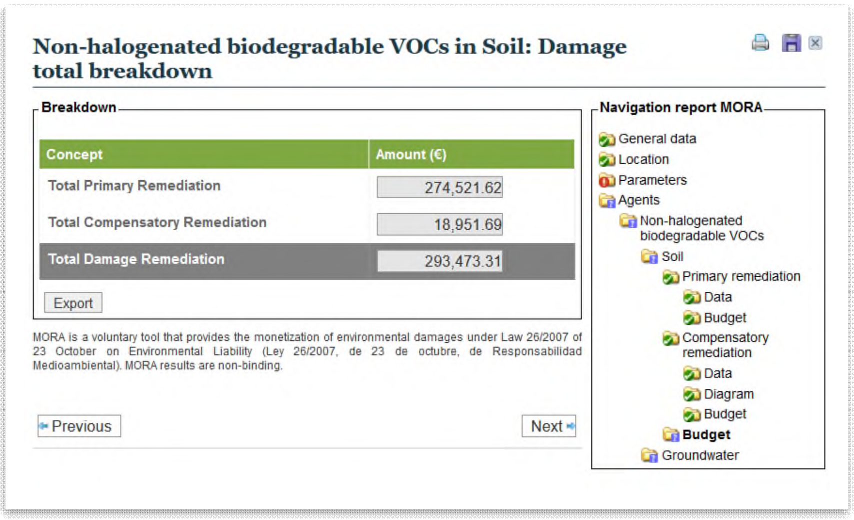


Figure AIV. 7.8-8. Total breakdown of damage in primary and compensatory remediation. Source: SIRMA.

As indicated, in MORA it would be necessary to repeat the previous procedure as many times as agent-resource combinations have been entered in the tool. However, in order to avoid this repetition, this document does not include the screens regarding the damage caused by biodegradable halogenated VOCs to groundwater.

7.9. ACCESS COST BUDGET

The last costs considered before calculating the total cost of the environmental damage is the cost of access to the affected site. In this case since it is assumed the existence of a pre-existing communication route is assumed, these costs are zero.

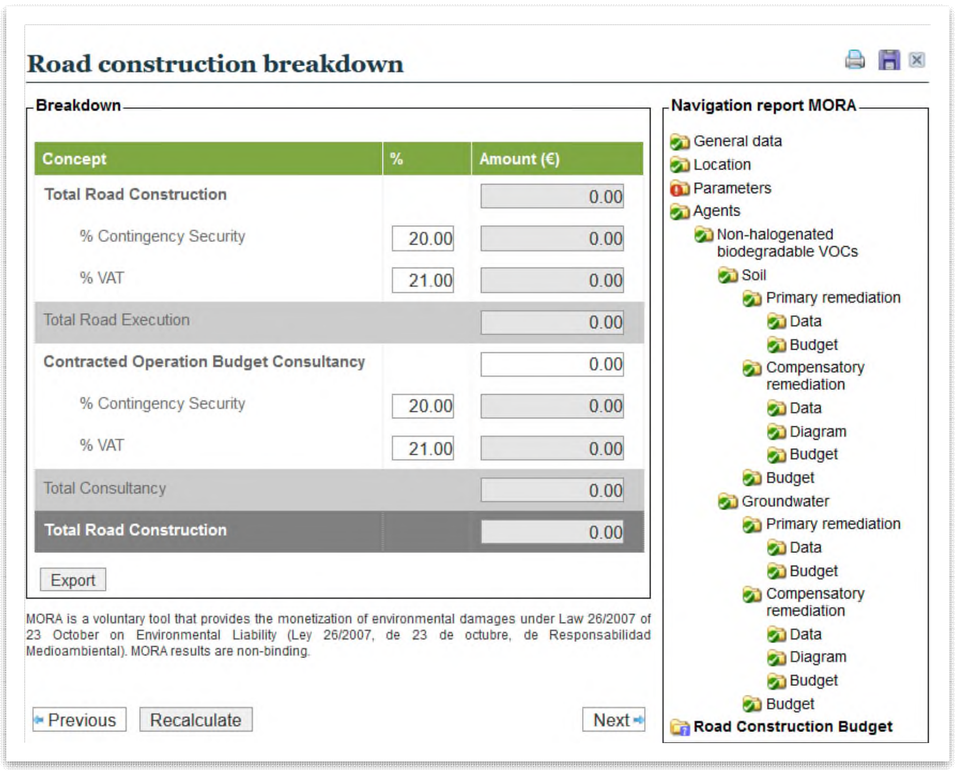


Figure AIV. 7.9-1. Budget for the construction of the communication route. Source: SIRMA.

7.10. AMOUNT OF FINANCIAL SECURITY

In this screen the tool calculates the amount of financial security for environmental liability. It includes, on the one hand, the possibility of marking the availability of ISO or EMAS certification - in which case, it would modify the mandatory range of the financial security amount - and, on the other hand, the possibility of modifying the percentage of prevention and avoidance costs. By default, the tool offers 10% for prevention and avoidance, but the user can increase this amount if necessary. In this example, the activity is not ISO or EMAS certified and prevention and avoidance costs are estimated at 10%. As a result, the amount of the financial security for the activity is € 846,147.39.

Financial security

Setting of the financial security

Do you want to include the financial security proposal?

Yes ◉ No ○

☐ ISO or EMAS certified

Concept	%	Amount (€)
Primary Remediations		769,224.90
Road Construction		0.00
Primary Remediations + Road Construction		769,224.90
% Prevention and Avoidance	10.00	76,922.49
Financial security proposal		**846,147.39**

According to the data entered and in accordance with the provisions of article 24.1 of Law 26/2007, the operator of a facility included in article 37.2 of its development regulations will be obliged to provide a financial guarantee for the minimum amount offered the computer application.

Previous | Next

Figure AIV. 7.10-1. Financial security budget table. Source: SIRMA.

7.11. FINAL REPORT

Once this procedure is concluded, the user has the possibility of finalizing their report in such a way that its content is blocked and, in this way, protected against editing. The output products offered by MORA are:

– The report in PDF format in which all the data entered are included.
– A summary table with the costs of the repairs.

Remediation summary

Agent-resource combinations of the accidental scenario	Action type	Amount (€)
Non-halogenated biodegradable VOCs-Soil	Primary remediation	274,521.62
	Compensatory remediation	18,951.69
	Complementary remediation	0.00
	Subtotal	293,473.31
Non-halogenated biodegradable VOCs-Groundwater	Primary remediation	231,885.46
	Compensatory remediation	231,635.43
	Complementary remediation	0.00
	Subtotal	463,520.89
Road Construction Budget		0.00
Primary remediation total (including road construction)		506,407.08
Compensatory remediation total (without including road construction)		250,587.12
Complementary remediation total (without including road construction)		0.00
Remediation total		**756,994.20**

Export

Figure AIV. 7.11-1. Summary table of the cost of the repairs. Source: SIRMA.

8. DETERMINATION OF THE FINANCIAL SECURITY

As described in section 7.10. Amount of financial security, MORA offers the possibility of calculating the amount of financial security for environmental liability. It includes the amount of the primary remediation and the cost of prevention and avoidance of damage as described in article 33 of the Regulation for Partial Development of Law 26/2007, of October 23, which indicates that in order to include prevention and avoidance costs, the operator may:

a) Apply a percentage on the total amount of the mandatory financial security.
b) Estimate such prevention and avoidance costs through the environmental risk analysis.

In any case, the amount of the costs of prevention and avoidance of damage will be, at least, ten percent of the total amount of the financial security.

In this practical example, the financial security is calculated in an illustrative way based on the total amount of the primary remediation and increasing this amount by 10%. In this way, the operator would obtain a value of € 557,047.79.

Concept	Amount (€)
Primary remediation total (including road construction)	506,407.08
Prevention and avoidance of further damage	50,640.71
Amount of the financial security	557,047.79

Table AIV. 8-1. Calculation of the financial security for environmental liability. Source: Prepared by the authors.

GOBIERNO DE ESPAÑA

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

SECRETARY OF STATE FOR THE ENVIRONMENT

DIRECTORATE GENERAL FOR ENVIRONMENTAL QUALITY AND ASSESSMENT

TECHNICAL COMMISSION OF PREVENTION AND REMEDIATION OF ENVIRONMENTAL DAMAGES