Probability Assessment Methodology **Appendix C**

Following the methodology detailed in appendix A of this report, this section provides the results of the probability assessment for the 2006 survey. This assessment has been based on the methodology from the Health Protection Agency Publication RPD-EA-9-2005, formulae used has been referenced to the appropriate page in the HPA publication.

1. Estimate Number of Items per square metre of beach

No. of items detected	Nf	37		
Area surveyed	As	11000	m^2 of beach (surveyed)	
Area of beach	Ab	100000	m^2 of beach (total)	(Value is Estimated)
No of items per m^2	Fa	0.00336	per m^2 of beach	
Total items on beach	Ft	336.36364	items	

2. Calculating Item Density
(Page 3, RPD-EA-9-2005)

$$F_d = \frac{F_a}{d \times D_s}$$

Density of sand is calculated as an average of the following values
http://www.simetric.co.uk/si_materials.htm

	Density (kg m^{-3})
Sand, wet	1922
Sand, wet, packed	2082
Sand, dry	1602
Sand, loose	1442
Sand, rammed	1682
Sand, Water Filled	1922
Sand with Gravel, dry	1650
Sand with Gravel, wet	2020
Average Sand Density	1790.25

kg m^{-3}

Known Data

Depth of monitoring (d)	0.10	m
Items per m^2 (Fa)	3.36E-03	items
Density of sand	1.79E+06	g/m^3

Therefore,

Item Density (Fd)	1.88E-08	per g of sand

3. Probability of Inadvertent ingestion of a item with sand
(Page 28, RPD-EA-9-2005)

$$P_{ing} = F_d \times I_R \times O_R$$

P_{ing} is the probability of ingestion
F_d is the item density, g^{-1}
I_R is the inadvertent ingestion rate, g h^{-1}
O_R is the occupancy rate (per visit or per year)

Item Density F_d 1.87913E-08 per g of sand

Specific Data

Inadvertent Ingestion Rate

	I_R	
	Per Visit ($g\ h^{-1}$)	Annual ($g\ y^{-1}$)
Adult	0.005	10.000000
Child	0.01	3.000000
Infant	0.05	1.500000

(based on occupancy x I_R)

Occupancy Rate

	O_R	
	Per Visit (h)	Annual ($h\ y^{-1}$)
Adult	1	2000
Child	1	300
Infant	1	30

Calculated Probability of Inadvertent Ingestion

	P_{ing} Per Visit
Adult	9.39563E-11
Child	1.87913E-10
Infant	9.39563E-10

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{ing,ann} = 1 - P_{n\_ing,vis}^{O_R}$$

$P_{inh,ann}$ is the annual probability of ingestion
O_R is the annual occupancy rate
$P_{n\_ing,vis}$ is the probability of not ingesting an item on a single visit, which is calculated as follows:

$$P_{n\_ing,vis} = 1 - P_{ing,vis}$$

$P_{ing,vis}$ is the probability of ingesting an item per visit

Specific Data

	$P_{ing,vis}$ (Per Visit)	O_R (Annual, h)
Adult	9.39563E-11	2000
Child	1.87913E-10	300
Infant	9.39563E-10	30

Calculated Data

	$P_{ing,ann}$ (Annual)
Adult	1.8791E-07
Child	5.6374E-08
Infant	2.8187E-08

4. Probability of a item coming into direct contact with the skin

DRY SAND
(Page 31, RPD-EA-9-2005)

$$P_{skin,dry} = (S_1 + 0.5 \times S_2) \times D_{L,d} \times F_d \times D_{S,d}$$

$P_{skin,dry}$	is the probability of direct skin contact with dry sand
S_1	is the area of skin on hands and feet that was exposed to dry sand, cm^2
S_2	is the area of skin on other parts of the body that was exposed to dry sand, cm^2
$D_{L,d}$	is the dermal loading of dry sand on hands and feet
F_d	is the item density, g^{-1}
$D_{s,d}$	is the dermal loading of dry sand on other parts of the body

Item Density	F_d	1.88E-08	per g of sand
Dermal Loading of dry sand	$D_{L,D}$	0.0001	g cm^{-2}
Readherence Factor	D_s	2	-

Specific Data

	Skin Areas (m^2)						
Age Group	Lower Arms	Lower Legs	Hands	Palms & outstretched fingers	Feet	Soles of feet	Total Body
Adult	0.11	0.24	0.099	0.05	0.13	0.065	1.9
Child	0.059	0.13	0.059	0.03	0.085	0.043	1.12
Infant	0.026	0.049	0.028	0.014	0.037	0.019	0.53

therefore

	S_1 (cm^2)	S_2 (cm^2)
Adult	1150	3500
Child	730	1890
Infant	330	750

Calculated Probability of Item in direct contact with skin (dry sand)

	$P_{skin,dry}$ Per Visit
Adult	1.08989E-08
Child	6.29507E-09
Infant	2.64957E-09

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{skin,dry,ann} = 1 - P_{n\_skin,dry,vis}^{O_R}$$

$P_{skin,dry,ann}$ is the annual probability of skin contact with dry sand
O_R is the annual occupancy rate
$P_{n\_skin,dry,vis}$ is the probability of not coming into contact with an item in dry sand on a single visit, which is calculated as follows:

$$P_{n\_skin,dry,vis} = 1 - P_{skin,dry,vis}$$

$P_{skin,dry,vis}$ is the probability of coming into contact an item through dry sand per visit

Specific Data

	$P_{skin,dry,vis}$ (Per Visit)	O_R (Annual, h)
Adult	1.08989E-08	2000
Child	6.29507E-09	300
Infant	2.64957E-09	30

Calculated Data

	$P_{skin,dry,ann}$ (Annual)
Adult	2.1798E-05
Child	1.8885E-06
Infant	7.9487E-08

WET SAND
(Page 31, RPD-EA-9-2005)

$$P_{skin,wet} = (S_3 + 0.5 \times S_4) \times D_{L,w} \times F_d \times D_{S,w}$$

$P_{skin,wet}$	is the probability of direct skin contact with wet sand
S_3	is the area of skin on hands and feet that was exposed to wet sand, cm^2
S_4	is the area of skin on other parts of the body that was exposed to wet sand, cm^2
$D_{L,w}$	is the dermal loading of wet sand on hands and feet, g cm^{-2}
F_d	is the item density, g^{-1}
$D_{s,w}$	is a factor to account for the re-adherence of wet sand on skin during the visit

Known Data

Item Density	Fd	1.87913E-08 per g of sand
Dermal Loading of wet sand	Diw	0.005 g cm^{-2}
Readherence Factor	Ws	2 -

Specific Data

	Skin Areas (m^2)						
Age Group	Lower Arms	Lower Legs	Hands	Palms & outstretched fingers	Feet	Soles of feet	Total Body
Adult	0.11	0.24	0.099	0.05	0.13	0.065	1.9
Child	0.059	0.13	0.059	0.03	0.085	0.043	1.12
Infant	0.026	0.049	0.028	0.014	0.037	0.019	0.53

therefore

	S_3 (cm^2)	S_4 (cm^2)
Adult	1150	3500
Child	730	1890
Infant	330	750

Calculated Probability of item in direct contact with skin (wet sand)

	$P_{skin,wet}$ Per Visit
Adult	5.44947E-07
Child	3.14754E-07
Infant	1.32478E-07

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{skin,wet,ann} = 1 - P_{n\_skin,wet,vis}^{O_R}$$

$P_{skin,wet,ann}$ is the annual probability of skin contact with wet sand
O_R is the annual occupancy rate
$P_{n\_skin,wet,vis}$ is the probability of not coming into contact with an item in wet sand on a single visit, which is calculated as follows:

$$P_{n\_skin,wet,vis} = 1 - P_{skin,wet,vis}$$

$P_{skin,wet,vis}$ is the probability of coming into contact an item through wet sand per visit

Specific Data

	$P_{skin,wet,vis}$ (Per Visit)	O_R (Annual, h)
Adult	5.44947E-07	2000
Child	3.14754E-07	300
Infant	1.32478E-07	30

Calculated Data

	$P_{skin,wet,ann}$ (Annual)
Adult	1.0893E-03
Child	9.4422E-05
Infant	3.9743E-06

WET & DRY SAND
(Page 32, RPD-EA-9-2005)

$$P_{skin,dry\&wet} = \left[\left(\frac{S_1 + 0.5 \times S_2}{50}\right) + \left(S_3 + 0.5 \times S_4\right)\right] \times D_{L,wet} \times F_d \times D_{s,d\&w}$$

$P_{skin,dry\&wet}$	is the probability of direct skin contact with both dry & wet sand
S_1	is the area of skin on hands and feet that was exposed to dry sand, cm^2
S_2	is the area of skin on other parts of the body that was exposed to dry sand, cm^2
S_3	is the area of skin on hands and feet that was exposed to wet sand, cm^2
S_4	is the area of skin on other parts of the body that was exposed to wet sand, cm^2
$D_{L,wet}$	is the dermal loading of wet sand on hands and feet, g cm^{-2}
F_d	is the item density, g^{-1}
$D_{s,d\&w}$	is a factor to account for the re-adherence of both dry & wet sand on skin during the visit

Known Data

$D_{L,wet}$	0.005 g cm^{-2}
F_d	1.87913E-08 per g of sand
$D_{s,d\&w}$	2

Specific Data

	S1	S2	S3	S4
Adult	1150	3500	1150	3500
Child	730	1890	730	1890
Infant	330	750	330	750

Calculated Probability of a item coming into direct contact with the skin (in dry and wet conditions)

	$P_{skin,dry\&wet}$ Per Visit
Adult	5.56E-07
Child	3.21E-07
Infant	1.35E-07

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{skin,dry\&wet,ann} = 1 - P_{n\_skin,dry\&wet,vis}^{O_R}$$

$P_{skin,dry\&wet,ann}$ is the annual probability of skin contact with dry and wet sand
O_R is the annual occupancy rate
$P_{n\_skin,dry\&wet,vis}$ is the probability of not coming into contact with an item in dry and wet sand on a single visit, which is calculated as follows:

$$P_{n\_skin,dry\&wet,vis} = 1 - P_{skin,dry\&wet,vis}$$

$P_{skin,dry\&wet,vis}$ is the probability of coming into contact an item through dry and wet sand per visit

Specific Data

	$P_{skin,dry\&wet,vis}$ (Per Visit)	O_R (Annual, h)
Adult	5.55846E-07	2000
Child	3.21049E-07	300
Infant	1.35128E-07	30

Calculated Data

	$P_{skin,dry\&wet,ann}$ (Annual)
Adult	1.1111E-03
Child	9.6310E-05
Infant	4.0538E-06

5. A Item under the fingernails
(Page 37, RPD-EA-9-2005)

$$P_{nails} = F_d \times S_n$$

P_{nails}	is the probability of contacting a item in sand trapped under nails per beach visit
F_d	is the item density, g^{-1}
S_n	amount of sand trapped under nails per visit to the beach, g

Known Data

item Density	Fd	1.87913E-08 per g of sand
Sand Density	Sd	1.79E+06 g/m^3

Specific Data

	$S_{n,volume}$ (m^3)	$S_{n,mass}$ (g)
Adult	2.40E-07	0.430
Child	8.60E-08	0.154
Infant	1.90E-08	0.034

Calculated Probability of a item being trapped under the fingernails

	P_{nail} Per Visit
Adult	8.07273E-09
Child	2.89273E-09
Infant	6.39091E-10

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{nail,ann} = 1 - P_{n\_nail,vis}^{O_R}$$

$P_{nail,ann}$ is the annual probability of an item becoming lodged under a fingernail
O_R is the annual occupancy rate
$P_{n\_nail,vis}$ is the probability of not getting an item lodged under the fingernails which is calculated as follows:

$$P_{n\_nail,vis} = 1 - P_{nail,vis}$$

$P_{nail,vis}$ is the probability of getting an item lodged under the fingernails per visit

Specific Data

	$P_{nail,vis}$ (Per Visit)	O_R (Annual, h)
Adult	8.07273E-09	2000
Child	2.89273E-09	300
Infant	6.39091E-10	30

Calculated Data

	$P_{nail,ann}$ (Annual)
Adult	1.6145E-05
Child	8.6782E-07
Infant	1.9173E-08

6. A item on clothes
(Page 37, RPA-EA-9-2005)

$$P_{cl,v} = F_d \times A_c \times L_d \times f_s$$

$P_{cl,v}$	is the probability of an item adhering to clothing per beach visit
F_d	is the item density, g^{-1}
A_c	is the area of clothing exposed, cm^2
L_d	is the loading of sand on clothing, g cm^{-2}
f_s	is a factor to account for the change of sand adhering during the visit

Known Data

Item Density	F_d	1.87913E-08	per g of sand
Sand Loading on Clothes	L_d	0.0001	g cm^{-2}
Sand adherence change factor	f_s	2	-

Specific Data

	A_c (m^2)
Adult	1.9
Child	1.12
Infant	0.53

is the total body skin area

Calculation of Probability of items on clothes

	P_{cl} Per Visit
Adult	7.14068E-08
Child	4.20924E-08
Infant	1.99187E-08

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{cl,ann} = 1 - P_{n\_cl,vis}^{O_R}$$

$P_{cl,ann}$ is the annual probability of an item becoming lodged on clothing
O_R is the annual occupancy rate
$P_{n\_cl,vis}$ is the probability of not getting an item lodged on clothing which is calculated as follows:

$$P_{n\_cl,vis} = 1 - P_{cl,vis}$$

$P_{cl,vis}$ is the probability of getting an item lodged on clothing per visit

Specific Data

	$P_{cl,vis}$ (Per Visit)	O_R (Annual, h)
Adult	7.14068E-08	2000
Child	4.20924E-08	300
Infant	1.99187E-08	30

Calculated Data

	$P_{cl,ann}$ (Annual)
Adult	1.4280E-04
Child	1.2628E-05
Infant	5.9756E-07

7. A item in a shoe
(Page 38, RPD-EA-9-2005)

$$P_{shoe,y} = F_d \times S_s$$

$P_{shoe,y}$	is the probability of a item being trapped in an individual's shoe per visit
F_d	is the item density, g^{-1}
S_s	amount of sand trapped in shoes per visit to the beach, g

Known Data

Item Density	F_d	1.87913E-08	per g of sand
Trapped Sand in Shoe (per visit)	S_s	10	g

Specific data

NB: there is no age specific data for Ss

Calculation of Probability of Items in shoe

	P_{shoe} Per Visit
Adult	1.87913E-07
Child	1.87913E-07
Infant	1.87913E-07

Calculation of Annual Probability

To calculate the annual probability the following formula is used

$$P_{shoe,ann} = 1 - P_{n\_shoe,vis}^{O_R}$$

$P_{shoe,ann}$ is the annual probability of an item becoming lodged in a shoe
O_R is the annual occupancy rate
$P_{n\_shoe,vis}$ is the probability of not getting an item lodged in a shoe which is calculated as follows:

$$P_{n\_shoe,vis} = 1 - P_{shoe,vis}$$

$P_{shoe,vis}$ is the probability of getting an item lodged in a shoe per visit

Specific Data

	$P_{shoe,vis}$ (Per Visit)	O_R (Annual, h)
Adult	1.87913E-07	2000
Child	1.87913E-07	300
Infant	1.87913E-07	30

Calculated Data

	$P_{shoe,ann}$ (Annual)
Adult	3.7575E-04
Child	5.6372E-05
Infant	5.6374E-06