36. 愛知県名古屋市鳴海工場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
愛知県	名古屋市千種区	1,076	898	178	47	47	38	9	1
	名古屋市東区	476	217	259	11	16	4	12	0
	名古屋市中村区	996	49	947	25	46	2	44	2
	名古屋市中区	481	461	20	2	33	32	1	2
	名古屋市昭和区	717	717	0	32	27	27	0	1
	名古屋市瑞穂区	734	734	0	23	35	35	0	3
	名古屋市熱田区	450	450	0	42	12	12	0	0
	名古屋市中川区	2,387	1,146	1241	50	93	43	50	5
	名古屋市港区	1,656	1,285	371	89	65	51	14	5
	名古屋市南区	1,276	1,276	0	60	50	50	0	7
	名古屋市緑区	2,291	2,291	0	136	80	80	0	2
	名古屋市名東区	1,671	985	686	56	84	49	35	9
	名古屋市天白区	1,768	1,768	0	141	66	66	0	2
	豊明市	685	685	0	9	14	14	0	0
	日進市	776	674	102	4	23	20	3	1
	東郷町	413	336	77	3	19	16	3	1
	刈谷市	1,684	155	1,529	27	52	6	46	1
	三好町	566	22	544	14	27	1	26	0
	東海市	1,041	670	371	56	45	33	12	1
	大府市	843	739	104	24	39	34	5	1
	計	21,987	15,558	6,429	851	873	613	260	44

37. 兵庫県高砂市美化センターごみ焼却施設

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
兵庫県	姫路市	5,459	1,374	4,085	157	231	64	167	14
	加古川市	2,671	2,265	406	69	92	79	13	4
	播磨町	367	141	226	3	14	4	10	0
	高砂市	1,004	1,004	0	36	31	31	0	5
	計	9,501	4,784	4,717	265	368	178	190	23

38. 兵庫県宍粟郡宍粟環境美化センター

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
兵庫県	佐用町	59	0	59	2	3	0	3	0
	南光町	28	2	26	3	6	1	5	1
	山崎町	234	5	229	7	13	1	12	0
	一宮町	93	27	66	3	3	0	3	0
	波賀町	54	49	5	0	0	0	0	0
	千種町	51	51	0	1	2	1	1	0
鳥取県	若桜町	16	0	16	15	0	0	0	0
岡山県	東粟倉村	0	0	0	0	0	0	0	0
	計	535	134	401	31	27	3	24	1

39. 和歌山県海南市海南市クリーンセンター

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
和歌山県	和歌山市	3,625	2,019	1,606	134	146	92	54	5
	海南市	291	291	0	47	14	14	0	2
	下津町	104	103	1	15	0	0	0	2
	野上町	44	40	4	0	1	1	0	0
	美里町	19	0	19	0	1	0	1	0
	貴志川町	181	118	63	2	9	7	2	0
	有田市	325	31	294	16	11	0	11	1
	吉備町	156	17	139	2	6	1	5	0
	金屋町	79	15	64	2	5	0	5	0
	計	4,824	2,634	2,190	218	193	115	78	10

40. 和歌山県有田郡有田郡衛生体育施設事務組合

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
和歌山県	下津町	104	78	26	15	0	0	0	3
	有田市	325	325	0	16	11	11	0	1
	湯浅町	127	127	0	1	7	7	0	0
	吉備町	156	156	0	2	6	6	0	0
	金屋町	79	61	18	2	5	4	1	0
	日高町	55	2	53	2	0	0	0	0
	由良町	59	21	38	1	4	3	1	0
	川辺町	59	0	59	2	4	0	4	0
	中津村	16	0	16	0	0	0	0	0
	計	980	770	210	41	37	31	6	4

42. 広島県廿日市市廿日市市清掃センター

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
広島県	広島市西区	1,903	363	1,540	74	64	14	50	2
	広島市佐伯区	1,419	1,319	100	26	49	43	6	2
	大竹市	285	1	284	6	13	0	13	0
	廿日市市	636	632	4	23	21	21	0	1
	大野町	143	143	0	61	3	3	0	3
	湯来町	48	0	48	1	1	0	1	0
	佐伯町	87	61	26	4	2	2	0	0
	宮島町	0	0	0	11	0	0	0	0
	計	4,521	2,519	2,002	206	153	83	70	8

43. 広島県安芸郡府中町清掃事務所

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
広島県	広島市中区	867	867	0	87	29	29	0	2
	広島市東区	1,338	1,338	0	41	46	46	0	0
	広島市南区	1,284	1,277	7	30	28	28	0	3
	広島市西区	1,903	1,294	609	74	64	45	19	2
	広島市安佐南区	2,442	1,440	1,002	71	73	44	29	4
	広島市安佐北区	1,432	375	1,057	26	35	11	24	1
	広島市安芸区	872	860	12	17	21	21	0	2
	呉市	1,770	124	1,646	80	78	0	78	6
	府中町	611	611	0	11	14	14	0	2
	海田町	418	418	0	4	7	7	0	0
	熊野町	101	101	0	123	1	1	0	1
	坂町	56	56	0	37	1	1	0	0
	黒瀬町	181	0	181	17	14	0	14	1
	計	13,275	8,761	4,514	618	411	247	164	24

44. 広島県御調町御調町一般廃棄物処理施設

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
広島県	三原市	711	10	701	15	29	4	25	1
	尾道市	820	124	696	12	31	4	27	1
	御調町	54	54	0	1	0	0	0	0
	久井町	31	23	8	0	0	0	0	0
	甲山町	44	18	26	2	2	1	1	1
	世羅町	64	9	55	2	2	1	1	1
	福山市	3,966	0	3,966	111	137	0	137	4
	府中市	359	107	252	11	11	2	9	0
	計	6,049	345	5,704	154	212	12	200	8

45. 広島県向島町向島町クリーンセンター

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
広島県	三原市	711	210	501	15	29	10	19	1
	尾道市	820	798	22	12	31	29	2	1
	因島市	195	141	54	7	8	2	6	0
	瀬戸田町	48	8	40	2	1	0	1	0
	向島町	6	6	0	121	0	0	0	3
	福山市	3,966	192	3,774	111	137	5	132	4
	内海町	17	17	0	2	0	0	0	0
	沼隈町	100	0	100	5	1	0	1	0
	計	5,863	1,372	4,491	275	207	46	161	9

47. 山口県楠町楠町清掃工場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
山口県	山口市	1,174	15	1,159	18	70	1	69	1
	宇部市	1,520	1,157	363	61	72	59	13	3
	小野田市	346	346	0	20	15	15	0	0
	美禰市	144	0	144	2	12	0	12	1
	阿知須町	0	0	0	73	0	0	0	1
	楠町	60	54	6	0	5	5	0	0
	山陽町	182	149	33	5	11	9	2	2
	計	3,426	1,721	1,705	179	185	89	96	8

平成9年度 住所情報の2次元情報解析

48. 山口県厚狭郡山陽町清掃工場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
山口県	下関市	2,135	228	1,907	43	92	9	83	0
	宇部市	1,520	0	1,520	61	72	0	72	3
	小野田市	346	303	43	20	15	12	3	0
	美祢市	144	6	138	2	12	1	11	1
	楠町	60	35	25	0	5	4	1	0
	山陽町	182	182	0	5	11	11	0	2
	菊川町	48	22	26	2	1	0	1	0
	計	4,435	776	3,659	133	208	37	171	6

49. 愛媛県西海町西海町ごみ焼却場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
愛媛県	内海村	14	7	7	0	0	0	0	3
	御荘町	91	91	0	0	2	2	0	1
	城辺町	89	83	6	1	7	7	0	1
	一本松町	42	7	35	1	2	0	2	0
	西海町	19	19	0	0	0	0	0	0
	計	255	207	48	2	11	9	2	5

50. 愛媛県喜多郡廃棄物処理場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
愛媛県	小田町	16	2	14	4	1	0	1	0
	中山町	29	15	14	6	1	0	1	0
	双海町	24	0	24	1	1	0	1	0
	大洲市	375	188	187	26	14	3	11	0
	内子町	76	76	0	1	3	3	0	0
	五十崎町	38	38	0	0	5	5	0	1
	肱川町	1	0	1	31	1	0	1	0
	河辺村	7	4	3	0	0	0	0	0
	計	566	323	243	69	26	11	15	1

平成9年度 住所情報の2次元情報解析

51. 福岡県甘木市甘木市総合衛生ｾﾝﾀｰ

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
福岡県	筑紫野市	786	0	786	31	30	0	30	2
	久留米市	2,628	1	2,627	34	112	0	112	4
	小郡市	118	9	109	376	1	0	1	9
	吉井町	1	0	1	159	0	0	0	6
	田主丸町	182	137	45	4	2	2	0	0
	北野町	132	27	105	6	5	0	5	0
	大刀洗町	135	135	0	6	9	9	0	0
	甘木市	330	330	0	69	14	14	0	7
	杷木町	84	0	84	4	5	0	5	0
	朝倉町	48	48	0	3	0	0	0	0
	三輪町	100	100	0	1	3	3	0	0
	夜須町	117	86	31	1	9	6	3	0
	小石原村	9	0	9	0	0	0	0	1
	嘉穂町	61	0	61	15	3	0	3	0
	筑穂町	81	0	81	7	3	0	3	0
	計	4,812	873	3,939	716	196	34	162	29

53. 福岡県田川郡下田川塵芥清掃センター

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
福岡県	北九州市小倉南区	2,384	0	2,384	23	90	0	90	2
	北九州市八幡西区	2,534	101	2,433	103	106	7	99	5
	田川市	468	417	51	20	22	20	2	0
	香春町	74	66	8	3	3	3	0	0
	金田町	77	77	0	1	4	4	0	0
	糸田町	0	0	0	93	0	0	0	10
	川崎町	190	42	148	7	9	2	7	0
	赤池町	74	74	0	2	2	2	0	0
	方城町	69	69	0	1	4	4	0	1
	直方市	514	502	12	13	33	31	2	0
	小竹町	86	86	0	1	1	1	0	0
	鞍手町	106	0	106	1	4	0	4	1
	宮田町	146	131	15	3	7	5	2	0
	飯塚市	723	567	156	4	32	26	6	0
	稲築町	167	72	95	2	8	7	1	0
	穂波町	238	101	137	5	13	5	8	0
	庄内町	97	97	0	0	3	3	0	1
	頴田町	55	55	0	9	4	4	0	0
	計	8,002	2,457	5,545	291	345	124	221	20

54. 佐賀県多久市多久市ごみ処理場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
佐賀県	唐津市	770	0	770	108	29	0	29	5
	浜玉町	116	0	116	1	6	0	6	0
	七山村	24	0	24	1	1	0	1	0
	厳木町	38	38	0	3	2	2	0	1
	相知町	69	51	18	2	0	0	0	0
	伊万里市	595	3	592	7	31	0	31	0
	多久市	204	204	0	1	10	10	0	1
	富士町	42	3	39	1	5	1	4	0
	小城町	148	148	0	68	1	1	0	6
	三日月町	121	34	87	1	4	0	4	0
	牛津町	123	0	123	4	3	0	3	0
	武雄市	395	12	383	15	25	2	23	3
	北方町	84	40	44	0	4	3	1	0
	大町町	57	0	57	1	4	0	4	1
	江北町	80	42	38	0	3	0	3	0
	計	2,866	575	2,291	213	128	19	109	17

55. 佐賀県小城郡天山地区共同塵芥処理場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
佐賀県	佐賀市	1,844	1,071	773	23	75	40	35	3
	多久市	204	85	119	1	10	4	6	1
	東与賀町	53	53	0	0	5	5	0	0
	久保田町	76	76	0	0	4	4	0	0
	大和町	235	43	192	6	19	4	15	0
	小城町	148	148	0	68	1	1	0	6
	三日月町	121	121	0	1	4	4	0	0
	牛津町	123	123	0	4	3	3	0	0
	芦刈町	46	46	0	1	4	4	0	1
	北方町	84	0	84	0	4	0	4	0
	大町町	57	57	0	1	4	4	0	1
	江北町	80	80	0	0	3	3	0	0
	白石町	146	88	58	1	10	7	3	0
	福富町	63	63	0	2	3	3	0	0
	計	3,280	2,054	1,226	108	149	86	63	12

56. 佐賀県佐賀郡川副町・東与賀町清掃ｾﾝﾀｰ

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
福岡県	大川市	346	325	21	9	20	19	1	4
	柳川市	365	342	23	3	29	26	3	0
佐賀県	大和町	131	31	100	9	8	4	4	0
	三橋町	182	115	67	4	13	9	4	0
	佐賀市	1,844	658	1,186	23	75	27	48	3
	諸富町	134	134	0	1	3	3	0	0
	川副町	162	162	0	3	3	3	0	0
	東与賀町	53	53	0	0	5	5	0	0
	久保田町	76	43	33	0	4	4	0	0
	芦刈町	46	6	40	1	4	0	4	1
	福富町	63	0	63	2	3	0	3	0
	計	3,402	1,869	1,533	55	167	100	67	8

57. 長崎県西彼杵郡高島町塵芥焼却場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
長崎県	長崎市	3,746	280	3,466	62	168	10	158	7
	香焼町	24	24	0	0	1	1	0	1
	伊王島町	7	7	0	0	0	0	0	0
	高島町	0	0	0	5	0	0	0	0
	野母崎町	40	35	5	4	2	2	0	0
	三和町	69	69	0	1	5	5	0	0
	計	3,886	415	3,471	72	176	18	158	8

58. 長崎県南高来郡小浜町清掃ｾﾝﾀｰ

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
長崎県	島原市	300	0	300	24	23	0	23	5
	国見町	81	0	81	27	4	0	4	5
	瑞穂町	0	0	0	41	0	0	0	1
	吾妻町	63	0	63	3	3	0	3	0
	愛野町	52	0	52	2	2	0	2	0
	千々石町	0	0	0	52	0	0	0	2
	小浜町	80	80	0	1	8	8	0	0
	南串山町	0	0	0	43	0	0	0	2
	加津佐町	0	0	0	51	0	0	0	3
	口之津町	0	0	0	33	0	0	0	1
	南有馬町	0	0	0	36	0	0	0	2
	北有馬町	0	0	0	50	0	0	0	1
	西有家町	67	67	0	2	6	6	0	0
	有家町	79	70	9	4	6	6	0	1
	布津町	0	0	0	26	0	0	0	2
	深江町	0	0	0	70	0	0	0	3
	計	722	217	505	465	52	20	32	28

59. 長崎県北松浦郡鷹島町ごみ処理場

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
佐賀県	肥前町	76	65	11	0	4	4	0	0
	玄海町	67	38	29	0	3	3	0	0
長崎県	松浦市	224	0	224	0	13	0	13	0
	福島町	23	10	13	0	0	0	0	0
	鷹島町	17	17	0	0	0	0	0	0
	計	407	130	277	0	20	7	13	0

60. 長崎県若松町若松町塵芥処理ｾﾝﾀｰ

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
長崎県	奈留町	24	4	20	2	1	0	1	0
	若松町	29	29	0	7	3	3	0	0
	上五島町	76	15	61	3	2	0	2	0
	有川町	71	0	71	18	3	0	3	0
	奈良尾町	21	21	0	2	0	0	0	0
	計	221	69	152	32	9	3	6	0

61. 長崎県上五島町上五島町清掃ｾﾝﾀｰ

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
長崎県	若松町	29	24	5	7	3	2	1	0
	上五島町	76	76	0	3	2	2	0	0
	新魚目町	48	27	21	4	2	2	0	0
	有川町	71	71	0	18	3	3	0	0
	奈良尾町	21	4	17	2	0	0	0	0
	計	245	202	43	34	10	9	1	0

62. 長崎県奈良尾町奈良尾町清掃ｾﾝﾀｰ

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
長崎県	若松町	29	27	2	7	3	3	0	0
	上五島町	76	8	68	3	2	0	2	0
	有川町	71	0	71	18	3	0	3	0
	奈良尾町	21	4	17	2	0	0	0	0
	計	197	39	158	30	8	3	5	0

64. 大分県臼杵市臼杵市清掃ｾﾝﾀｰ

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
大分県	大分市	4,357	273	4,084	244	172	9	163	0
	臼杵市	256	237	19	23	20	20	0	0
	津久見市	166	10	156	1	7	3	4	0
	佐賀関町	67	0	67	1	5	0	5	0
	野津町	45	16	29	10	1	0	1	0
	犬飼町	17	1	16	3	1	0	1	0
	計	4,908	537	4,371	282	206	32	174	0

65. 大分県南海部郡宇目清掃ｾﾝﾀｰ

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
大分県	本匠村	14	3	11	0	1	1	0	0
	宇目町	20	20	0	2	3	3	0	0
	直川村	9	0	9	1	2	0	2	1
	三重町	166	1	165	2	12	0	12	0
宮崎県	北川町	36	0	36	2	2	0	2	0
	計	245	24	221	7	20	4	16	1

67. 大分県西国東郡高田地域衛生事業組合清掃工場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
大分県	国見町	32	2	30	1	0	0	0	0
	安岐町	92	0	92	8	1	0	1	0
	山香町	47	0	47	1	3	0	3	0
	豊後高田市	137	137	0	6	3	3	0	1
	宇佐市	442	78	364	10	10	5	5	2
	大田村	9	2	7	0	0	0	0	0
	真玉町	28	28	0	8	3	3	0	0
	香々地町	12	3	9	9	1	1	0	0
	計	799	250	549	43	21	12	9	3

68. 宮崎県北川町北川町塵芥処理場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
宮崎県	延岡市	1,283	547	736	35	73	31	42	0
	北川町	36	18	18	2	2	0	2	0
	計	1,319	565	754	37	75	31	44	0

69. 鹿児島県大島郡与論島清掃ｾﾝﾀｰ

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
鹿児島県	与論町	56	56	0	2	2	0	2	1
	計	56	56	0	2	2	0	2	1

70. 鹿児島県大口市ごみ処理場

		出生	(出生10km圏内)	(出生10km圏外)	出生unmatch	死産	(死産10km圏内)	(死産10km圏外)	死産unmatch
宮崎県	えびの市	170	0	170	14	4	0	4	0
鹿児島県	鶴田町	35	0	35	3	0	0	0	0
	薩摩町	25	0	25	2	0	0	0	0
	出水市	278	0	278	100	18	0	18	3
	大口市	142	142	0	6	9	9	0	0
	菱刈町	72	72	0	0	2	2	0	0
	栗野町	92	0	92	0	0	0	0	1
	吉松町	40	0	40	0	0	0		0
	計	854	214	640	125	33	11	0	4

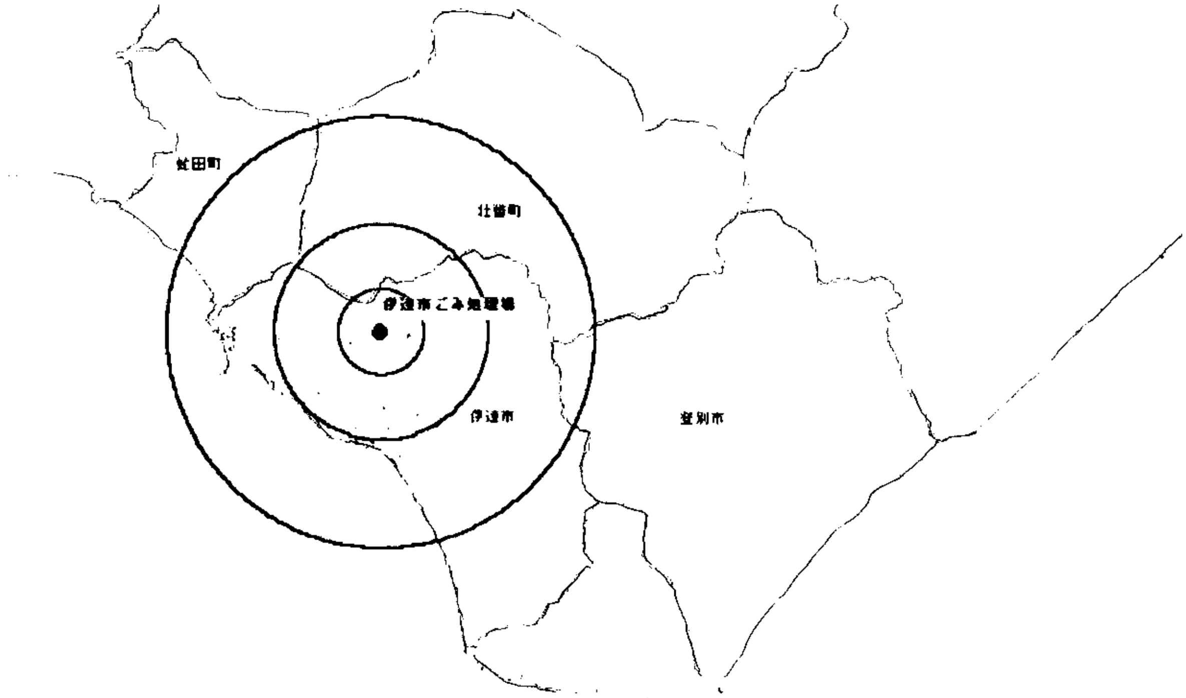
71. 沖縄県島尻郡東部清掃施設組合

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
沖縄県	宜野湾市	1,227	910	317	46	65	49	16	2
	中城村	137	105	32	3	13	9	4	1
	那覇市	3,446	3,119	327	115	166	159	7	17
	浦添市	1,608	1,600	8	55	77	75	2	2
	糸満市	685	81	604	34	38	4	34	0
	西原町	394	394	0	14	14	14	0	4
	豊見城村	660	577	83	33	23	20	3	4
	東風平町	171	171	0	8	6	6	0	0
	具志頭村	75	75	0	7	4	4	0	1
	玉城村	74	74	0	8	6	6	0	1
	知念村	50	49	1	4	2	2	0	0
	佐敷町	95	95	0	6	3	3	0	0
	与那原町	196	196	0	7	7	7	0	1
	大里村	100	100	0	4	3	3	0	1
	南風原町	459	459	0	23	18	18	0	1
	計	9,377	8,005	1,372	367	445	379	66	35

71. 沖縄県中頭郡中城青葉苑

		出生	（出生10km圏内）	（出生10km圏外）	出生unmatch	死産	（死産10km圏内）	（死産10km圏外）	死産unmatch
沖縄県	具志川市	735	221	514	27	63	20	43	2
	勝連町	142	21	121	4	12	1	11	0
	宜野湾市	1,227	1,227	0	46	65	65	0	2
	沖縄市	1,520	1,444	76	36	116	110	6	1
	嘉手納町	143	6	137	2	13	0	13	2
	北谷町	335	335	0	4	20	20	0	0
	北中城村	185	185	0	9	7	7	0	0
	中城村	137	137	0	3	13	13	0	1
	那覇市	3,446	388	3,058	115	166	19	147	17
	浦添市	1	1	0	0	77	64	13	2
	西原町	394	394	0	14	14	14	0	4
	与那原町	196	158	38	7	7	5	2	1
	南風原町	459	15	444	23	18	0	18	1
	計	8,920	4,532	4,388	290	591	338	253	33

北海道伊達市　伊達市ごみ焼却施設　平成9年出生



1．北海道伊達市伊達市ごみ処理場

		出生	（出生10km圏内）	（出生10km圏外）
北海道	登別市	447	0	447
	伊達市	259	251	8
	虻田市	58	56	2
	壮瞥町	18	11	7
	計	782	318	464

北海道伊達市　伊達市ごみ焼却施設　平成9年死産

1．北海道伊達市伊達市ごみ処理場

		死産	（死産10km圏内）	（死産10km圏外）
北海道	登別市	28	0	28
	伊達市	2	2	0
	虻田市	4	4	0
	壮瞥町	0	0	0
	計	34	6	28

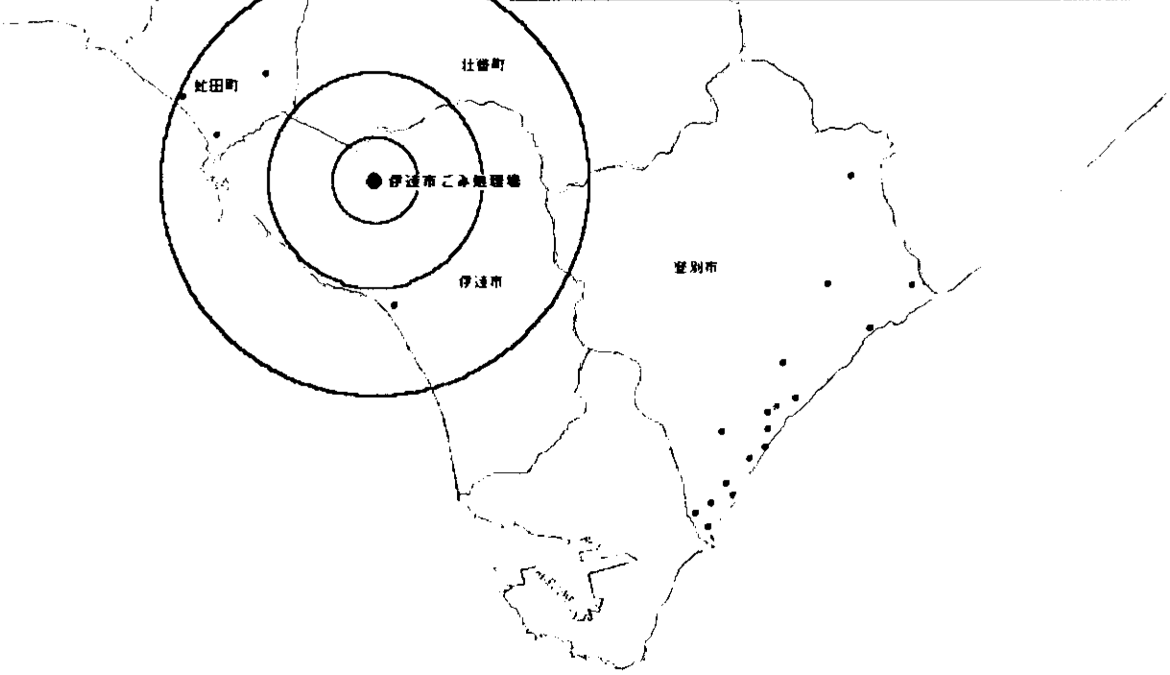
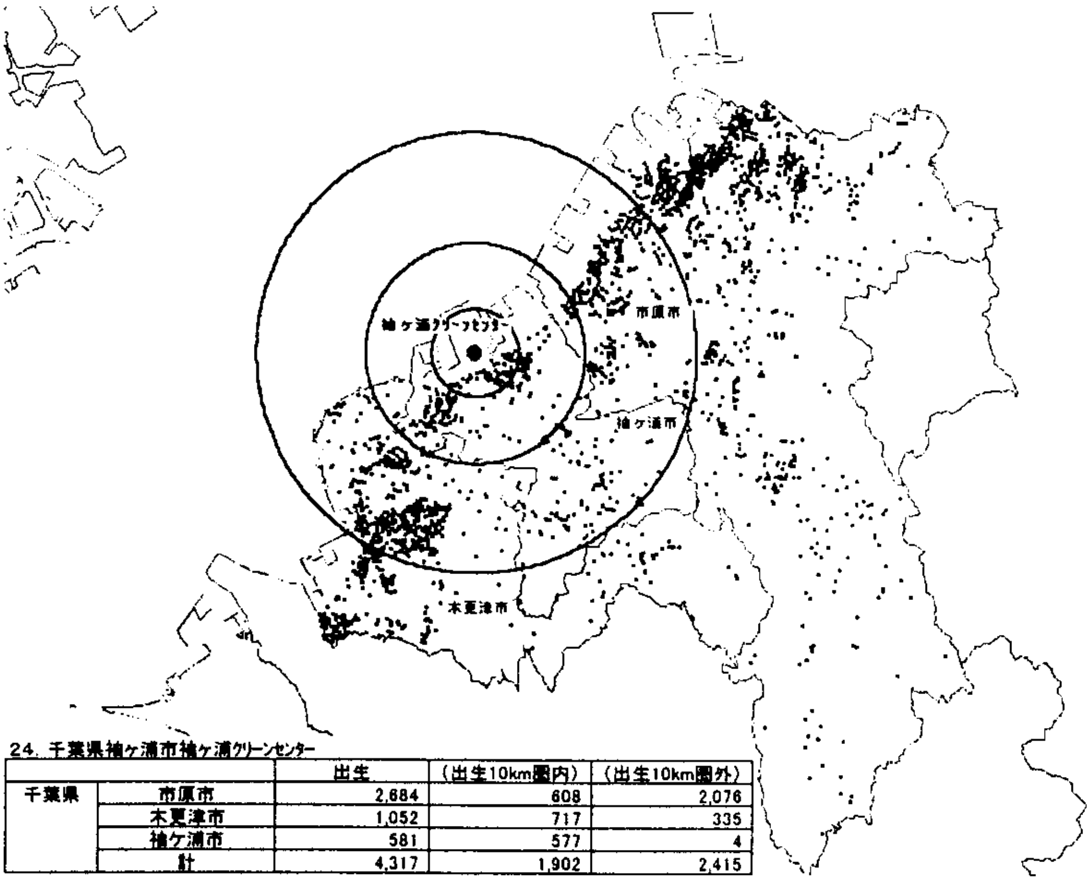


図１　ごみ焼却施設毎の調査対象地域における出生、死産の住所マップ

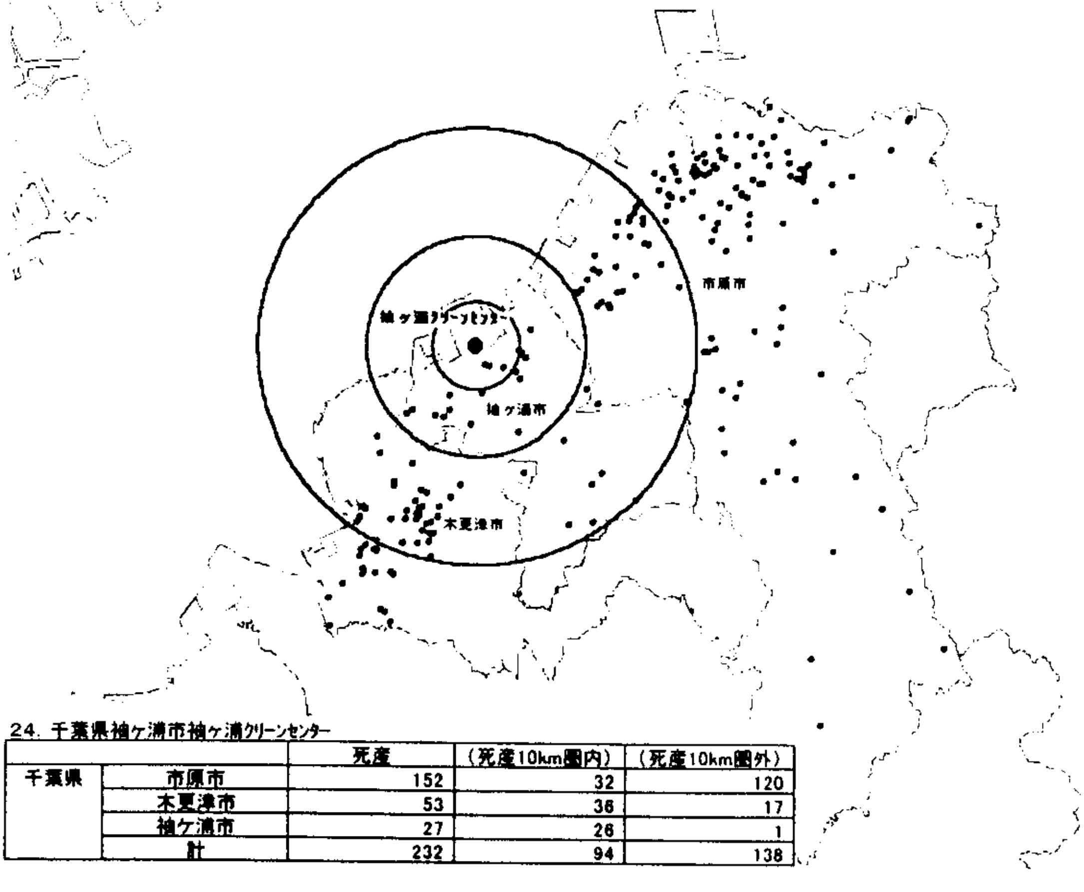
千葉県袖ヶ浦市　袖ヶ浦ｸﾘｰﾝｾﾝﾀｰ　平成9年出生



24. 千葉県袖ヶ浦市袖ヶ浦ｸﾘｰﾝｾﾝﾀｰ

		出生	（出生10km圏内）	（出生10km圏外）
千葉県	市原市	2,684	608	2,076
	木更津市	1,052	717	335
	袖ヶ浦市	581	577	4
	計	4,317	1,902	2,415

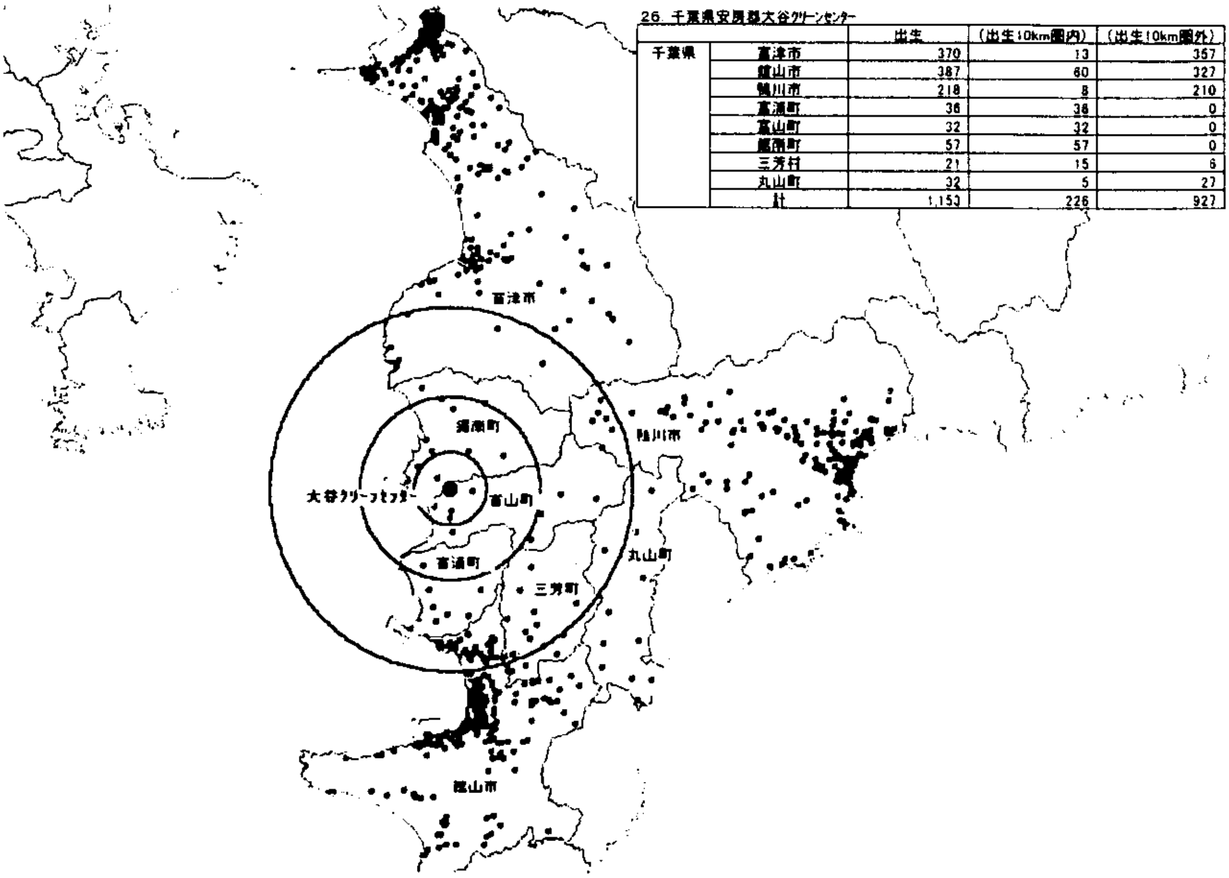
千葉県袖ヶ浦市　袖ヶ浦ｸﾘｰﾝｾﾝﾀｰ　平成9年死産



24. 千葉県袖ヶ浦市袖ヶ浦ｸﾘｰﾝｾﾝﾀｰ

		死産	（死産10km圏内）	（死産10km圏外）
千葉県	市原市	152	32	120
	木更津市	53	36	17
	袖ヶ浦市	27	26	1
	計	232	94	138

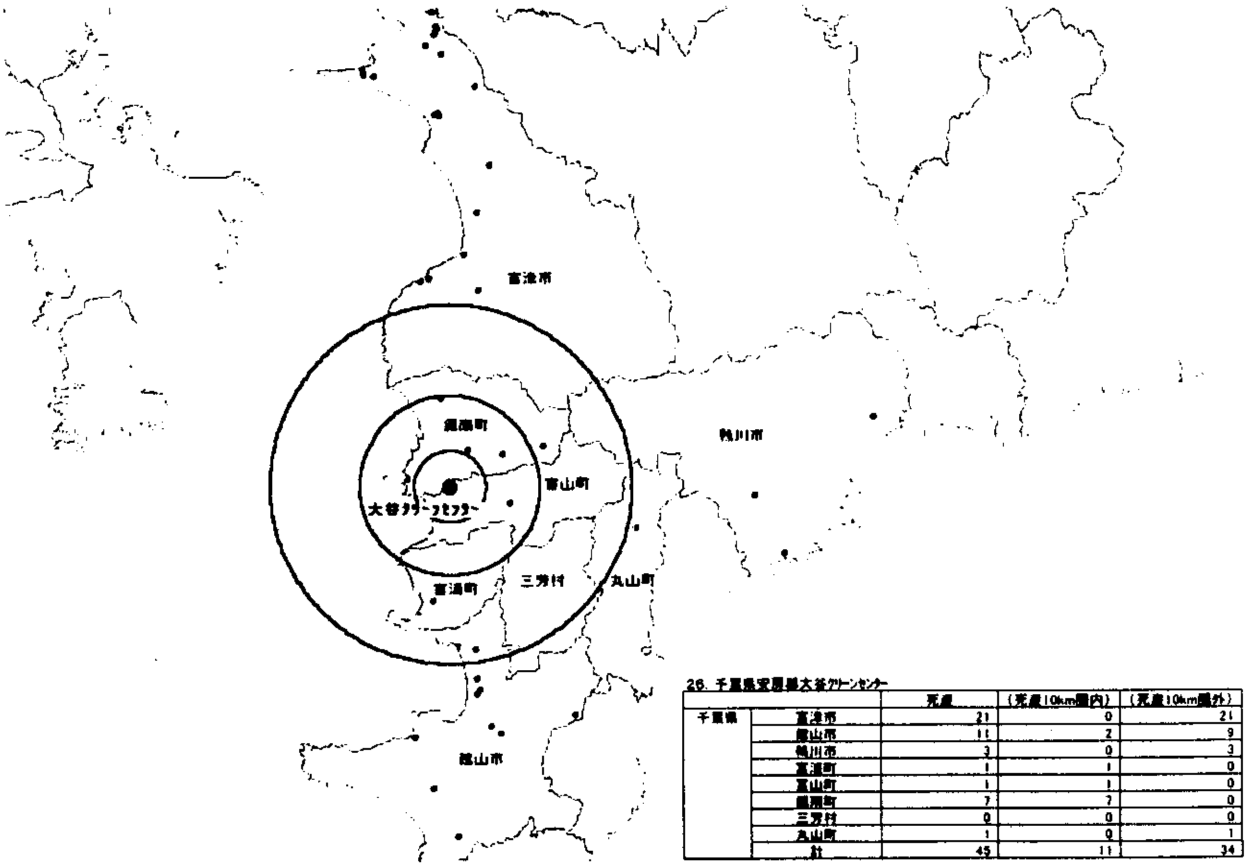
千葉県安房郡鋸南町　大谷クリーンセンター　平成9年出生



26. 千葉県安房郡大谷クリーンセンター

		出生	（出生10km圏内）	（出生10km圏外）
千葉県	富津市	370	13	357
	館山市	387	60	327
	鴨川市	218	8	210
	富浦町	36	36	0
	富山町	32	32	0
	鋸南町	57	57	0
	三芳村	21	15	6
	丸山町	32	5	27
	計	1,153	226	927

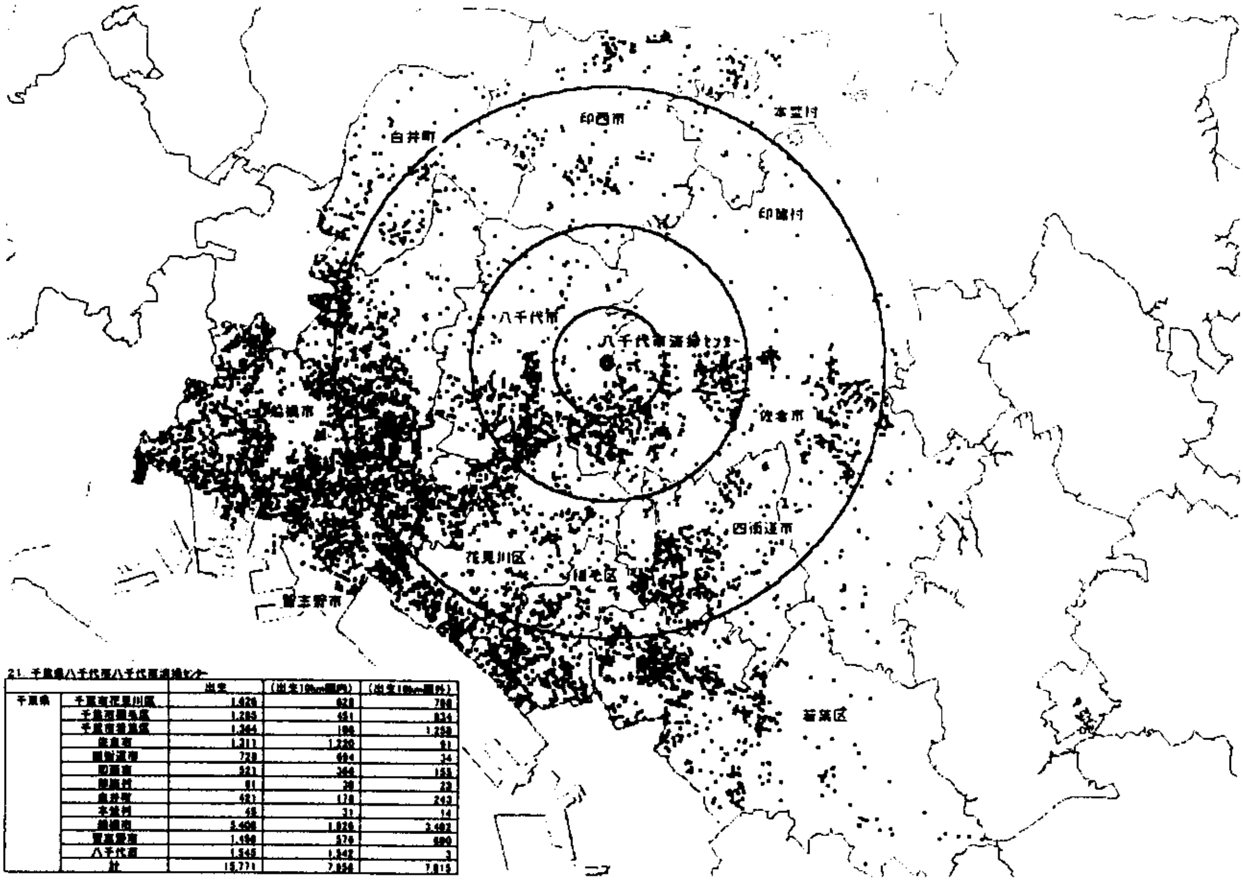
千葉県安房郡鋸南町　大谷クリーンセンター　平成9年死産



26. 千葉県安房郡大谷クリーンセンター

		死産	（死産10km圏内）	（死産10km圏外）
千葉県	富津市	21	0	21
	館山市	11	2	9
	鴨川市	3	0	3
	富浦町	1	1	0
	富山町	1	1	0
	鋸南町	7	7	0
	三芳村	0	0	0
	丸山町	1	0	1
	計	45	11	34

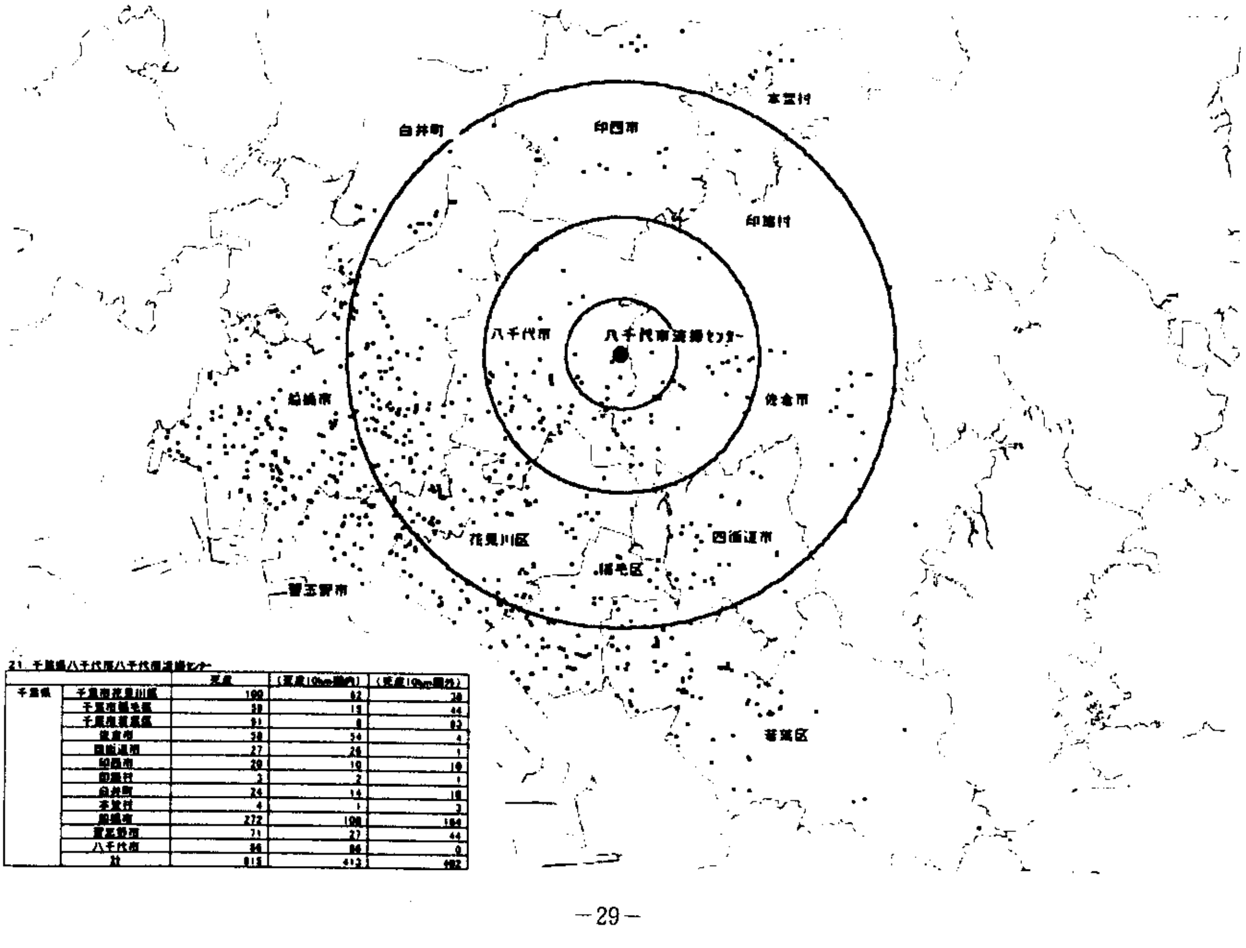
千葉県八千代市　八千代市清掃センター　平成9年出生



21．千葉県八千代市八千代市清掃センター

		出生	(出生10km圏内)	(出生10km圏外)
千葉県	千葉市花見川区	1,426	628	798
	千葉市稲毛区	1,285	451	834
	千葉市若葉区	1,364	106	1,258
	佐倉市	1,311	1,220	91
	四街道市	728	694	34
	印西市	521	366	155
	印旛村	61	39	22
	白井町	421	178	243
	本埜村	45	31	14
	船橋市	5,408	1,926	3,482
	習志野市	1,490	570	920
	八千代市	1,545	1,542	3
	計	15,771	7,956	7,815

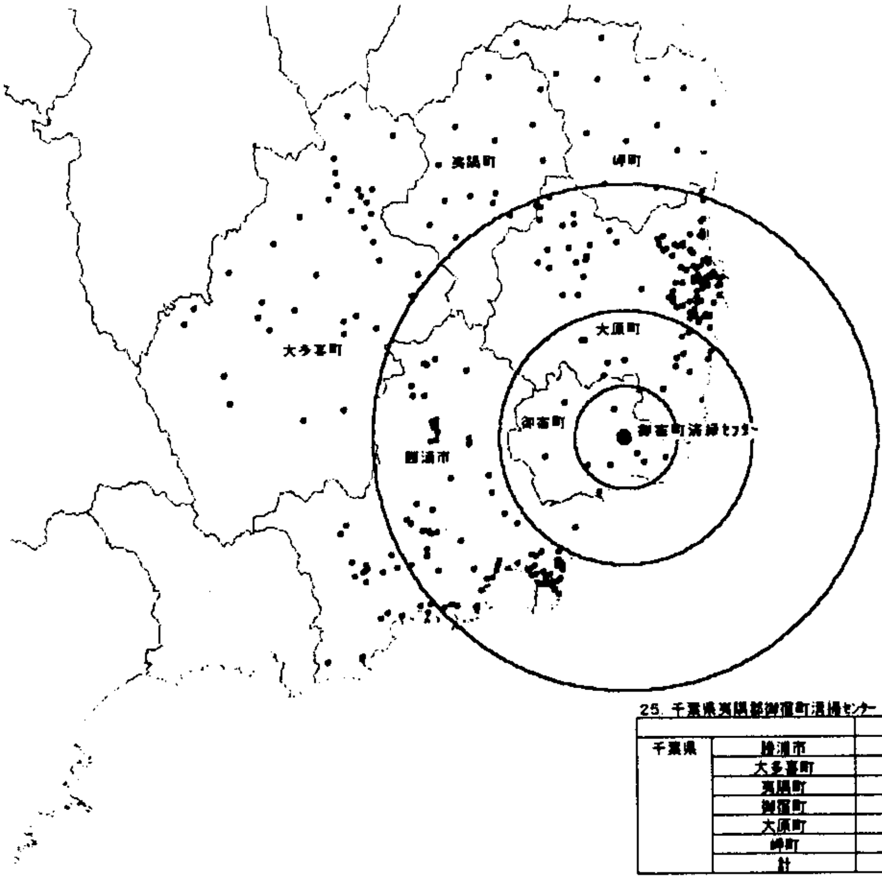
千葉県八千代市　八千代市清掃センター　平成9年死産



21．千葉県八千代市八千代市清掃センター

		死産	(死産10km圏内)	(死産10km圏外)
千葉県	千葉市花見川区	100	62	38
	千葉市稲毛区	59	15	44
	千葉市若葉区	91	8	83
	佐倉市	58	54	4
	四街道市	27	26	1
	印西市	20	10	10
	印旛村	3	2	1
	白井町	24	14	10
	本埜村	4	1	3
	船橋市	272	108	164
	習志野市	71	27	44
	八千代市	86	86	0
	計	815	413	402

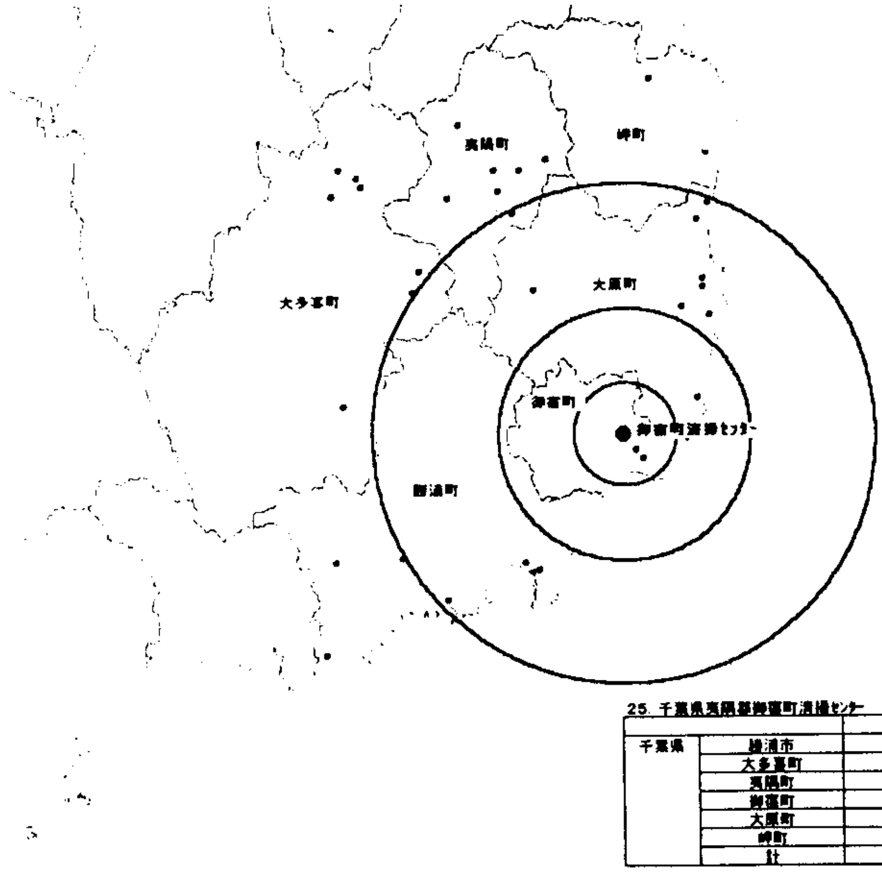
千葉県夷隅郡御宿町　御宿町清掃センター　平成9年出生



25. 千葉県夷隅郡御宿町清掃センター

		出生	（出生10km圏内）	（出生10km圏外）
千葉県	勝浦市	119	93	26
	大多喜町	77	0	77
	夷隅町	54	1	53
	御宿町	45	39	6
	大原町	144	142	2
	岬町	104	5	99
	計	543	280	263

千葉県夷隅郡御宿町　御宿町清掃センター　平成9年死産



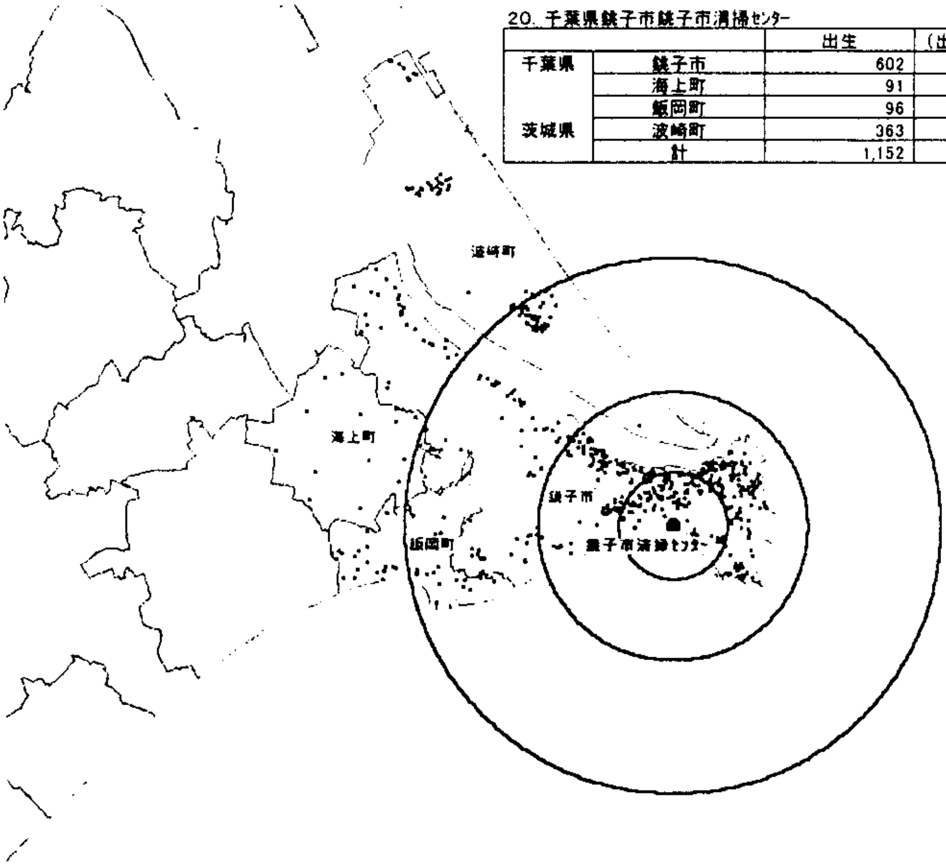
25. 千葉県夷隅郡御宿町清掃センター

		死産	（死産10km圏内）	（死産10km圏外）
千葉県	勝浦市	7	4	3
	大多喜町	8	0	8
	夷隅町	10	3	7
	御宿町	6	3	3
	大原町	8	8	0
	岬町	2	0	2
	計	41	18	23

千葉県銚子市　銚子市清掃センター　平成9年出生

20. 千葉県銚子市銚子市清掃センター

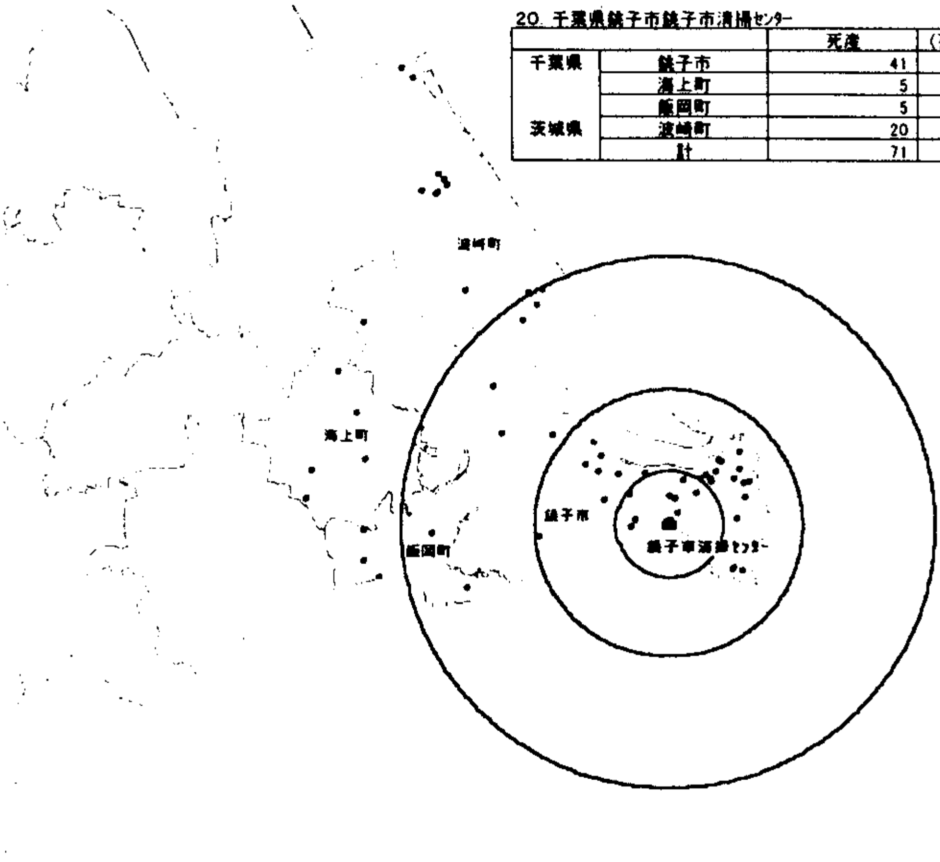
		出生	（出生10km圏内）	（出生10km圏外）
千葉県	銚子市	602	550	52
	海上町	91	0	91
	飯岡町	96	45	51
茨城県	波崎町	363	146	217
	計	1,152	741	411



千葉県銚子市　銚子市清掃センター　平成9年死産

20. 千葉県銚子市銚子市清掃センター

		死産	（死産10km圏内）	（死産10km圏外）
千葉県	銚子市	41	39	2
	海上町	5	0	5
	飯岡町	5	2	3
茨城県	波崎町	20	3	17
	計	71	44	27



ごみ焼却施設周辺のダイオキシン汚染の健康影響評価の統計的方法論に関する研究
（生活安全総合研究事業）分担研究報告書

研究者　丹後俊郎　国立公衆衛生院付属図書館長

研究要旨：Stoneの方法に代表される従来の健康影響を検出する統計的方法では単一のごみ焼却施設を想定し、かつ、直近が最もリスクが高く施設からの距離に反比例してリスクが減衰する仮定を置いていた。しかし、本研究では複数の施設が至近距離にあり、かつ、現実には施設から２－３ｋｍ程度が最も汚染状況が悪い可能性も否定できない。本研究では、様々な距離に依存したリスク関数を導入することにより適応的に対応できる方法を導出し、さらに検定の多重性を考慮するなど、これまでの問題点を克服した新しい検出力の高い方法論を開発した。

A. 研究目的

Stoneの方法に代表される従来の健康影響を検出する統計的方法では単一のごみ焼却施設を想定し、施設直近が最もリスクが高く施設からの距離に反比例してリスクが減衰する仮定を置いていた。しかし、本研究では複数の施設が至近距離にあり、かつ、現実には施設から２－３ｋｍ程度が最も汚染状況が悪い可能性も否定できない。本研究では、このような現実的状況に対処できる様々なリスク関数（曝露関数に比例）を導入することにより適応的に対応できる方法を導出し、さらに検定の多重性を考慮するなど、これまでの問題点をある程度克服した新しく検出力の高い方法を開発する。

B. 研究方法

本研究では１）複数のごみ焼却施設からの影響を考慮でき、２）距離に反比例したリスク関数(monotone risk models)以外にも、ある距離でリスク最大となるリスク関数(peak-decline risk models)など，様々な距離パターンを表現でき、かつ，３）最適リスク関数の推定・検定のための推論の多重性を考慮した方法を検討する。その方法の性能の検証には、実際の調査で遭遇するであろうデータを想定したシミュレーションを行うとともに，本調査研究における健康影響の検出力に関して他の方法との比較を行う。

C. 研究結果

本研究で提案した健康影響を評価する統計的検定手法はごみ焼却施設からの距離のある属に含まれる関数をスコアとした Score trend 検定を基礎としている。ごみ焼却施設が複数ある場合にはそのスコアの合計を考える。そして，その最適関数の選択を Monte Carlo Simulation により決定する方法である。その性質は既存の方法に比較して優れていることがいくつかのsimulationにより確認された。性質と検出力の詳細は別紙の英文論文（現在，国際雑誌 Statistics in Medicine へ投稿中）に記述したのでそれを参照されたい。

D. 考察・結論

本研究で提案された検定方法は従来のStoneの方法に代表される方法に比べて多くの現実的状況に対応できる柔軟性があり、かつ検出力が比較的高いことが検証され、本調査研究の統計解析に利用できる準備がととのったと考えている。

F. 研究発表

学会発表

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Score Tests for Detecting Excess Risks Around Putative Sources

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SUMMARY

Focused clustering studies examine raised disease risk around prespecified point sources. As statistical methods to detect such clusters, Stone's maximum likelihood ratio test against the general ordered alternatives and score tests which score each case the reciprocal of the distance from a point source as a surrogate exposure are popular among others. This paper considers extensions of score tests in that (1) it can allow us to select the best among pre-specified parametric exposure functions to avoid multiple testing problems and (2) it can be applied to a possible situation that the hazardous substance levels have a peak at some distance from a point source. Simulation study shows that the powers of the proposed tests are higher than that of Stone's test over all the alternatives considered. The proposed tests are illustrated with hypothetical data as well as simulated data to be expected in an epidemiological study currently in progress regarding an excess risk of perinatal undesirable outcomes near municipal solid waste incinerators in Japan.

Key words: dioxin; relative risk; small area; waste incinerator

1 INTRODUCTION

Since the 1980s there has been growing interest in the analysis of small area data to investigate the relation between the risk of a disease and proximity of residence to a prespecified putative source of hazard. It is well known that the apparent excess of cases of childhood leukaemia near the nuclear reprocessing plant such as that in the village of the Seascale at Sellafield has been extensively investigated (for example, see Bithell *et al.*[1]). More recently, there is great public concern on the health effects of so called *dioxin*, organic compounds such as polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) emitted from municipal solid waste incinerators[2].

The primary statistical problems arising in the traditional approach to these epidemiological studies are *post hoc* analyses of the *reported clusters* of cases near putative sources. Bias in selection of regions due to prior knowledge of an apparent effect may cause unconscious multiple testing problems and subjectivity in interpreting the study results. To avoid these inferential problems, many statistical procedures, called *focused tests*, to detect such an execss risk or a cluster of cases around a putative source of hazard have been proposed. Among others, Stone's test[3] is very popular since it is based on traditional epidemiological estimates SMR or SIR (standardized mortality or incidence ratio). It has, however, been shown to be not so powerful. As a locally most powerful test, score tests have been proposed as an alternative test [4]-[6]. Bithell[7] considered a *linear risk* score test based on the reciprocal of the rank of the distance from a point source in relation to the most powerful test against any given alternative hypothesis. Diggle[5], Diggle and Rowlingson[9] and Diggle *et al.*[10] have proposed point process models based on exact locations of cases. Lawson and Waller[11] review an extensive literature in this area.

In this paper, we shall propose extensions of score tests based on small area data in that (1) it allows us to select the best among pre-specified parametric exposure functions to avoid multiple testing problems and (2) it can be applied to a possible situation that the hazardous substance levels tend to peak at some distance from a point source. The properties of the proposed tests and their power are examined and illustrated with hypothetical data as well as the power calculation conducted in an epidemiological study currently in progress in Japan.

2 The NIPH Epidemiological Study

Our motivation is in the NIPH (National Institue of Public Health in Japan) Epidemiological Study currently in progress. In section 4, we will illustrate the proposed tests with the power calculation con-

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ducted in its design stage. This study is a Japan's nationwide first-ever large-scale study to estimate the risks of perinatal undesirable outcomes such as *increase* of foetal death, congenital malformations, female live births (a possible dioxin's antioestrogenic effect) and *decrease* of birth weight associated with maternal residential proximity to municipal solid waste incinerators. Recently in Japan, there is great public concern about risks from pollutants especially organic compounds such as polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) included in clouds of smoke emitted from the municipal solid waste incinerator chimney. The design of this study is very similar to that by Elliott *et al.* [2] in which cancer incidence near municipal solid waste incinerators had been investigated in Great Brtain. The study areas are selected at outset to be within 10 km of 73 major incinerators selected from 1,854 incinerators in Japan as shown in Figure 1. Each study site is scheduled to be divided into ten zones delimited by ten circles of radii of $1, 2, ..., 10$ km. To conduct this study, we are developping a sort of postcoded database to obtain observed and expected number of cases in each of ten zones. The detailed report of this study will be published elsewhere.

3 METHODS

Consider the situation that an entire study area is divided into m regions. The number of cases in the ith region is denoted by the random variable N_i with observed value n_i, $i = 1, 2, ..., m$ and $n = n_1 + \cdots + n_m$. Under the null hypothesis of no clustering, the N_i are independent Poisson variables with mean e_i :

$$H_0 : E(N_i) = e_i, \quad (i = 1, ..., m), \tag{1}$$

where the e_i are the null expected numbers of cases of the ith region. The e_i are ususally calculated using the rates r_k from some reference population (unconditional approach). If the external rates r_k are considered to be inappropriate for some reasons or missing, then we will go on to take the conditional approach using internally calculated rates r'_k :

$$e_i = \sum_{i=1}^{K} \xi_{ik} r'_k = \sum_{k=1}^{K} \xi_{ik} \left(\frac{n_{+k}}{\sum_{j=1}^{m} \xi_{jk}} \right), \quad (i = 1, ..., m) \tag{2}$$

where ξ_{ik} denote the number of individuals at risk or population size in the kth category of the set of potential confounders such as age and sex of the ith region and $n_{+k} = n_{1k} + ... + n_{mk}$. It should be recognized, however, that standardizing internally would be hazardous in that the effect of the putative source of pollution could be reduced if, say, more elderly people live close to the source.

An alternative hypothesis of clustering can be expressed as

$$H_1 : E(N_i) = \theta_i e_i, \quad (i = 1, ..., m), \tag{3}$$

where the θ_i denote the region-specific relative risk. If we have enough information on the relative risks θ_i, the most powerful test is of the form[7]:

$$T = \sum_{i=1}^{m} n_i \log(\theta_i) \geq t_0 \tag{4}$$

where t_0 should be chosen to ensure the correct type I error α for the test. However, it is very rare that we can have a good idea of the θ_i's. Bithell[7] called this kind of test linear risk score (LRS) test using θ_i as scores. When we are interested in detecting the clusters of rare diseases under study around the pre-specified putative point source and we cannot assume values for the relative risks θ_i, an alternative is to consider the simple ordering that the risk does not increase with increasing distance from the point source :

$$H_1 : \theta_{(1)} \geq \theta_{(2)} \geq \cdots \geq \theta_{(m)} \tag{5}$$

where $\theta_{(i)}$ denote the relative risk for the region which is the i-th nearest to the point source. Bithell[7] then examines LRS tests by replacing unknown $\theta_{(i)}$ by a suitable relative risk function of distance such as "1/distance" and the reciprocal of distance rank. Of course, there are many other possibilities for monotonic functions of distance. Stone[3], on the other hand, proposed a maximum likelihood ratio (MLR) test which, under the order-restricted H_1, calculates the maximum likelihood estimators $\hat{\theta}_{(i)}$ which is easily obtained by using so-called "pool-adjacent violators" algorithm (see, Barlow *et al.*[12]):

$$\hat{\theta}_{(i)} = \min_{s \leq i} \max_{t \geq i} \frac{\sum_{r=s}^{t} n_{(r)}}{\sum_{r=s}^{t} e_{(r)}}, \quad i = 1, ..., m. \tag{6}$$

where $n_{(r)}$ and $e_{(r)}$ denote the observed and expected number of cases, respectively, for the region which is the r-th nearest to the point source. Since there are order restrictions on the parameters, the usual asymptotic properties of the maximum likelihood ratio test are not guaranteed. Then, Stone[3] proposed the first parameter estimator $\hat{\theta}_{(1)}$ under the order restriction as an alternative test statistic whose null distribution can be obtained without simulation. However, since the power of MLR test is generally higher than that based on the $\hat{\theta}_{(1)}$ except for the case where nearly all the excess risk is concentrated very close to the putative source of hazard, it may well be preferable to carry out a Monte Carlo test using the MLR test.

Related to the LRS tests are a class of locally most powerful tests based on the efficient score under the additive excess risk model

$$\theta_i = 1 + g_i\epsilon, \quad (i = 1, ..., m) \tag{7}$$

where the g_i denote surrogates for exposure to the point source.

We call the g_i "exposure function" throughout the paper. Oviously, the most powerful test for this alternative is the LRS test based on $\sum_{i=1}^{m} n_i \log(1+g_i\epsilon)$ which is asymptotically (as $\epsilon \to 0$) equivalent to the efficient score test based on $\sum_{i=1}^{m} n_i g_i$. The latter has the advantage that it does not depend on the unknown ϵ. Waller *et al.*[4] proposed a locally most powerful test based upon the efficient score assuming the g_i is related *inversely* to geograhic distance d_i from the point source. Lawson[5] also proposed similar score tests. These tests are identical in form to score tests used in epidemiologic settings where one knows exposure values for each of several strata (for example, see Breslow and Day[15]). Waller and Lawson[13] and Waller[14] have shown that the score test based on inverse distance has greater powers than Stone's test based on $\theta_{(1)}$ and other tests against alternatives that they thought were of more practical interest. However, like the score or the relative risk functions required in the LRS tests, the choice of transformation we use to achieve a suitable *inverse measure* of distance introduces an element of arbitrariness and will cause multiple testing problems.

4 Extended Score Tests

Some problems associated with the methods described so far are summarized as follows:

P1. How to deal with multiple point sources, $\{S_1, ..., S_J\}$? Several authors[4],[13],[16],[17] suggest the use of the distance to the *nearest point source*. However, this type of procedure has low power in a sense that it takes no account of total exposures. Calculation of total amount of exposures depends on the relative geographical locations of point sources.

P2. Selection of unknown exposure functions g_i for the score tests and relative risk functions for the LRS tests will cause multiple testing problems.

P3. The simple non-increasing restriction (5) is not always valid. There may be a situation that the hazardous substance levels tend to have a peak at some distance from the putative source of hazard. Therefore, a test for detecting a peak-decline trend is needed. For this purpose, Lawson[5] proposed a score test based on the model $\theta_i = \exp(\beta_0 \log(d_i) + \beta_1 d_i)$. However, the score test derived under this model cannot be an appropriate test for peak-decline trend since this model assumes the exposure to be proportional to the distance.

To cope with the first problem **P1**, we shall consider total exposures for g_i as

$$g_{i+} \;=\; \sum_{j=1}^{J} g_{ij} \tag{8}$$

where g_{ij} denote some exposure function for the region i to the point source S_j. If we do not have enough exposure information from each of the point sources, it may not be unreasonable to assume that the exposure levels due to the point sources have similar decay function of distance regardless of the point source. Although we have many choices regarding a decay function of exposure, we shall assume here a common exponential form with one parameter λ

$$g_{ij} \equiv g_{ij}(\lambda) = w_j \exp\{-4(\frac{d_{ij}}{\lambda})^2\}, \tag{9}$$

where d_{ij} denote the distance between the region i and the jth point source, λ is the scale parameter and g_{ij} attains nearly zero at $d_{ij} = \lambda$ and w_j is a predetermined relative weight proportional to the amount of pollutants x_j emitted from the j-th point source, i.e., $w_j \propto x_j / \sum_j^J x_j$. If all the point sources can be assumed to have the similar exposure level, then w_j may be equal to 1. Underestimating w_j might produce a test result biased toward null.

This decay function has been used in a *global* test[6, 18] for detecting disease clustering. Large λ will give a test sensitive to large cluster and small λ to small cluster. Based on this exposure function, we shall propose the following score statistic for testing focused clustering :

$$C_{F:\lambda} \;=\; \sum_{i=1}^{m} g_{i+}(\lambda)(n_i - e_i) \tag{10}$$

which is asymptotically normally distributed with mean 0 and variance equal to the Fisher Information:

$$\mathrm{Var}(C_{F:\lambda}) \;=\; \left\{ \sum_{i=1}^{m} e_i g_{i+}^2(\lambda) - \left(\sum_{i=1}^{m} e_i g_{i+}(\lambda) \right)^2 \right\} \tag{11}$$

If the e_i are unconditionally calculated, then e_i should be replaced by $ne_i / \sum_{j=1}^{m} e_j$ in (10) and (11). Tango[6] proposed a quite similar test statistic for focused clustering in which the location of the jth point source was approximated by the centroid of the region including it, which is not always good an approximation since small changes in data might cause big different test results (see, Bithell[17]).

To take the multiple testing problem **P2** associated with the selection of λ into account, we shall propose, as an extended score test, *the minimum of the profile P-value of* $C_{F:\lambda}$ *for* λ where λ varies continuously from a small value near zero upwards untill λ reaches to about half the size of the whole study area. The proposed test statistic P_{mon} for monotone trend is defined as

$$\begin{aligned} P_{mon} &= \min_{\lambda} \Pr\{C_{F:\lambda} > c_{F:\lambda} \mid H_0, \lambda\} \\ &= \Pr\{C_{F:\lambda} > c_{F:\lambda} \mid H_0, \lambda = \lambda^*\} \\ &= 1 - \Phi\left(\frac{c_{F:\lambda^*}}{\sqrt{\mathrm{Var}(C_{F:\lambda^*})}}\right) \end{aligned} \tag{12}$$

where $c_{F:\lambda}$ is the observed test statistic as a function of λ, λ^* attains the minimum p-values of $C_{F:\lambda}$ and $\Phi(.)$ denotes the standard normal distribution function. Practical implementation of this procedure is to use "line search" by discretization of λ. The null distribution of P_{mon} can be obtained by Monte Carlo simulation. Tango[18] has considered a *global* test for detecting disease clusters by applying a similar adjustment method, in which we have no pre-specified putative sources.

Finally, to make the above procedure applicable to the problem **P3**, we shall modify the exposure decay function g_{ij}/w_j into two dimensional one such as

$$g_{ij}/w_j = \begin{cases} g^{(0)}(d_{ij}, s) \geq 1 & \text{if } d_{ij} \leq s \ (s > 0) \\ g^{(1)}(d_{ij}, s) \leq 1, & \text{otherwise} \end{cases} \tag{13}$$

where $g^{(0)}(s,s) = g^{(1)}(s,s) = 1$ and the g_{ij} is defined as a monotone exposure function when $s = 0$. Here also, the choice of these functions may be variable depending on the situation but here, for ease of interpretations, we shall use the following particular function

$$g^{(0)}(d,s) = 1 - 4\frac{a-1}{s^2}d(d-s), \tag{14}$$

$$g^{(1)}(d,s) = \exp\{-4(\frac{d-s}{\lambda})^2\}, \tag{15}$$

where $g^{(0)}$ attains a pre-determined constant a at distance $d = s/2$. The choice of a also looks arbitrary but we have only to set a larger than a possible maximum relative risk, say $a = 2.0$ or 3.0. In our experiences, the result does not change essentially by the choice of a greater than the maximum relative risk. In terms of *estimation* of the exposure function, the above function seems to be little realistic in that the first parital derivative with respect to d is not continuous. However, for *detecting* a peak-decline profile near the point source, it will be shown to be useful by simulation in the next section. Then the extended score test deviced for both monotone and peak-decline trends is given by

$$\begin{aligned} P_{both} &= \min_{\lambda,\ s} \Pr\{C_{F:\lambda,\ s} > c_{F:\lambda,\ s} \mid H_0, \lambda,\ s\} \\ &= 1 - \Phi\left(\frac{c_{F:\lambda^*,s^*}}{\sqrt{\mathrm{Var}(C_{F:\lambda^*,s^*})}}\right) \end{aligned} \tag{16}$$

where $c_{F:\lambda,s}$ is the observed test statistic as a function of λ and (λ^*, s^*) attains the minimum p-values of $C_{F:\lambda,s}$. Practical implementation of this procedure is also to use "numerical search" by discretization of λ and s. The null distribution of P_{both} can be obtained by Monte Carlo simulation.

Whether P_{mon} or P_{both} should be used strongly depends on prior knowledge of exposures and also the availability of detailed address information of cases and controls around the point sources. In general, a monotone declining trend is a good approximation for an epidemiological study based on centroids of small areas. However, in a study where more precise individual data are available, we had better consider the possibility of a peak-decline trend together with a monotone-declining one.

5 ILLUSTRATIONS AND POWERS

In this section, the proposed tests are compared with Stone's MLR test and illustrated with hypothetical data as well as power calculations done in the NIPH epidemiological study regarding excess risks around municipal solid waste incinerators.

5.1 Hypothetical data in Tokyo Metropolitan area

To illustrate the proposed test for monotone trend (12) and also to compare its power with that of Stone's MLR test, we shall consider $m = 113$ regions comprising the wards, cities and villages in the Tokyo Metropolis and the Kanagawa prefecture in Japan as an entire study population. The variability of regional populations for the 113 regions is: 25 percentile = 56,704, median= 142,320 and 75 percentile = 200,936. In Figure 2, 113 circles with various sizes are plotted. The center of a circle is the location of population centroid of the corresponding region and the radius is proportional to the population size. The maximum and minimum distance between regions are 93.82 km and 1.58 km, respectively. In this particular application, as half the maximum distance among regions is about $93.82/2 \approx 40$, we shall take a sequence of values of λ as $\lambda = 2, 4, 6, ..., 40$ to obtain the test statistic P_{mon}

$$P_{mon} = \min_{\lambda \in \{2,4,\ldots,40\}} \Pr\{C_{F:\lambda} > c_{F:\lambda} \mid H_0, \lambda\} \quad (17)$$

Figure 3 shows 20 exposure functions $g_i(\lambda)$, $\lambda = 2, 4, ..., 40$, with $w = 1$.

5.1.1 Clustering model

We shall consider the following two models of focused clusters, namely "clinal" and "hot spot" clusters, defined by Wartenberg and Greenberg[19]. Clinal clusters have a monotone decrease in disease risk as distance from the point source increases. Hot spot clusters are characterized by a constant elevated disease risk in regions near the point source(hot spot) and background disease risk elsewhere.

1. Clinal cluster: we consider two situations (a) one point source is located in the region 33 and (b) two point sources are located in the regions 33 and 41, which are illustrated in Figure 2. The distance between region 33 and 41 is $d_{33,41} = 16.49$ km. In both situations, the location of point source is approximated by the centroid of the region including it and the true relative risks are assumed as

   $$\theta_{ij} = 1 + (RR - 1)\exp(-d_{ij}/5), \quad RR = 2, 3, 4, 5. \quad (18)$$

   Figure 4 illustrates a clinal cluster with RR=3 occurred around the region 33 in which the radius of each circle is set proportional to the relative risk assumed.

2. Hot spot cluster: here also we consider two cases; one point source and two point sources. The location of clusters are the same as those of clinal cluster models. In both cases, the true relative risks are set as

   $$\theta_{ij} = \begin{cases} RR, & \text{if } d_{ij} \le 5 \text{ km}, \quad RR = 2, 3, 4, 5, \\ 1.0, & \text{otherwise} \end{cases}$$

5.1.2 Illustrative example

As an illustration of calculation of the proposed test to detect monotone model of clustering, we shall apply the proposed procedure to the disease map shown in Figure 5 which is a random sample with n=100 from clinal cluster model with one point source with $RR = 3.0$. The circle for the point source (region 33) is shaded and a circle is drawn only for the region whose O/E (observed/expected) ratio, n_i/e_i, is statistically significantly ($p < 0.05$) larger than 1.0 or

$$Q_i = \Pr\{N_i \ge n_i \mid N_i \sim \text{Pois}(e_i)\} < 0.05$$

where $\text{Pois}(e_i)$ is a Poisson distribution with expected number of cases e_i. The radius of circle is set inversely proportional to the upper tail probability Q_i. The number shown in Figure 5 indicates the number of observed cases $n_i (> 0)$ for the region i. Although Figure 5 seems to suggest a cluster around the region 33, we can observe that regions having significant O/E ratio's are scattered. The profile P-value of $C_{F:\lambda}$ for λ is shown in Figure 6 and we found that $P_{mon} = 3.96 \times 10^{-6}$ at $\lambda^* = 8$. This p-value is the fourth-largest among 999 P_{mon}'s calculated by Monte Carlo repliactions of 999 random disease maps generated under the null hypothesis. Therefore, the adjusted p-value of $P_{mon} = 4/(999+1) = 0.004$, indicating a significant cluster around the region 33.

5.1.3 Power comparisons

To compare the power of the proposed extended test P_{mon} with that of Stone's MLR test, we shall show Monte Carlo simulation results. To estimate the upperbound of the power, we include the most powerful test T defined in equation (4) where each θ_i or θ_{ij} is defined in equation (18) for the clinal cluster model, but when there are two point sources we use their sum

$$\theta_i = \theta_{i1} + \theta_{i2} - 1.$$

and the same value of RR's is assumed for the two point sources. In the case of the hot spot cluster model, on the other hand, the inclusion of the most powerful test is given up since the distribution of T is markedly discrete and power comparisons at the nominal α level are not easy. Stone's MLR test adopts the distance to the nearest point source when we have two point sources. The resultant powers for tests of nominal α leves of 0.05 and 0.01, sample size $n = 100$ and $RR = 2, 3, 4, 5$ are shown in Table 1 and 2 for clinal cluster model and hot spot cluster model, respectively. As expected, the most powerful test has the highest power. Stone's MLR test appears to be less powerful than the proposed extended score test for monotone trend by about 10 per cent to 20 per cent depending on the alternatives.

5.2 Power calculations in the NIPH Epidemiological Study

We shall illustrate here the proposed tests with the power calculations conducted in the NIPH Epidemiological Study introduced in section 2. In this special application, we considered the distance between the j-th zone and waste incinerator is defined as $d_j = \mid j - 1 \mid$ since we would like to consider the relative exposure compared with the reference zone with radius 1 km. Further, in order to obtain P_{both} defined in (16), we have conducted a two dimensional search over the grids (λ, s) defined by combinations of discrete values of $\lambda \in \{2, 4, 6, ..., 40\}$ and $s \in \{0, 1, ..., 5\}$. The range of s is determined according to some observed peak-decline decay curves of expousure levels experienced in a few investigations regarding atmospheric levels of pollutants such as polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) around waste incinerators. The value of $a = 2$ was determined by considering that a possible maximum relative risk attained in the study will be around 1.1-1.2. Further, we examined the effect of value a on the power of the proposed test by considering larger values for a but we had no essential changes.

To calculate sample sizes required for this study, we have conducted power calculations based on Monte Carlo simulation. In this paper, we shall show a part of them in which we adopt the following scheme:

1. The risks are assumed to increase only within 3 km from the incinerator. Let R_i denote the relative risk of the i-th nearest zone to the waste incinerator. We consider ten typical risk patterns to be expected in the study, which are shown in Table 3.

2. The total observed number of cases is assumed to be one of n = 5,000, 10,000, 20,000, 30,000, 40,000, 50,000, 100,000 in this paper. Surely a more accurate estimate of the total number of cases can be obtained for the specific outcome being considered.

3. Expected number in each zone is assumed to be proportional to the area of zone, i.e., we shall assume homogeneous population density in this simulation.

To illustrate the calculation of proposed tests and compare with Stone's MLR test, we shall generate a random sample of size $n = 10,000$ simulated under the alternative hypothesis with risk pattern No. 4 which has a peak at zone 2, $\{R_2 = 1.1, R_k = 1.0, k = 1, 3, 4, ..., 10\}$. The data and test results are shown in Table 4: a significant cluster was not detected by applying Stone's MLR test ($p = 0.128$) and extended score test for monotone trend ($p = 0.117$ at $\lambda^* = 4$). Extended score test for both trends, on the other hand, produced $p = 0.022$ at $s^* = 2$ and $\lambda^* = 40$, suggesting a peak at zone 2 which is identical to the visual impression of data. Estimated p-values of these tests are based on 999 random replicates generated under the null hypothesis, respectively.

The resultant powers for tests of nominal α levels of 0.05 and 0.01 are shown in Tables 5 and 6, in which we can observe several interesting characteristics of tests. First, the extended score test for monotone trend has the highest power against all the monotone alternative hypotheses considered (No. of relative risk pattern $= 1, 2, 5, 7, 9$). The extended score test deviced for both trends appears to have slightly higher powers than those of Stone's MLR in these monotone alternatives. Second, the extended score test deviced for detecting both trends has the highest powers against peak-decline alternatives (No. of the relative risk pattern $= 3, 4, 6, 8, 10$). Third, Stone's MLR test seems to have the lowest power on an average but it is sometimes slightly more poweful than the extended score test for monotone trend when we have peak-decline alternatives. The third observation will be clearly due to the misspecification of the alternative hypothesis of the parametric score test. The score test deviced for monotone trend is clearly shown to lose powers against the non-monotone alternatives and even less powerful than Stone's nonparametric MLR test depending on the situations.

6 DISCUSSION

In this paper, we proposed the extended score tests in which the surrogate exposure g is modelled using a continuous function of distance from the source. The optimal model or p-value was determined by finding *the minimum of the profile P-value* of the extended score tests defined in (12) or (16). This procedure looks like the *maximum* likelihood method in a fully parametric approach. It may be said that the parametric approach allows such parameters as λ, a, s to be estimated and withdraws the need to consider a set of somewhat arbitrary values. However, the reason why we did not adopt a parametric approach is mainly the difficulty of deriving a reliable test and of obtaining reliable estimates of parameters involved. Our basic model is of the form:

$$\theta \quad = \quad 1 + \epsilon \; g(d \mid \beta).$$

where β denotes the vector of parameters defining the exposure function of distance d. Namely, in