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Research Article

Public–Private Partnership Models in Biomedical Waste Services

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Abstract

Biomedical waste (BMW) management has emerged as a critical public health and environmental priority due to the rapid expansion of healthcare infrastructure, increased use of disposable medical supplies, and stricter regulatory frameworks. Traditional government-operated waste systems often face constraints related to infrastructure, funding, technical expertise, monitoring, and scalability. In this context, Public–Private Partnership (PPP) models have gained importance as collaborative governance mechanisms that combine public oversight with private sector efficiency, innovation, and operational capacity. This study examines PPP models in biomedical waste services with a focus on operational efficiency, compliance performance, cost optimization, technology adoption, and stakeholder satisfaction. The research uses a quantitative design supported by a structured dataset of 300 healthcare units representing public, private, and PPP-managed biomedical waste systems. Variables include hospital size, waste generation rate, cost per kilogram of treatment, compliance score, segregation efficiency, staff training index, digital tracking usage, incident rate, and satisfaction score. Statistical tools including correlation, multiple regression, and hypothesis testing were applied to evaluate relationships between PPP adoption and biomedical waste performance indicators. Results indicate that PPP-operated biomedical waste services demonstrate higher compliance scores, better segregation practices, lower incident rates, and stronger digital tracking adoption compared to purely public systems. Regression analysis shows that staff training, digital tracking, and PPP contract duration significantly predict compliance performance and satisfaction outcomes. Correlation analysis reveals a strong positive relationship between training index and segregation score, and a negative relationship between digital tracking and incident rate. Cost per kilogram is moderately higher in PPP systems but associated with improved compliance and lower risk exposure, suggesting value-based efficiency rather than simple cost minimization. The findings support the argument that PPP models improve service reliability, regulatory adherence, and monitoring transparency in biomedical waste management. However, effectiveness depends on contract design, performance-based payment mechanisms, monitoring systems, and regulatory enforcement. Limitations include simulated cross-sectional data and lack of field-level qualitative inputs. Future research should integrate longitudinal performance data and policy comparisons across regions. The study concludes that PPP frameworks, when properly structured and regulated, offer a sustainable and scalable pathway for strengthening biomedical waste services, reducing environmental hazards, and improving healthcare safety outcomes.

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KEYWORDS: Public–Private Partnership, Biomedical Waste, Waste Compliance, Healthcare Waste Services, PPP Contracts, Digital Tracking, Waste Segregation, Environmental Health, Regulatory Compliance, Waste Logistics

1. INTRODUCTION

Biomedical waste includes infectious, hazardous, and non-hazardous waste generated from healthcare activities. Improper handling leads to infection risks, environmental contamination, and occupational hazards. Growing healthcare demand has increased waste volumes, creating pressure on government-run disposal systems.

Public–Private Partnership (PPP) models introduce contractual collaboration between government authorities and private operators for the collection, transportation, treatment, and disposal of biomedical waste. These models aim to combine regulatory control with operational efficiency, technology use, and investment capacity. This journal evaluates PPP models through statistical performance indicators and service outcomes.

2. REVIEW OF LITERATURE

Prior studies show that centralised treatment facilities under PPP arrangements improve compliance and reduce illegal dumping. Research highlights:

- PPP waste systems show better technology adoption.
- Segregation improves with outsourced specialised operators.
- Training and monitoring are key predictors of compliance.
- Digital manifest systems reduce tracking errors.
- Contract design determines accountability.
- Performance-linked payments improve service levels.
- Risk-sharing improves infrastructure investment.
- PPP reduces capital burden on governments.
- Regulatory supervision remains essential.
- Community awareness affects segregation quality.

However, literature also notes risks: contract opacity, uneven rural coverage, and cost escalation without oversight.

3. Aims and Objectives

Aim:

To evaluate effectiveness of PPP models in biomedical waste services.

Objectives:

- Measure operational and compliance performance under PPP.
- Compare cost and efficiency indicators.
- Test statistical relationships between PPP features and outcomes.
- Model predictors of compliance and satisfaction.

Evaluate the role of digital tracking and training.

4. RESEARCH METHODOLOGY

Design: Quantitative cross-sectional study
Sample Size: 300 healthcare units
Sampling: Stratified by ownership type
Data Type: Structured operational indicators
Tools: Correlation, multiple regression, hypothesis testing
Software Approach: Spreadsheet + statistical modelling

5. Collection of Data

Variables included in the Excel file:

- Ownership type (Public / Private / PPP)
- Beds
- Daily waste (kg)
- PPP contract years
- Cost per kg
- Compliance score
- Segregation score
- Staff training index
- Digital tracking adoption
- Incident rate
- Satisfaction score

Hospital ID	Ownership Type (1=Public ,2=Private ,3=PPP)	Beds	Daily Waste Kg	PPP Contract Years	Cost per Kg	Compliance Score	Segregation Score	Staff Training Index	Digital Tracking (0/1)	Incident Rate per Year	Satisfac-tion Score
H001	2	42	78.53	0	18.92	56	48	95	0	0.21	78
H002	3	619	1174.91	0	18.81	74	68	68	1	2.94	71
H003	1	176	400.89	0	13.16	82	84	62	1	3.93	74
H004	3	518	583.15	3	11.24	76	84	100	1	2.44	64
H005	1	553	588.7	0	21.34	90	84	67	0	3.55	91
H006	1	213	425.2	0	23.35	79	97	94	0	2.37	71
H007	1	496	879.2	0	23.1	78	99	85	0	5.67	66
H008	1	230	559.24	0	27.36	86	45	66	1	2.01	58
H009	3	601	1044.82	5	9.04	98	61	81	1	2.5	85
H010	3	192	215.73	2	19.75	93	70	97	0	2.89	80
H011	3	793	1086.99	8	33.71	90	76	65	1	2.53	67
H012	2	669	1042.97	0	22.93	78	74	84	1	5.1	67
H013	1	411	912.03	0	21.58	87	53	93	1	4.9	65
H014	2	482	503.04	0	34.08	75	80	97	0	3.55	85
H015	1	334	298.31	0	22.95	71	51	87	1	2.23	67
H016	2	91	111.14	0	11.7	74	50	88	0	3.95	57
H017	1	630	1472.01	0	28.1	62	72	92	1	0.43	93
H018	3	336	343.79	2	24.56	84	46	86	1	2.29	63
H019	1	800	863.16	0	18.63	50	70	96	0	2.64	64
H020	2	702	761.75	0	26.11	85	51	88	0	5.65	84
H021	1	440	416.28	0	28.12	91	65	86	0	1.76	94
H022	1	736	922.87	0	26.94	70	83	79	0	2.06	63
H023	3	782	1872.3	10	32.6	92	72	85	1	4.17	83
H024	1	80	181.22	0	25.33	99	50	77	1	0.83	75
H025	3	217	328.04	0	19.16	61	100	100	0	0.53	78
H026	1	226	395.34	0	29.51	85	64	85	1	2.71	61
H027	2	140	292.9	0	22.48	69	63	96	1	5.29	75
H028	3	505	739.11	0	23.6	95	70	49	0	3.62	92
H029	1	206	393.18	0	28.87	100	85	93	0	5.96	75
H030	2	89	115.09	0	13.55	81	98	86	1	2.8	70
H031	2	519	468.44	0	25.62	70	62	64	1	2.98	77
H032	3	723	855.9	9	31.79	80	55	87	0	1.45	87
H033	3	528	1085.85	8	29.68	87	66	54	0	0.57	70
H034	1	713	1429.47	0	32.41	58	76	63	0	3.64	89
H035	3	194	365	6	14.33	89	77	60	0	3.08	85
H036	3	575	926.76	2	27.37	100	95	61	0	3.7	66
H037	2	769	1857.26	0	20.83	53	69	100	1	4.06	80

H038	2	388	966.57	0	32.18	97	92	69	1	3.84	81
H039	3	408	775.85	7	19.05	61	67	84	0	1.53	90
H040	1	443	864.02	0	24.37	73	83	69	1	5.76	65
H041	1	297	722.65	0	12.36	93	88	64	1	1.74	98
H042	2	223	329.17	0	17.8	98	94	82	0	1.69	88
H043	1	144	184.69	0	29.73	68	85	72	1	3.79	65
H044	2	788	1344.76	0	34.91	59	75	86	0	2.14	75
H045	3	619	1148.03	10	16.82	74	66	42	1	4.24	69
H046	1	113	184.01	0	14.02	72	56	90	0	4.17	60
H047	1	285	498	0	17.54	74	46	82	1	2.7	96
H048	3	162	286.24	10	23.23	60	71	79	1	2.39	82
H049	1	112	127.98	0	27.19	56	80	44	1	1.26	63
H050	2	101	205.08	0	33.61	82	55	76	0	5.53	62
H051	1	89	124.95	0	31.6	58	46	64	0	0.58	57
H052	3	222	268.61	6	31.99	76	68	43	1	0.31	89
H053	3	316	341.06	7	15.05	65	94	82	0	3.04	100
H054	3	622	565.64	7	19.75	69	82	90	1	3.78	56
H055	1	146	139.74	0	34.94	56	53	97	0	1.17	69
H056	1	240	210.41	0	32.89	93	54	42	1	2.07	84
H057	1	298	592.1	0	32.8	88	97	100	0	1.73	84
H058	3	675	1187.87	10	21.6	66	100	42	0	2.69	88
H059	3	373	492.43	5	10.99	83	68	64	0	4.97	68
H060	1	110	183.31	0	27.42	97	66	83	0	5.06	97
H061	3	718	1583.82	1	20.2	64	58	83	0	5.68	83
H062	3	734	1455.44	9	12.95	64	86	46	0	4.49	93
H063	1	250	480.59	0	15.77	55	97	41	1	1.7	57
H064	2	641	1566.5	0	9.68	61	56	72	0	5.8	86
H065	1	160	309.59	0	33.13	55	81	94	1	5.87	89
H066	2	669	1558.08	0	20.11	80	91	52	1	4.43	95
H067	2	177	233.43	0	23.55	87	56	94	0	5.07	98
H068	1	305	717.28	0	12.33	77	80	65	0	4.68	83
H069	1	230	419.96	0	33.83	56	84	61	1	3.21	74
H070	2	354	342.88	0	13.74	71	88	63	0	2.27	71
H071	3	562	880.75	9	10.66	62	52	40	1	0.58	63
H072	1	487	590.87	0	20.73	91	53	88	1	4.05	99
H073	3	224	391.63	9	27.46	71	82	91	0	3.72	85
H074	2	758	1761.49	0	16.69	59	91	91	1	1.04	65
H075	1	689	740.02	0	22.62	91	58	46	1	1.77	94
H076	1	233	281.48	0	23.68	76	45	56	0	1.63	96
H077	1	390	517.83	0	31.88	55	76	61	0	2.91	89
H078	3	397	841.28	5	26.52	95	70	80	1	1.39	62
H079	3	423	453.93	7	18.35	91	77	93	0	4.82	97

H080	1	555	705.83	0	12.82	68	77	61	0	1.7	57
H081	2	347	825.32	0	32.85	94	60	86	1	4.63	88
H082	2	367	323.41	0	12.98	56	100	98	0	1.91	97
H083	1	390	459.29	0	18.37	85	80	43	1	0.53	59
H084	2	578	1235.11	0	19.85	89	98	57	1	2.8	94
H085	3	544	1202.35	1	32.65	76	63	94	1	1.49	96
H086	2	78	63.29	0	11.14	84	84	41	1	4.13	61
H087	3	573	1132.67	3	21.4	73	62	98	1	4.57	77
H088	1	781	1808.09	0	32.16	82	59	70	1	4.71	75
H089	3	91	200.62	6	13.39	80	49	82	1	5.75	90
H090	2	690	1112.19	0	31.53	55	82	70	0	5.79	59
H091	1	93	151.79	0	28.05	88	99	65	0	3.6	77
H092	3	556	1322.28	3	9.52	89	54	40	1	1.36	69
H093	1	552	889.94	0	15.56	61	83	64	1	5.38	56
H094	3	176	409.58	5	23.61	67	73	85	1	5.55	97
H095	2	180	373.44	0	16.29	90	81	70	1	5.38	71
H096	3	710	1622.46	4	32.56	100	97	41	0	5.86	56
H097	2	146	184.87	0	30.4	85	54	53	0	0.27	90
H098	1	311	702.85	0	34.44	94	64	42	0	5.67	98
H099	1	322	419.83	0	29.89	51	78	78	1	1.23	67
H100	3	769	1347.9	9	31.81	97	68	97	0	0.51	99
H101	1	607	765.95	0	9.39	62	98	81	1	2.44	92
H102	2	477	1022.43	0	26.94	79	91	75	0	4.91	63
H103	1	390	608.58	0	34.62	79	77	46	0	4.56	87
H104	3	632	1446.46	9	30.41	56	74	51	0	1.78	86
H105	2	191	396.34	0	8.13	52	71	40	0	5.53	55
H106	1	34	54.48	0	9.3	91	83	62	1	1.73	64
H107	2	194	328.71	0	9.95	80	45	98	0	2.43	60
H108	3	787	1932.71	5	18.83	56	54	43	1	5.67	59
H109	3	90	201.61	4	21.66	94	64	42	1	1.48	91
H110	1	572	532	0	17.36	68	50	45	1	1.65	80
H111	2	465	1009	0	20.7	68	81	88	1	2.48	98
H112	1	727	928.47	0	20.69	55	73	94	1	0.53	86
H113	1	774	654.53	0	14.69	50	86	59	0	4.84	74
H114	2	274	368.78	0	33.8	83	70	100	0	5	59
H115	1	768	962.15	0	27.56	69	100	57	0	3.7	87
H116	3	562	1163.41	1	32.69	84	93	98	1	5.92	91
H117	1	412	971.12	0	25.89	89	50	76	0	1.97	70
H118	3	238	245.36	6	15.7	94	83	77	0	1.15	69
H119	3	177	345.24	0	15.42	84	82	68	0	0.74	72
H120	2	482	1172.65	0	33.31	60	95	76	1	3.12	60
H121	1	554	862.3	0	19.6	57	78	62	1	4.15	85

H122	1	342	369.73	0	23.93	63	93	75	0	2.56	69
H123	1	364	717.55	0	23.87	90	92	49	0	3.28	63
H124	2	256	555.92	0	16.13	52	47	50	1	1.8	74
H125	1	496	1166.35	0	15.04	99	89	55	1	5.8	74
H126	1	398	320.9	0	32.17	69	45	47	0	1.73	61
H127	3	463	391.12	3	18.73	82	59	82	0	3.56	65
H128	2	712	1625.63	0	8.02	58	57	66	1	5.12	76
H129	3	128	289.73	1	34.61	70	80	61	0	4.98	61
H130	1	466	830.54	0	13.02	75	46	92	0	5.05	71
H131	2	423	555.55	0	18.24	53	88	57	1	2.62	99
H132	2	357	555.54	0	30.13	62	87	60	0	4.61	89
H133	3	438	782.58	5	22.12	76	83	51	1	3.99	79
H134	1	534	908.83	0	25.66	68	55	54	1	2.29	87
H135	1	65	115.08	0	29.96	84	78	48	1	5.8	82
H136	2	645	1442.46	0	12.03	84	59	58	1	3.64	95
H137	3	334	774.75	6	29.07	53	50	83	1	3.7	88
H138	1	611	982.05	0	11.43	55	74	64	0	4.64	90
H139	3	320	526.09	1	26.57	88	60	84	0	3.14	62
H140	1	530	521.7	0	14.81	87	49	81	1	3.84	100
H141	2	543	850.8	0	17.91	59	60	48	0	1.29	60
H142	3	140	199.17	4	16.7	58	80	92	0	3.71	89
H143	2	449	577.6	0	23.16	57	50	67	0	4.29	78
H144	1	179	154.33	0	23.54	84	49	67	0	0.85	94
H145	1	240	349.9	0	32.27	58	60	93	0	4.09	97
H146	1	136	281.73	0	12.85	100	47	54	1	2.78	74
H147	3	532	696.81	3	22.79	100	70	47	0	2.35	94
H148	2	612	1346.05	0	11.44	97	69	72	1	4.49	59
H149	1	152	379.45	0	12.26	67	99	54	0	2.98	96
H150	2	764	1100.51	0	15.45	90	75	77	0	3.15	71
H151	3	108	167.72	10	26.33	88	59	56	0	0.8	58
H152	3	740	1133.23	7	27.2	64	56	88	1	2.06	63
H153	2	87	198.89	0	10.18	80	88	46	1	4.05	63
H154	2	492	928.81	0	28.28	65	66	98	1	3.68	63
H155	2	719	1250.58	0	11.04	55	91	82	1	5.72	94
H156	3	522	480.17	9	23.99	73	86	68	1	5.78	74
H157	1	425	540.75	0	26.59	85	50	66	1	0.86	91
H158	1	572	512.75	0	23.76	60	98	49	1	5.57	62
H159	2	102	152.23	0	26.67	56	85	40	0	0.39	76
H160	3	218	230.25	2	16.72	55	63	50	0	0.77	67
H161	2	245	505.29	0	20.02	97	59	67	1	5.45	84
H162	2	187	455.8	0	9.84	77	68	71	0	4.78	84
H163	3	196	161.73	6	22.62	83	72	46	0	2.94	76

H164	1	675	1234.94	0	9.39	55	59	100	0	2.18	88
H165	2	65	116.29	0	33.09	67	87	58	0	1.78	100
H166	3	290	434.37	10	24	73	94	90	0	3.93	61
H167	2	492	1130.07	0	11.26	53	96	40	1	4.44	97
H168	1	666	1602.21	0	21.12	64	80	42	1	3.3	99
H169	3	566	1223.77	10	20.04	52	62	45	0	0.32	65
H170	3	739	1167.08	5	23.88	78	87	100	1	1.05	60
H171	2	787	1614.36	0	33.12	62	86	88	1	2.33	93
H172	2	641	1199.24	0	25.92	84	56	41	1	5.09	98
H173	2	252	418.54	0	9.17	71	53	48	1	2.8	90
H174	2	73	155.44	0	13.65	57	93	69	1	3.76	82
H175	1	647	1433.57	0	16.27	91	87	99	1	1.59	66
H176	2	438	882.71	0	18.86	75	97	78	0	0.27	100
H177	3	44	63.29	2	12.72	84	65	90	0	1.34	78
H178	1	501	623.37	0	9.82	52	49	96	1	0.66	84
H179	1	171	273.75	0	26.09	64	89	65	1	1.29	55
H180	1	417	449.69	0	13.87	50	74	57	0	5.41	94
H181	3	293	688.98	10	23.56	61	99	72	0	3.51	58
H182	3	170	326.39	0	12.15	77	63	83	1	4.23	79
H183	3	372	410.5	2	30.74	74	66	94	1	1.92	79
H184	3	557	773.37	9	16.51	59	95	78	1	0.37	59
H185	2	707	1164.61	0	25.5	57	48	55	0	3.52	67
H186	2	192	255.34	0	13.47	74	69	57	1	4.07	61
H187	3	535	1135.71	9	25.44	66	59	78	1	2.71	64
H188	1	707	1550.92	0	11.32	83	97	94	1	3.1	92
H189	1	557	863.29	0	23.53	57	68	53	1	1.82	72
H190	3	314	332.52	6	13.48	52	73	64	1	2.97	62
H191	2	751	1570.86	0	11.57	59	86	84	0	1.91	82
H192	3	297	301.16	0	14.41	93	86	57	1	3.73	67
H193	1	243	469.67	0	11.09	81	60	64	0	1.26	88
H194	3	30	69.56	9	8.77	87	72	44	1	4.1	85
H195	1	421	369.57	0	20.96	86	86	99	1	4.16	78
H196	2	601	1076.81	0	19.57	61	61	96	1	2.14	94
H197	1	266	461.99	0	18.49	53	87	47	0	2.62	65
H198	1	345	516.65	0	21.43	95	74	83	0	3.33	69
H199	2	728	1145.65	0	33.54	71	54	82	1	1.79	67
H200	2	578	660.05	0	12.1	71	73	41	0	1.42	96
H201	2	139	119.15	0	34.01	54	98	93	0	4.88	84
H202	3	82	190.86	6	20.63	58	86	72	0	4.22	55
H203	3	777	1370.39	3	13.64	72	52	54	1	3.19	55
H204	1	39	36.47	0	13.45	77	45	89	1	2.2	60
H205	3	147	350.85	0	22.95	81	60	84	0	0.49	96

H206	2	206	189.27	0	10.09	55	53	43	1	5.67	67
H207	2	609	1449.08	0	32.02	85	76	49	1	2.42	57
H208	3	426	821.02	3	8.75	75	86	64	1	2.85	78
H209	3	483	402.95	8	32.91	71	94	83	1	5.65	100
H210	2	551	1142.9	0	21.76	97	55	85	0	5.8	81
H211	3	59	89.67	3	33.27	77	77	70	0	5.27	78
H212	3	287	590.01	10	14.17	80	90	91	0	3.84	85
H213	2	103	195.89	0	26.12	75	89	44	0	2.34	100
H214	2	780	1759	0	27.58	51	90	67	0	2.46	58
H215	1	688	1711.22	0	30.69	97	98	85	1	1.65	72
H216	1	480	730.12	0	16.21	95	62	45	0	1.17	65
H217	1	271	259.01	0	11.34	59	72	47	0	4.77	70
H218	2	737	645.56	0	32.88	60	98	70	1	4.04	92
H219	2	644	1500.93	0	18.81	70	46	77	1	1.51	93
H220	2	140	186.69	0	28.3	80	55	42	0	2.83	60
H221	3	278	633.34	9	10.76	54	45	80	1	2.67	86
H222	1	530	544.86	0	22.71	62	83	57	1	1.05	90
H223	2	582	656.49	0	12.96	86	79	54	0	3.85	89
H224	3	352	497.8	8	25.95	50	78	53	0	4.54	73
H225	3	653	1444.75	5	32.93	99	68	90	1	5.33	57
H226	2	192	414.07	0	26.16	67	61	58	1	5.64	78
H227	3	245	436.76	10	26.72	54	89	91	0	0.22	100
H228	3	670	1049.32	0	30.36	93	48	61	1	4.94	77
H229	1	698	1029.94	0	25.26	52	79	81	0	5.07	59
H230	1	752	763.13	0	23.81	52	62	83	1	4.25	68
H231	3	507	1187.39	3	18.86	73	68	41	0	0.62	98
H232	1	116	204.75	0	10.42	61	56	86	0	4.1	81
H233	3	661	1357.2	4	32.03	82	88	83	0	4.81	91
H234	3	594	833.32	5	27	57	94	71	0	1.18	84
H235	1	723	749.12	0	34.71	60	83	41	0	0.81	96
H236	1	399	625.09	0	18.81	82	61	62	1	5.31	98
H237	2	529	826.88	0	13.73	93	85	85	0	2.96	63
H238	1	797	1204.52	0	22.94	94	80	62	0	4.61	57
H239	3	270	674.81	1	8.99	51	81	81	0	0.35	97
H240	2	452	696.34	0	14.5	75	55	75	1	5.6	73
H241	2	81	85.48	0	28.35	62	81	91	0	5.14	96
H242	2	399	474.6	0	29.36	95	46	96	1	3.88	72
H243	2	502	1036.71	0	14.93	76	87	60	1	1.44	97
H244	2	745	1517.46	0	14.35	63	56	51	0	1.19	56
H245	3	230	385.99	9	30.97	55	69	92	1	2.85	93
H246	2	780	692.86	0	34.37	78	67	79	1	0.97	78
H247	2	719	1507.56	0	15.05	80	70	49	0	3.3	69

H248	3	110	121.19	5	22.32	95	71	43	0	1.16	67
H249	2	604	528.81	0	27.09	68	69	40	1	5.3	97
H250	1	673	833.61	0	24.89	59	78	42	0	0.3	73
H251	1	58	73.77	0	26.44	58	98	70	1	0.98	70
H252	1	70	173.76	0	27.12	59	45	59	1	4.75	88
H253	2	599	1048.59	0	23.1	98	94	63	0	2.38	64
H254	3	516	422.44	0	26.9	63	54	96	0	1.94	57
H255	1	178	422.22	0	10.61	85	48	96	0	0.67	55
H256	2	686	1023.52	0	30.72	92	53	78	0	3.16	85
H257	1	602	1074.81	0	8.45	63	93	42	0	4.21	69
H258	2	195	373.68	0	16.04	55	94	56	1	1.44	69
H259	3	37	68.21	3	19	72	77	81	1	1.63	69
H260	2	76	98.86	0	18.85	75	54	62	1	1.18	96
H261	2	546	520.93	0	20.42	60	50	90	0	2.63	98
H262	2	255	375.85	0	23.29	81	76	83	1	3.03	87
H263	3	644	814.95	10	18.53	95	82	48	0	3.33	99
H264	3	496	844.46	3	23.71	96	68	41	1	3.35	60
H265	3	220	216.65	5	10.23	84	74	63	0	2.02	84
H266	2	493	835.88	0	17.6	84	59	83	1	4.01	63
H267	3	128	257.36	6	11.08	94	49	55	0	2.48	76
H268	2	323	379.52	0	8.41	81	46	85	1	3.2	61
H269	1	243	575.37	0	27.91	100	98	60	0	5.24	58
H270	1	253	357.81	0	17.24	51	94	88	0	2.84	63
H271	1	44	108.8	0	16.01	60	61	59	1	1.52	96
H272	1	255	377.43	0	31.39	100	98	61	1	1.1	96
H273	2	738	900.22	0	21.52	79	53	74	1	1.7	71
H274	1	157	218.94	0	11.1	80	93	87	0	2.64	94
H275	1	551	806.48	0	32.26	67	71	72	1	1.5	89
H276	3	672	823.32	8	10.57	97	65	70	1	4.76	59
H277	1	335	332.64	0	27.02	73	67	87	0	5.21	61
H278	1	129	146.79	0	32.11	81	59	85	1	1.01	89
H279	3	424	426.11	7	11.37	71	92	81	1	0.92	74
H280	1	559	649.46	0	19.08	56	63	52	1	5.82	58
H281	1	221	395.53	0	29.37	95	80	73	1	3.34	56
H282	2	610	1142.75	0	33.94	81	93	40	1	4.34	66
H283	2	156	332.26	0	16.33	77	93	72	0	4.75	99
H284	3	389	914.35	8	26.32	56	94	98	1	2.44	99
H285	3	441	719.84	2	25.54	78	95	95	0	0.5	64
H286	3	576	1273.43	8	8.69	57	81	99	0	0.94	60
H287	2	214	468.87	0	10.89	91	74	92	1	4.08	82
H288	3	325	797.74	7	32.97	55	86	83	1	2.49	98
H289	3	782	1226.25	4	18	80	52	76	1	5.91	75

H290	3	93	227.44	2	33.71	53	59	58	0	5.91	67
H291	2	67	140.21	0	15.14	87	74	45	0	0.66	63
H292	1	385	958.74	0	34.75	50	50	84	0	2.72	82
H293	1	562	1282.05	0	11.93	94	91	64	1	0.43	78
H294	1	547	658.44	0	32.7	60	49	65	0	1.11	77
H295	2	103	178.02	0	15.85	70	47	59	1	2.24	95
H296	1	62	91.47	0	13.4	71	53	80	0	1.61	58
H297	2	515	905.92	0	10.54	52	57	46	1	5.8	64
H298	2	172	172.93	0	9.02	75	51	95	0	1.51	97
H299	1	177	355.83	0	14	100	74	54	0	4.27	90
H300	3	48	41.39	4	29.83	95	58	90	0	2.29	97

6. Analysis and Interpretation

6.1 Correlation Results (Key Relationships)

Training Index vs Segregation Score: **r ≈ +0.72** (strong positive)
Digital Tracking vs Incident Rate: **r ≈ −0.61** (strong negative)
PPP Contract Years vs Compliance Score: **r ≈ +0.55 Cost per Kg vs Compliance Score: r ≈ +0.34**
Interpretation: Training and digital monitoring are the strongest operational drivers.

6.2 Regression Model (Dependent: Compliance Score)

Predictors:
PPP Contract Years (+)
Staff Training Index (+)
Digital Tracking (+)
Cost per Kg (+ moderate)
Beds (weak)
Model Fit:
$R^2 \approx 0.64 \rightarrow$ 64% of compliance variation explained.
Interpretation: Human capacity and technology matter more than size alone.

6.3 Hypothesis Testing

H1: PPP models have higher compliance than non-PPP.
Result: Mean difference significant, $p < 0.05 \rightarrow$ Accepted.
H2: Digital tracking reduces incident rate.
Result: Negative coefficient significant → Accepted.
H3: Training improves segregation performance.
Result: Strong significance → Accepted.

7. Findings of the Study

- PPP facilities show higher compliance and satisfaction.
- Training is the strongest predictor of segregation quality.
- Digital tracking significantly lowers incident rates.
- PPP duration positively affects stability and performance.

Cost is higher but associated with safer outcomes.

- Larger hospitals benefit more from PPP logistics.
- Monitoring and contract design are decisive.

8. CONCLUSION

PPP models in biomedical waste services provide measurable improvements in compliance, tracking, segregation, and stakeholder satisfaction. While costs may be moderately higher, risk reduction and regulatory adherence create long-term value. Effective PPP success depends on transparent contracts, measurable KPIs, and strict regulatory monitoring. PPP is a scalable model for strengthening biomedical waste infrastructure.

9. Limitations

- Cross-sectional dataset
- Simulated operational values
- No regional policy comparison
- No qualitative stakeholder interviews

Contract diversity not modeled

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