

The Environmental Impact of Hip and Knee Joint Replacement Operations: An Analysis of Carbon Emissions and Disposal Costs

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INTRODUCTION: The increasing prevalence of hip and knee replacement surgeries to address osteoarthritis and the generation of significant waste in operating theatres necessitates addressing healthcare pollution emissions which currently do not align with Ireland’s climate change mitigation efforts and net-zero emission goals. A qualitative and quantitative study was conducted to assess the carbon emissions associated with operating waste and identify actions that can be implemented to minimize the impact on the environment.

METHODS: The study was conducted at the National Orthopaedic Hospital Cappagh (NOHC), measuring waste generated during primary and revision hip and knee replacement operations. Clinical, domestic, and recycled waste weights were recorded after every operation, including the segregation of CSSD Blue Wrap waste in ten operations. Equations from the Intergovernmental Panel on Climate Change (IPCC) were used to determine the Carbon Dioxide emissions (kgCO₂e) from clinical and domestic waste. Disposal costs were estimated for clinical, domestic, and recycled waste using the Health Service Executive Green Health Programme estimates.

RESULTS: In a sample of 100 joint replacement operations, the study found that revision knees produced 23.58 kgCO₂e per case, revision hips 23.50 kgCO₂e, primary knees 15.82 kgCO₂e, and primary hips 14.64 kgCO₂e. In the selected cases, CSSD Blue Wrap contributed on average 13.5% of total operating room waste, in which we estimated the carbon emissions and disposal costs for each operation in Table 2. Extrapolating these findings to the estimated number of joint replacement surgeries performed in 2022 at NOHC (1,556 hip and knee joint arthroplasty), the total CO₂ emissions were estimated to be 24,576 kgCO₂e, with the cost of disposal up to €29,228.

DISCUSSION: In this single-institution study at National Orthopaedic Hospital Cappagh (NOHC), we investigated the costs and environmental impact posed by waste generation in joint replacement surgeries to understand the quantity and types of waste generated can help healthcare facilities introduce sustainable operating theatre practices. To contextualize carbon emissions, after 24 primary hip or knee replacements (2-3 days at NOHC) the kgCO₂e is equivalent to the emissions from one passenger on a flight from Dublin, Ireland to New York, U.S.A (~300 kgCO₂e). Methods to maximize recycling would lead to significant reductions in CO₂ emissions by reducing a large number of emissions from landfills and incinerators. A significant portion of waste generated during a single operation, comprising approximately 80% of the total weight, falls into the "non-clinical waste" category. CSSD Wrapping, commonly known as "Blue Wrap," has emerged as a significant contributor to domestic waste due to its widespread use for preserving the sterility of surgical instruments in operating theaters. Reducing the consumption of CSSD Blue wrap through the consolidation of surgical kits and finding ways to recycle this material can effectively minimize the environmental impact and disposal costs per surgery. Finally, implementing environmentally sustainable practice training for surgical trainees is crucial in creating a new generation of environmentally conscious medical professionals. This research does have limitations such as this being a single institution which limits the applicability of the findings, and we assumed recycled waste produces no global greenhouse gases which oversimplifies the environmental impact of disposal processes.

SIGNIFICANCE/CLINICAL RELEVANCE:

Our methodology could potentially allow sustainability offices in hospitals to conduct waste audits for selected surgeries, compare waste generation, and offer strategies to reduce waste generation, carbon emissions, and disposal costs. Implementing our identified strategies for waste management practices, and training future surgeons in sustainable approaches, will help achieve net-zero emissions goals.

Table 1. Domestic, Clinical, Recycled Waste per Joint Replacement

	Cases (N)	Average Total Waste (kg)	Carbon Dioxide Emissions (kgCO ₂ e)	Disposal Costs (€)
TKR	43	12.05 ± 1.64	15.82	17.79 - 18.16
rTKR	6	17.50 ± 3.36	23.58	24.15 - 24.78
THR	46	12.03 ± 1.83	14.64	18.28 - 18.65
rTHR	5	16.30 ± 2.71	23.5	21.67 - 22.27

Table 1 presents the average weight with standard deviations of total waste, the average kilograms of carbon dioxide emissions and average total costs of disposal for each joint replacement operation.

Table 2. CSSD Blue Wrap CO₂e and Disposal Costs per Joint Replacement

	CO ₂ e (kg/case)	Cost (€/case)
TKR	5.1	0.21 – 0.33
rTKR	8.2	0.31 – 0.47
THR	4.3	0.21 – 0.32
rTHR	8.8	0.29 – 0.44

Table 2 displays the kgCO₂ emissions and disposal cost of CSSD wrap assuming it accounts for 13.5% of total weight in each operation.

Table 3. Total Waste, CO₂ Emissions, and Disposal Cost Estimates for 2022 NOHC Calendar Year

	Cases (N)	Waste (kg/Year)	CO ₂ e (kg/Year)	Cost (€)
TKR	670	8,075	10,596	11,920 - 12,168
rTKR	51	893	1,202	1,232 - 1,264
THR	773	9,297	11,320	14,131 - 14,415
rTHR	62	1011	1,457	1,344 - 1,381
Total	1,556	19,275	24,576	28,626 - 29,228

Table 3. The number of operations completed in NOHC in 2022 and estimates the total waste, CO₂ emissions, and disposal costs.