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Representation of Environmental Concepts Associated with Health Impacts in Computer Standardized Clinical Terminologies

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Summary

Objective: To evaluate the representation of environmental concepts associated with health impacts in standardized clinical terminologies.

Methods: This study used a descriptive approach with methods informed by a procedural framework for standardized clinical terminology mapping. The United Nations Global Indicator Framework for the Sustainable Development Goals and Targets was used as the source document for concept extraction. The target terminologies were the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT) and the International Classification for Nursing Practice (ICNP). Manual and automated mapping methods were utilized. The lists of candidate matches were reviewed and iterated until a final mapping match list was achieved.

Results: A total of 119 concepts with 133 mapping matches were added to the final SNOMED CT list. Fifty-three (39.8%) were direct matches, 37 (27.8%) were narrower than matches, 35 (26.3%) were broader than matches, and 8 (6%) had no matches. A total of 26 concepts with 27 matches were added to the final ICNP list. Eight (29.6%) were direct matches, 4 (14.8%) were narrower than, 7 (25.9%) were broader than, and 8 (29.6%) were no matches.

Conclusion: Following this evaluation, both strengths and gaps were identified. Gaps in terminology representation included concepts related to cost expenditures, affordability, community engagement, water, air and sanitation. The inclusion of these concepts is necessary to advance the clinical reporting of these environmental and sustainability indicators. As environmental concepts encoded in standardized terminologies expand, additional insights into data and health conditions, research, education, and policy-level decision-making will be identified.

Keywords

Nursing informatics; environmental health; standardized nursing terminology; systematized nomenclature of medicine; artificial intelligence.

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1 Introduction

Our health is interconnected with the air, water and land in which we live and work. However, environmental risks are not evenly distributed, as vulnerable populations may have a higher risk of exposure to air pollution, noise pollution and hazardous chemicals due to pre-existing health conditions, poor nutritional status and other environmental risk factors. In 2015, United Nations (UN) Member States formally adopted 17 Sustainable Development Goals (SDGs) to achieve by the year 2030. These goals provided a shared plan for the health, well-being, and prosperity of people and the planet. For example, SDG 3.9.1 considers the mortality rate attributed to ambient and household air pollution. Further SDG indicators consider the intersection of sustainability and human existence related to health,

poverty, pollution, water, education, gender equality, energy, and economic growth [1]. To further these goals, various disciplines have come together to collaborate on the concept of One Health.

One Health is a collaborative, multisectoral approach which highlights the absolute interconnectedness between human health and the complex ecosystems in which we live and share [2, 3]. This transdisciplinary approach is an important consideration as human populations are expanding into new geographic areas which has led to potential opportunities for diseases to pass between animals and people. Each year, millions of people are impacted by antimicrobial-resistant germs, vector-borne diseases, and ill health related to the contamination of water. Weather changes impacting temperature and humidity are also associated with adverse outcomes related to respiratory, cardiovascular, and neurological conditions and infectious diseases [4-7].

Environmental sustainability further informed this project. Morelli [8] describes environmental sustainability "…as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity."

The question remains how well healthcare is advancing towards meeting environmental sustainability, One Health and the SDGs. One such area where healthcare clinician contributions can be leveraged in this evaluation is through secondary data reuse of clinical documentation. Clinicians assess, diagnose, provide interventions and evaluate the care of people and communities affected by environmental impacts. In many settings, this documentation is captured in electronic format with embedded standardized clinical terminologies. Standardized clinical terminologies are databases of clinical terms that have computer-readable codes, are arranged in a polyarchy with defined relationships, have conceptual uniqueness and permanence, and can expand through multiple granularities [9]. As a mechanism to support data reuse, standardized clinical terminologies can be used to facilitate the aggregation of clinical data across disparate settings and applied in larger-scale evaluations. Two healthcare terminology standards often used in this capacity, are the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT), a multilingual clinical health terminology [10] and the International Classification for Nursing Practice (ICNP), a classification of nursing diagnosis, interventions, and outcomes specifically describing nursing practice [11]. These standardized terminologies are systematically organized and are computer-readable collections of medical terms that are defined, codified, and have synonyms associated with easier cross-mapping and comparison across systems and practice settings [12]. In 2021, the International Council of Nurses (ICN) and SNOMED International announced an agreement whereby ICNP would be managed and distributed by SNOMED International while content ownership would remain with ICN [13]. To support this work, reference sets and tables have been developed to describe the mapping equivalence between these two terminologies.

While much work has been advanced to represent healthcare concepts in SNOMED CT and ICNP, it is unknown if the suite of associated health concepts, represented in these SDGs, exists in these systems. Therefore, this study aimed to evaluate the representation of environmental concepts associated with health impacts in SNOMED CT and ICNP.

2 Objectives

The objective of this study was to evaluate the representation of environmental concepts associated with health impacts, in standardized clinical terminologies.

3 Methods

This study used a descriptive methodology informed by Block *et al.* [14] procedural framework for standardized clinical terminology mapping (Figure 1). As per the Canadian Tri-Council Policy Statement for Ethical Conduct for Research Involving Humans-Chapter 2 [15], this research study was excluded from requiring research ethics board approval, and as such, no formal ethics application was conducted.

3.1 Source Concepts

The Global Indicator Framework for the Sustainable Development Goals and Targets of the 2030 Agenda for Sustainable Development document was chosen as the source reference material to perform concept extraction [1]. Developed by the Inter-Agency and Expert Group on SDG Indicators, it contains a descriptive list of targets and indicators. To define source concept inclusion, this research group focused on the Good Health and Well-Being SDG and those SDG indicators whose custodial agency was, or, in discussion to be, the World Health Organization [16]. The remaining indicators were excluded from this study.

3.2. Source Concept Extraction Protocol

A total of 41 SDG indicators were identified as health-related from the source document of the Global Indicator Framework document. These indicators were then divided among five nursing researchers (established & emerging) for concept extraction. For this paper, a concept targeted for extraction was defined as the identification of unique, explicit concepts which correspond to a singular meaning and term/phrase [9]. The researchers a) reviewed the assigned indicator; b) identified clinical concept(s); c) categorized the concepts into a domain type (as per SNOMED CT) [17]; and d) added possible synonyms or extensions as interpreted by their own clinical knowledge and expertise. These were then reviewed by the research team for verification of completeness and accuracy. Disagreement was discussed until consensus was achieved.

3.3 Conceptual Modeling

The researchers assigned domain type(s) to facilitate an understanding of the orientation and descriptive meaning of the extracted concepts (*e.g.*, the extracted concept was "tuberculosis" and the domain type was

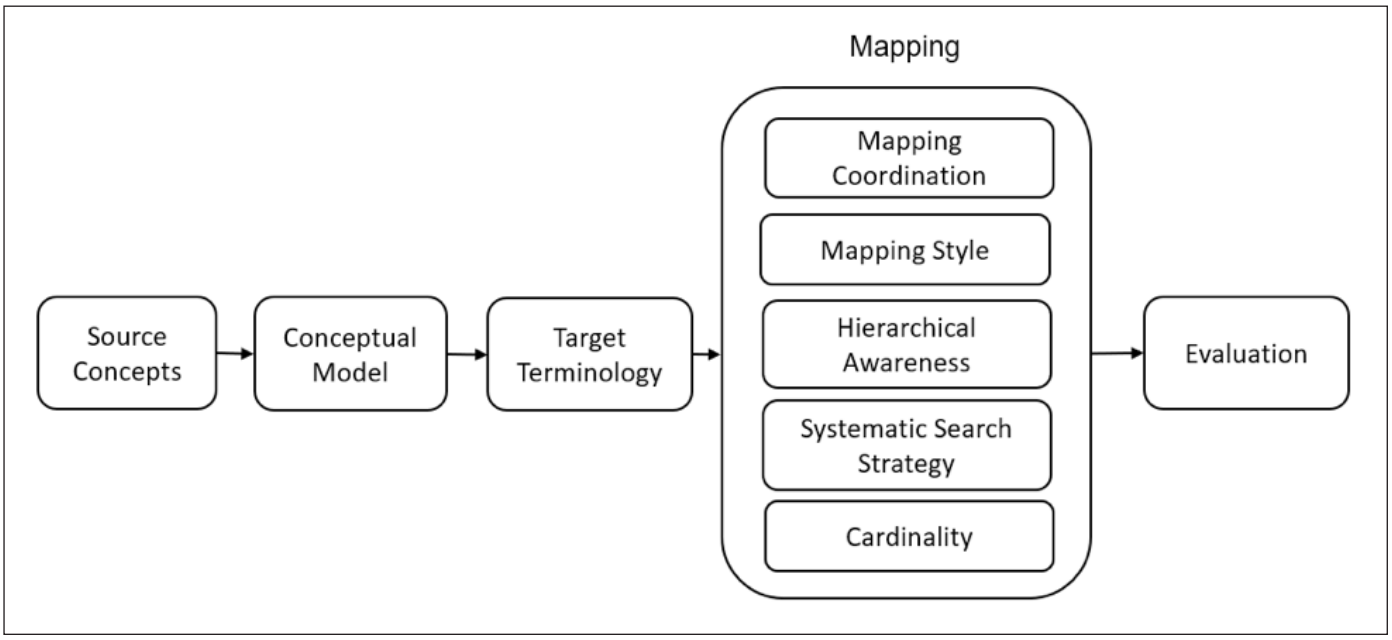

Fig. 1 Procedural Framework for Standardized Clinical Terminology Mapping (inspired from [14]).

"diagnosis"). The purpose of this step was to embed a dimension of meaning, awareness, and boundary to the conceptual phenomena the symbolized 'word' was interpreted to portray [18, 19]. The domain types were informed by the conceptual domains used in SNOMED CT and ICNP to arrange health concepts into the terminologies of polyhierarchical ontology structures [20].

3.4 Target Terminology

The target terminologies were: 1) SNOMED CT International Edition (manual: 2022-09-30 version; automated 2022-07-31 version), and 2) ICNP 2019 Edition. All the extracted source concepts were prepared for SNOMED CT mapping. Given the scope of ICNP, only source concepts represented as diagnosis, interventions, and outcomes were included.

3.5 Mapping

The following mapping procedures were sequentially applied in this study:

- Mapping Coordination: Pre-coordination;
- Mapping Style: Manual and Automated (SNOMED CT); Manual (ICNP);
- Hierarchical Awareness: All extracted concepts had potential alignment to existing hierarchies in SNOMED CT and were therefore candidates for SNOMED CT mapping. All extracted concepts aligned to diagnosis, intervention and outcomes had potential alignment to existing hierarchies in ICNP and were therefore candidates for ICNP mapping;
- Systematic Search Strategy (see below);
- Cardinality (see below).

3.5.1 Systematic Search Strategy

Both manual and automated methods were used. These methods were chosen as a means to leverage the strengths of human and computer mapping selection, as well as, control for possible selection bias [19, 21, 22]. During the manual mapping phase, extracted concepts were uploaded into an excel spreadsheet and divided among four researchers where each concept was independently, manually mapped twice. Table 1 outlines the systematic search strategy used in each terminology online browser.

During the automated mapping phase, extracted concepts were uploaded into an excel spreadsheet. All punctuation was removed to facilitate CSV upload to the automated mapping tool Snap2SNOMED CT [23]. All concepts were tasked as an 'automap', whereby the Snap2SNOMED CT software automatically assigned candidate matches.

3.5.2 Cardinality

The types of manual mapping matches were defined as:

- Direct match means that the concept matches exactly to the concept found in SNOMED CT or ICNP;
- Broader than match means that the concept found in SNOMED/ICNP was conceptually broader (more general) than the concept found in the source concept list;
- Narrower than match means that SNOMED/ICNP was conceptually narrower (more specific) than the concept found in the source concept list;
- No match means there were no matches in the target terminology (*i.e.*, SNOMED CT, ICNP).

Table 1 Systematic Search Strategy.

Search direction and question	Decision
Search using exact concept phrasing → exact match?	IF Yes (stop) IF No match found then, next step
Search using truncated concept phrasing → exact match?	IF Yes (stop) IF No match found then, next step
Search for synonyms with the same conceptual meaning → exact match?	IF Yes (stop) IF No match found then, next step
Search for related concept → broader than, narrower than?	IF Yes (stop) IF No match found then, next step
Conclude there is no match	

The cardinality of matches produced through the automated mapping tool did not include comments of match type, and was, therefore, not applicable.

3.6 Evaluation

The candidate lists, from manual mapping and automated mapping, were presented to two researchers who were not part of the manual or automated mapping phases. The researchers were tasked to review the extracted concept, and the candidate mapping matches, and then choose the 'best' fit mapping and cardinality match(es). The two team members took note of any concepts or mapping matches which were ambiguous or required further review. The results of this work were then reviewed by several members of the researcher group over three meetings, where fit results, alignment, and ambiguity were discussed. This discussion iterated, refined and verified the final mapping list.

4 Results

A total of 169 concepts were initially extracted from the 41 source SDG indicators and used as candidates for SNOMED CT mapping. Of these 169 concepts, 31 were given a domain related to a diagnosis, intervention, or outcome and were therefore also mapped to ICNP. Through iterative review and group consensus, a total of 119 concepts with 133 mapping matches were added to the final SNOMED CT mapping list (Table 2). Similarly, a total of 26 concepts with 27 mapping matches were added to the final ICNP mapping list. Of these 133 SNOMED CT mapping matches, 53 (39.8%) were direct matches, 37 (27.8%) were narrower than matches, 35 (26.3%) were broader than matches, and 8 (6%) had no matches. Of these 27 ICNP mapping matches, 8 (29.6%) were direct matches, 4 (14.8%) were narrower than, 7 (25.9%) were broader than, and 8 (29.6%) were no matches. Of note, some of these concepts were repeated through the extraction phase of the 41 SDG indicators (e.g., mortality rate) and for the purposes of reporting SNOMED CT mapping results, these repeats were counted. When no matches and repeated concepts were removed, a total of 107 unique concepts were represented in SNOMED CT.

5 Discussion

Informed by the principle of One Health, whereby health is linked to the ecosystems with which we live, this study sought to explore the representation of environmental concepts associated with health impacts, in standardized clinical terminologies. We chose to extract concepts described in the UN Global Indicator Framework for the Sustainable Development Goals and Targets and mapped them using a structured process, to SNOMED CT and ICNP. The multiple methods used added strength to our approach (*e.g.*, manual and automated mapping). As well, our international research team added a depth of meaningful interpretation through the lenses of varied clinical nursing, research, and lived experiences, aiding in the progression of concept extraction, synonym development, mapping selection, and iterative evaluation.

5.1 Mapping Results

Overall, our mapping processes found that the extracted concepts were moderately well represented in SNOMED CT and ICNP. Of the 133 SNOMED CT mapping matches found, 53 (39.8%) were direct matches, 37 (27.8%) were narrower than matches, 35 (26.3%) were broader than matches, and 8 (6%) had no matches. Of those concepts which were direct matches, 14 (10.5%) were of the disorders (diagnosis) ontological axis. In contrast, only 1 (0.7%) broader than and 4 (3%) narrower than mapping matches were of the disorders axis. This strong coverage may be related to the generally well-developed diagnosis content of SNOMED CT [21, 35, 36]. Of the 27 ICNP mapping matches, 8 (29.6%) were direct matches, 4 (14.8%) were narrower than, 7 (25.9%) were broader than, and 8 (29.6%) were no matches. Of these, 4 (15%) of the no matches were related to specific medical diagnoses (*e.g.*, tuberculosis, malaria, hepatitis B, and HIV) and would unlikely be candidates for specific ICNP inclusion (*i.e.*, this was an anticipated ICNP mapping finding). One of the ICNP matches was equivalent to that found in SNOMED CT (*i.e.*, substance abuse). This was expected given the work to cross-reference ICNP in SNOMED CT. However, there were several concepts chosen during the manual mapping process, which were different. For example, for the source concept "chronic respiratory disease", the mapping match in SNOMED CT was "chronic disease of respiratory system (disorder)", while the ICNP match was "Impaired Respiratory System Function". This difference may relate to the specificity of using the nursing

Table 2 Final Mapping Results between UN Sustainability Concepts, SNOMED CT, and ICNP.

	UN Sustainability Goal	Extracted Concepts	SNOMED CT Mapping	SNOMED CT Cardinality	ICNP Mapping	ICNP Cardinality
1.a.2	Proportion of total government spending on essential services (education, health and social protection)	Governmental expenditure	No Match	No Match		
		Essential services	Services (qualifier value)	Broader Than		
2.2.1	Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age	Children under 5	Child (person)	Broader Than		
		Height for age	Body height for age percentile (observable entity)	Direct Match		
		Standard deviation	Standard deviation (qualifier value)	Direct Match		
		Child growth standards	Childhood growth AND/OR development finding (finding)	Narrower Than		
		Stunting	Nutritional stunting (disorder)	Narrower Than		
2.2.2	Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)	Malnutrition	Nutritional disorder (disorder)	Broader Than		
		Wasting	Nutritional wasting (disorder)	Narrower Than		
		Overweight	Overweight (finding)	Direct Match		
		Children under 5	Child (person)	Broader Than		
2.2.3	Prevalence of anaemia in women aged 15 to 49 years, by pregnancy status (percentage)	Anaemia	Anemia (disorder)	Direct Match		
3.1.1	Maternal mortality ratio	Maternal mortality	Maternal death (event)	Direct Match		
		Maternal	Mother (person)	Narrower Than		
3.1.2	Proportion of births attended by skilled health personnel	Birth attended by skilled health personnel	Delivery by midwife (procedure)	Narrower Than		
		Birth	Birth (finding)	Direct Match	Child Birth	Direct Match
		Skilled health personnel	Healthcare professional (occupation)	Narrower Than		
			Professional nurse (occupation)	Narrower Than		
3.2.1	Under-5 mortality rate	Under 5	Younger child (person)	Broader Than		
		Mortality rate	Mortality rate (observable entity)	Direct Match		
3.2.2	Neonatal mortality rate	Neonatal mortality	Newborn death (event)	Narrower Than		
		Neonatal	Neonatal (qualifier value)	Direct Match		
		Mortality rate	Mortality rate (observable entity)	Direct Match		
3.3.1	Number of new HIV infections per 1,000 uninfected population, by sex, age and key populations	Number of new HIV infection	Human immunodeficiency virus infection (disorder)	Narrower Than		
		HIV	Human immunodeficiency virus status (observable entity)	Direct Match		
		Key population	Population (social concept)	Broader Than		
		Uninfected	Non-infected (qualifier value)	Direct Match	No Infection	Direct Match
		Age	Current chronological age (observable entity)	Narrower Than		
			Age (qualifier value)	Narrower Than		
			Aging (finding)	Narrower Than		
		HIV infection	Human immunodeficiency virus	Direct Match		

Table 2 (continued) Final Mapping Results between UN Sustainability Concepts, SNOMED CT, and ICNP.

	UN Sustainability Goal	Extracted Concepts	SNOMED CT Mapping	SNOMED CT Cardinality	ICNP Mapping	ICNP Cardinality
			(organism)			
			Human immunodeficiency virus infection (disorder)	Direct Match	No Match	No Match
3.3.2	Tuberculosis incidence per 100,000 population	Tuberculosis	Mycobacterium tuberculosis (organism)	Direct Match		
			Tuberculosis (disorder)	Direct Match	No Match	No Match
3.3.3	Malaria incidence per 1,000 population	Malaria	Malaria (disorder)	Direct Match	No Match	No Match
			Plasmodium malariae (organism)	Direct match		
3.3.4	Hepatitis B incidence per 100,000 population	Hepatitis B	Viral hepatitis type B (disorder)	Direct Match	No Match	No Match
			Exposure to Hepatitis B virus (event)	Direct Match		
			Hepatitis B status (observable entity)	Direct Match		
3.3.5	Number of people requiring interventions against neglected tropical diseases	Number requiring intervention	Intervention regime (regime/therapy)	Broader Than		
		Tropical Disease management	Tropical medicine (qualifier value)	Broader Than	Epidemiology	Broader Than
		Interventions	No Match	No Match	Intervention	Direct Match
3.4.1	Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease	Mortality rate	Mortality rate (observable entity)	Direct Match		
		Cardiovascular disease	Disorder of cardiovascular system (disorder)	Direct match	Impaired Cardiovascular System	Direct Match
		Cancer	Malignant neoplasm, primary (morphologic abnormality)	Narrower Than	Cancer Pain	Narrower Than
		Diabetes	Diabetes mellitus (disorder)	Direct Match	Diabetes	Direct Match
		Chronic respiratory disease	Chronic disease of respiratory system (disorder)	Direct Match	Impaired Respiratory System Function	Broader Than
		Chronic disease	Chronic disease (disorder)	Direct Match	Chronic	Broader Than
3.4.2	Suicide mortality rate	Suicide	Suicide (event)	Direct Match		
		Mortality rate	Mortality rate (observable entity)	Broader Than		
3.5.1	Treatment interventions (pharmacological, psychosocial and rehabilitation and aftercare services) for substance use disorders	Substance use disorders	Substance abuse (disorder)	Direct Match	Substance Abuse	Direct Match
		Pharmacological treatment	Pharmacologic (qualifier value)	Broader Than	No Match	No Match
		Psychosocial treatment	Psychosocial procedure (procedure)	Narrower Than	No Match	No Match
		Rehabilitation treatment	Rehabilitation therapy (regime/therapy)	Direct Match	Implementing Rehabilitation Regime	Narrower Than
		Aftercare service treatment	Aftercare (regime/therapy)	Direct Match	No Match	No Match
3.5.2	Alcohol per capita consumption (aged 15 years and older) within a calendar year in litres of pure alcohol	15 years and older	Adolescent (person)	Broader Than		
			Adult (person)	Broader Than		
		Pure alcohol	Alcohol (substance)	Broader Than		
		Pure alcohol consumption	Alcohol intake above recommended sensible limits (finding)	Broader Than	Alcohol Abuse	Broader Than
3.6.1	Death rate due to road traffic injuries	Injury	Physical injury status (observable entity)	Narrower Than		
			Traumatic or non-traumatic injury (disorder)	Direct Match		

Table 2 (continued) Final Mapping Results between UN Sustainability Concepts, SNOMED CT, and ICNP.

	UN Sustainability Goal	Extracted Concepts	SNOMED CT Mapping	SNOMED CT Cardinality	ICNP Mapping	ICNP Cardinality
		Road traffic injury	Road traffic accident injury examination (procedure)	Narrower Than		
			Motor vehicle traffic accident (event)	Narrower Than		
		Death rate	Mortality rate (observable entity)	Direct Match		
3.7.1	Proportion of women of reproductive age (aged 15–49 years) who have their need for family planning satisfied with modern methods	Women of reproductive age	Reproductive function (observable entity)	Narrower Than		
		Aged 15-49 years	Adult (person)	Broader Than		
		Family planning	Family planning education (procedure)	Narrower than	Family Planning	Direct Match
3.7.2	Adolescent birth rate (aged 10–14 years; aged 15–19 years) per 1,000 women in that age group	Adolescent birth	Teenage pregnancy (finding)	Direct Match		
		Birth rate	Number of births at term (observable entity)	Direct Match		
		Adolescent	Adolescent (person)	Direct Match		
3.8.1	Essential health services	Health services	Healthcare services (qualifier value)	Direct Match	Health Service	Direct Match
3.8.2	Proportion of population with large household expenditures on health as a share of total household expenditure or income	Large household expenditure	No Match	No Match		
		Health expenditure	No Match	No Match		
3.9.1	Mortality rate attributed to household and ambient air pollution	Mortality	Mortality rate (observable entity)	Broader Than		
		Household air pollution	Air pollution (event)	Broader Than		
		Ambient air pollution	Air pollution (event)	Broader Than		
		Air pollution	Air pollution (event)	Direct Match		
		Pollution	Pollution (event)	Direct Match		
3.9.2	Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)	Mortality rate	Mortality rate (observable entity)	Direct Match		
		Unsafe water	Water pollution (event)	Broader Than		
		Exposure	Exposure to (contextual qualifier) (qualifier value)	Direct Match		
		Unsafe sanitation	Inadequate sanitation (finding)	Broader Than		
		Lack of hygiene	Ability to maintain standard of personal hygiene (observable entity)	Broader Than		
			Ability to perform personal care activity (observable entity)	Broader Than		
			Degree of personal cleanliness (observable entity)	Narrower Than		
3.9.3	Mortality rate attributed to unintentional poisoning	Mortality rate	Mortality rate (observable entity)	Direct Match		
		Unintentional poisoning	Accidental poisoning (disorder)	Direct Match		
3.a.1	Age-standardized prevalence of current tobacco use among persons aged 15 years and older	Tobacco use	Tobacco user (finding)	Direct Match	No Match	No Match
		Tobacco	Tobacco (substance)	Direct Match		
		Person Age 15 years or older	Adolescent (person)	Broader Than		
3.b.1	Proportion of the target population covered by all vaccines included in their national programme	All vaccines	Vaccine product (medicinal product)	Narrower Than		
3.b.2	Total net official development assistance to medical	Development assistance	Administrative procedure (procedure)	Narrower Than		

Table 2 (continued) Final Mapping Results between UN Sustainability Concepts, SNOMED CT, and ICNP.

	UN Sustainability Goal	Extracted Concepts	SNOMED CT Mapping	SNOMED CT Cardinality	ICNP Mapping	ICNP Cardinality
	research and basic health sectors	Assistance	No Match	No Match		
		Funding	Management of financial circumstance (procedure)	Broader Than	Financial Service	Broader Than
			Provision of written information about financial support (procedure)	Narrower Than	Facilitating Financial Recovery	Narrower Than
		Support (financial, material, human resource)	Has support (link assertion)	Broader Than	Supporting	Broader Than
3.b.3	Proportion of health facilities that have a core set of relevant essential medicines available and affordable on a sustainable basis	Relevant essential medicines	Able to use medication (finding)	Narrower Than		
		Available	Availability of (contextual qualifier) (qualifier value)	Direct match		
		Sustainable	Sustained (qualifier value)	Narrower Than		
		Affordable	No Match	No Match		
		Core set	No Match	No Match		
3.c.1	Health worker density and distribution	Health worker	Healthcare professional (occupation)	Narrower than		
		Density	Density (qualifier value)	Direct Match		
		Distribution	Distribution (attribute)	Direct Match		
3.d.1	International Health Regulations (IHR) capacity and health emergency preparedness	---	---	---		
3.d.2	Percentage of bloodstream infections due to selected antimicrobial-resistant organisms	Bloodstream infections	Infection of bloodstream (disorder)	Direct Match	Septic Shock	Narrower than
		Antimicrobial-resistant organisms	Antimicrobial resistant virus (organism)	Narrower Than		
5.2.1	Proportion of ever-partnered women and girls aged 15 years and older subjected to physical, sexual or psychological violence by a current or former intimate partner in the previous 12 months, by form of violence and by age	Intimate partner	Sexual partners (observable entity)	Narrower Than		
		Intimate partner physical, sexual or psychological violence	Partner in relationship (person)	Broader Than		
			Victim of physical violence (finding)	Narrower Than		
		Violence	Domestic violence (event)	Narrower Than	Violence	Broader Than
6.1.1	Proportion of population using safely managed drinking water services	Access to safely managed drinking water services	Access to potable water (observable entity)	Direct Match		
		Managed drinking water services	Potable water (substance)	Broader Than		
6.2.1	Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water	Safely managed	Safety precautions management (procedure)	Narrower Than		
		Sanitation services	Access to toileting facilities (observable entity)	Narrower Than		
		Handwashing facility	Handwashing station	Narrower Than		
		Using hand washing soap and water	Ability to wash hands with soap and water (observable entity)	Narrower Than		
		Using safely managed sanitation services	Adequate sanitation (finding)	Broader Than		
6.3.1	Proportion of domestic and industrial	Wastewater	Waste water (substance)	Direct Match		

Table 2 (continued) Final Mapping Results between UN Sustainability Concepts, SNOMED CT, and ICNP.

	UN Sustainability Goal	Extracted Concepts	SNOMED CT Mapping	SNOMED CT Cardinality	ICNP Mapping	ICNP Cardinality
	wastewater flows safely treated	Domestic wastewater	Waste water (substance)	Broader Than		
		Industrial wastewater	Waste water (substance)	Broader Than		
6.a.1	Amount of water- and sanitation-related official development assistance that is part of a government coordinated spending plan	Water	Water (substance)	Direct Match		
		Sanitation	Sanitation finding (finding)	Broader Than		
		Water and sanitation management	Provision of adequate water supply (procedure)	Narrower Than		
6.b.1	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	Water	Water (substance)	Direct Match		
		Sanitation	Sanitation finding (finding)	Broader Than		
		Water and sanitation management	Provision of adequate water supply (procedure)	Narrower Than		
		Community engagement	No Match	No Match		
7.1.2	Proportion of population with primary reliance on clean fuels and technology	Reliance on reliable modern technology and fuels	Fuel (substance)	Broader Than		
11.6.2	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	Fine particulate matter	Particulate matter inhalation injury (disorder)	Narrower than		
		Cities	City environment (environment)	Direct Match		
		Mean level	Mean (qualifier value)	Direct match		
16.1.1	Number of victims of intentional homicide per 100,000 population, by sex and age	Intentional homicide	Homicide (event)	Broader than		
		Victims of intentional homicide	Victim of crime (finding)	Broader Than		

ICNP browser versus the larger cohort of concepts delivered through the SNOMED CT browser. This difference may also relate to specific nursing knowledge and interpretation of the concepts extracted from the source document (*i.e.*, nursing diagnosis versus medical diagnosis). It also demonstrates the variance in manual mapping when two browsers, with related content, are used. Overall, we found value to explore both the browsers as a mechanism to crosswalk the extracted concepts between a large interdisciplinary terminology and a nursing-specific terminology. It also highlights an opportunity to further explore the UN Global Indicator Framework for the Sustainable Development Goals and Targets, for the inclusion, comprehensiveness and interpretation of nursing care delivery.

For concepts relating to cost expenditures, affordability, and community engagement, gaps were noted and SNOMED CT did not have extensive concept representation. For example, SDG 3.9.1 evaluates the proportion of the population with large household expenditures on health as a share of total household expenditure or income. The concepts of large household expenditure and health expenditure both had no matches in SNOMED CT. These concepts require further development in SNOMED CT as they relate to broader implications of sustainability as well as topics associated with social determinants of health. For example, researchers have reported on the relationship between large out-of-pocket health expenditures, poverty [24] and poor infant and maternal outcomes [25-27]. Further, researchers have demonstrated clinicians do document concepts related to expenditure and health costs, suggesting opportunities exist to use standardized terminology thoughtfully, as a way to report on and improve patient health and equity [28].

Finally, through the mapping process, we found many concepts had narrower than and broader than matches. Several of these concepts were related to water, air and sanitation. For example, the concepts of domestic wastewater and industrial wastewater were mapped to the broader than SNOMED CT concept: Waste water (substance); household air pollution and ambient air pollution concepts were mapped to the broader than SNOMED CT concept: Air pollution (event); sanitation services was mapped to the narrower than SNOMED CT concept: Access to toileting facilities (observable entity); and using safely managed sanitation services was mapped to the broader than SNOMED CT concept: Adequate sanitation (finding). The nuance and specificity of these source concepts are lost as these direct matches do not exist in SNOMED CT. Point-of-care clinicians, such as homecare and public healthcare nurses, interact with patients and observe community settings impacted by these environmental factors (*e.g.*, household wood-burning stoves used for cooking and heating leading to the exasperation of upper respiratory conditions or having managed wastewater disposal in remote communities as a means to protect drinking water) [29-31]. Therefore, the evaluation, expansion, and inclusion of these concepts in SNOMED CT are necessary to advance the clinical reporting of these environmental and sustainability indicators.

5.2 Concept Representation for Artificial Intelligence and Data Reuse

Standardized clinical terminologies have long been used to provide data for population-based analytics, including trend analysis and public health surveillance, as well as clinical research [32]. In the context of capturing climate change impacts on health, capturing standardized environmentally-specific clinical data permits the contextualization of vast amounts of data to predict service demands and population needs during natural disasters and climate-related events, health promotion and disease prevention and benchmarking of any subsequent interventions. Researchers have also demonstrated the use of these terminologies in developing or training models based on methods broadly defined as artificial intelligence (AI) [33, 34]. SNOMED CT, for example, has been used in natural language processing tasks, utilizing machine learning methodologies to search and analyze free text clinical documentation entries [35]. Standardized clinical terminologies add to these approaches as a way of providing sharable and comparable data across settings; thus, helping to produce AI models that are transferable across settings. As environmental concepts encoded in standardized terminologies expand and ontological relationships associating these to health impacts develop, using AI methods could provide additional insights into trends in data and health conditions, as well as for predictive analytics to support better practice, research, education, and policy-level decision-making. While large-scale use of standardized clinical terminologies in advanced clinical AI applications has yet to be realized, its ability to formally represent healthcare language and its ability to be used in automatic encoding (*e.g.*, natural language processing) suggests its use will be increasingly valuable as these technologies advance [36].

6 Limitations

This study has noted limitations. While the scope of this study phase modeled a component of a concept by defining a domain type, the explication of relationships amongst the set of concepts was not completed (*e.g.*, using Unified Modeling Language to develop a conceptual model) [12]. Future researchers may wish to further develop these linkages. This study approached the extraction and mapping of environmental and sustainability health concepts from a descriptive, small-group, perspective. The intention was to begin exploring the representation of these types of concepts in two (SNOMED CT and ICNP) international standardized clinical terminologies. Ongoing work to expand, develop, and test these representations is recommended to strengthen, add rigour, and expand the conceptual nuances of this topic in these codified knowledge systems. As well, we limited our concept extraction to specific concepts associated to health and whose SDG indicator was linked to the World Health Organization. Work to expand and explore other SDG indicators for possible inclusion in clinical standardized terminologies is needed.

7 Conclusions

To track the impacts of climate change on human health and to develop climate-resilient systems able to respond to public health needs during climate-related events such as heatwaves, droughts, wildfires and floods, it is essential to have standardized data. By evaluating the representation of environmental concepts associated with health impacts, in standardized clinical terminologies, we provided a view into current content coverages as well as opportunities to expand. This study highlighted the availability, overlap, and gaps found for SDG terms in SNOMED CT and ICNP. However, future work is needed to more clearly define and model all possible environmental impacts from a One Health perspective. The availability of codified terminologies is important as it can enable clinicians, researchers and public health officials to manage vast amounts of clinical data in a way that can be easily retrieved, analyzed, related to the context in which the data was obtained, and embedded in AI applications. This permits policymakers and leaders to model demands on health services as a function of time and climate change pressures on the environment and prepares communities to adapt to these pressures whilst supporting the One Health approach.

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