

SPARCS Cluster – White Paper

Safety assessment of PARticles and Chemicals

Executive summary

SPARCS is an interdisciplinary research cluster built on existing strong research collaborations and expertise at Örebro University, Sweden, dedicated to advancing the **understanding of how particle and chemical exposures influence human health**. During the last decade, the necessity of a synergistic interconnected approach to fully understand the health consequence of particle and chemical exposure was envisioned and initiated. This inextricably linked cycle of exploring particle and chemical properties, their biological mechanisms and physiological outcome based on exposure, is repeatedly reexamined, revitalized, and further developed, and forms today the foundation of SPARCS. The Cluster is driven by research questions that emerge at the interface between societal needs and academic inquiry. By integrating expertise across exposure science, toxicology, biomedicine, materials science, chemistry, data science, and clinical specialties including pneumology and occupational and environmental medicine, SPARCS provides a coordinated scientific framework for proactive safety assessment of particles and chemicals. The Cluster bridges academia, industry, healthcare, and society to address emerging challenges related to engineered and incidental particles, chemicals and particle-associated chemicals, co-exposures, and low-dose, long-term, human-relevant exposure scenarios. Its ambition is to move beyond traditional hazard identification toward a deeper mechanistic understanding of exposure-related health effects, the development of biomarkers, and the translation of research into prevention, regulation, and safer innovations.

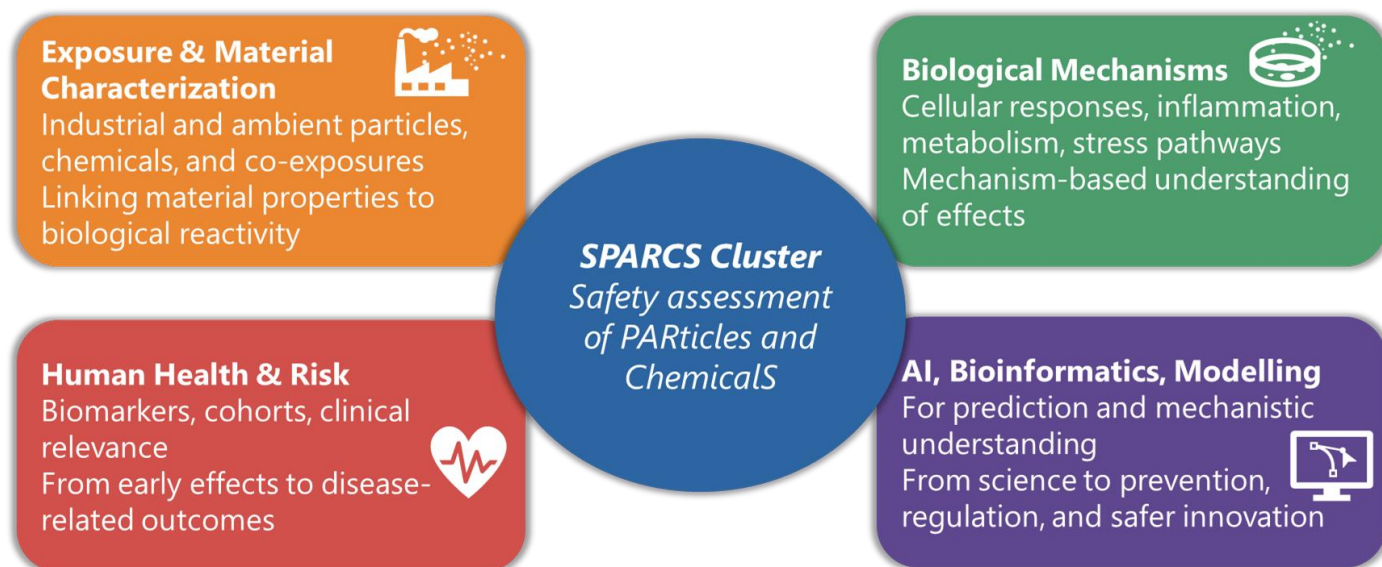


Figure 1. Conceptual framework of the SPARCS research cluster.

Why SPARCS? Societal and scientific need

Modern societies are increasingly **exposed to complex mixtures of particles and chemicals** originating from industrial processes, urban environments, consumer products, and emerging technologies. These exposures include engineered and process-generated particles, plastic and metal particles, chemical additives and transformation products, and combinations of particles and associated chemicals. They occur across industrial and occupational settings, ambient and urban environments, indoor environments, and healthcare-related contexts. Despite the scale and diversity of these exposures, current assessment approaches are often fragmented across disciplines, focused on hazard lists rather than underlying mechanisms, and only weakly



connected to relevant human health outcomes. SPARCS addresses this gap by creating an **integrated research cluster** where particle and chemical characteristics, exposure scenarios, biological responses, and health implications are studied together rather than in isolation. The Cluster aims to connect physical and chemical properties of particles and chemicals to biological responses, to move beyond descriptive toxicity testing toward understanding biological mechanisms and disease-related pathways, and to integrate exposure data with human-relevant health endpoints. Through the use of advanced bioanalytics and artificial intelligence (AI), SPARCS seeks to link complex datasets spanning materials/chemicals, life sciences, and health. In doing so, it positions research questions at the interface between societal needs and academic research, ensuring that scientific advances are aligned with pressing health and environmental challenges.

SPARCS vision and mission

The vision of SPARCS is a future in which **health risks associated with particles and chemicals are understood early, mechanistically, and in direct relation to human health and realistic exposure scenarios**. The mission of the Cluster is to integrate exposure science, material characterization, biological mechanisms, and human health research within an interdisciplinary framework that advances mechanistic health risk understanding, thereby supporting the development of safer technologies and environments.

Scientific scope of SPARCS

SPARCS focuses on the interface between particles, chemicals, and human health across a wide spectrum of exposure scenarios and material types. The Cluster addresses industrial and occupational particles, ambient and urban particle exposures, micro- and nanoscale materials, plastic particles and their associated chemicals, and co-exposures where particles and chemicals act together. Rather than treating these exposures as isolated issues, SPARCS studies them in relation to realistic exposures and **human-relevant biological outcomes**. Central to the Cluster's scientific approach is the integration of material characteristics, exposure assessment, biological mechanisms, biomarker discovery, and clinical assessment for health risk understanding, enabled by state-of-the-art AI and modelling. SPARCS emphasizes early biological mechanisms preceding adverse outcomes, seeking to observe, identify, and understand how exposures interact with cellular pathways, immune responses, metabolic regulation, and other physiological systems linked to disease susceptibility and development. This approach supports the identification of biomarkers of exposure and early biological effects, enabling earlier detection of health-relevant changes and a more nuanced understanding of long-term and low-dose effects.

Structure and core research pillars of SPARCS

SPARCS operates as a long-term collaborative research cluster built around a shared scientific identity and a light but effective coordination structure. It provides a recognizable and stable intellectual framework that brings together complementary expertise and serves as a natural home for current and future interdisciplinary projects. The Cluster creates continuity across funding cycles, strengthens scientific integration, and supports strategic development in the field of exposure science and human health. The research activities within SPARCS are structured around and enabled by the interplay of four interconnected pillars.

The **First Pillar** addresses exposure and material characterization. This includes the study of industrial and ambient exposure scenarios, advanced characterization of particles and chemicals, and the linking of material properties to biological reactivity. The integration of physical, chemical, and biological descriptors of materials allows for a more predictive understanding of which material features are most relevant for health risk outcomes.

The **Second Pillar** focuses on biological mechanisms and pathways. Research within this pillar investigates cellular and molecular response pathways, including inflammation, metabolic alterations, stress responses,



and other physiological processes relevant to disease susceptibility and development. Advanced phenotypic profiling and mechanistic studies, supported by AI and data integration approaches, are used to identify patterns of response and biomarkers that reflect early biological effects of exposure.

The **Third Pillar** addresses human health and risk outcomes. SPARCS builds on strong occupational and environmental cohorts, which represent a major strength of the Cluster, and integrates clinical research to ensure relevance to human disease. By translating mechanistic insights into health-related endpoints, this pillar aims to move from the identification of biological effects toward a more comprehensive understanding of health risks. Biomarkers identified in experimental studies are evaluated in human populations, supporting the connection between exposure, early biological changes, and potential disease development.

The **Fourth Pillar** addresses data integration and translation. The focus is on implementing and further developing methods to build and apply integrative mechanistic/AI hybrid models, to support understanding, monitoring and predicting effects of particles and chemicals on the levels of molecular mechanism, cellular and higher-level system, and human health. This will be achieved by addressing standard biomarker and biosignature screening methodology as well as advanced systems biological modelling, image analysis, representation learning, and hybrid prediction models.

Unique strengths of SPARCS

SPARCS is distinguished by the combination of **interdisciplinary depth, practical and societal relevance**. The research Cluster is a collaboration of experienced partners across multiple fields, creating a critical mass of expertise. Close collaboration with industrial and business partners provides relevance, knowledge and expertise, and access to state-of-the-art equipment, relevant materials, processes, and exposure scenarios, while established links to healthcare and hospital environments ensure clinical relevance and facilitate the translation of mechanistic findings into health-related contexts. In addition, SPARCS benefits from occupational cohorts with well-characterized exposure histories, representing a major strength for connecting exposure and mechanistic research to real human health outcomes.

SPARCS operates within a landscape of **state-of-the-art infrastructure**, including advanced exposure measurement technologies, high-resolution material and chemical characterization platforms, non-invasive biological sampling, advanced air-liquid interface exposure systems and *in vitro* models, phenomics capabilities, and omics. These are complemented by expertise in bioinformatics, mechanistic modelling, AI, and image analysis, which together enable the integration, modelling and interpretation of complex, multidimensional datasets. The use of AI enhances the Cluster's capacity to identify patterns and relationships across material properties, biological responses, and health-related endpoints that would otherwise remain hidden.

SPARCS also functions as a **unifying framework and funding umbrella** that strengthens complementarities among partners creating synergies. The Cluster integrates expertise across various scientific disciplines, while maintaining a strong connection to industrial relevance and implementation. This coordinated structure increases competitiveness in funding applications and supports the development of **ambitious, interdisciplinary projects** that would be difficult to realize within isolated research groups. The combination of different scientific disciplines enables SPARCS to address complex research questions that cannot be solved within a single discipline. It creates a research milieu in which the properties of materials and chemicals, the relevance of exposure, and the complexity of human biology are investigated together supported by state-of-the-art modelling and within a coherent and translational framework.

Finally, SPARCS provides a recognizable and **visible identity for collaborative research** in this field. Through joint publications, white papers, and coordinated dissemination activities to reach a wider audience, the



Cluster strengthens its presence at the interface between science, industry, regulators, and society, contributing to informed decision-making and the advancement of safer technologies and environments.

Education, training, and capacity building

SPARCS **contributes to education and capacity building** by strengthening teaching and training at the interface of toxicology, chemistry, materials science, data science, medicine and human health. The Cluster supports the integration of interdisciplinary knowledge into Örebro University's bachelor's and master's programs across these fields and promotes the inclusion of SPARCS-related topics in course content, project work, and thesis research. By linking research and education, SPARCS helps ensure that students encounter scientific and societal challenges associated with exposure and health risks. The Cluster also provides a collaborative framework for the **training of early-career researchers**, including PhD candidates and postdoctoral fellows. Through interdisciplinary supervision, shared methodologies, industry, and cross-disciplinary research environments, SPARCS equips young scientists with a unique skill set that spans exposure science, mechanistic biology, material characterization, and data analysis and modelling. This integrated training prepares researchers to address complex scientific questions that lie beyond the scope of single disciplines. By having business partners closely involved, many of which have a PhD degree, it also provides the students and young researchers with additional perspectives other than the basic academic track of employment. Vice versa, the close cooperation between the academy and the industry and life science sector creates added value and relevance by ensuring growth of the next generation of experts prepared to meet future needs and demands crucial to ensure high employability. Workshops, collaborative events, and thematic meetings organized within SPARCS further enhance learning and visibility, while promoting the exchange of ideas and methods across fields. In this way, SPARCS contributes to the development of the **next generation of scientists** capable of working at the complex interface between particles, chemicals, and human health, and strengthens long-term capacity in this emerging and societally important research area.

Collaboration and ecosystem

SPARCS operates as a research cluster that connects different academic disciplines, which represents an important area for continued strengthening across faculties at the Örebro University and collaborating partners. The Cluster connects industrial partners, healthcare and hospital environments, international academic collaborators, regulators, and innovation and knowledge transfer offices. Through these connections, SPARCS functions as a bridge between fundamental and applied research, and societal challenges and needs. The Cluster is also positioned to connect with broader regional, national, and European initiatives (e.g., Horizon Europe, COST), contributing to alliances and networks that address environmental and health challenges at larger scales. By functioning as a coordinated research cluster rather than a collection of isolated projects, SPARCS provides a stable and recognizable structure for long-term collaboration at Örebro University and beyond.

From knowledge to societal impact

The central ambition of SPARCS is to ensure that **research results lead to tangible societal benefits**. The Cluster aims to inform safer industrial practices, support regulatory preparedness, and contribute to the prevention of exposure-related diseases. By generating mechanistic knowledge that links material and chemical characteristics and exposure scenarios to health-relevant outcomes, SPARCS supports the development of **safer-by-design approaches** in technology and materials innovation. Close interaction with innovation offices and stakeholders facilitates the translation of scientific findings into practical applications, guidelines, and decision-support tools. In this way, SPARCS contributes not only to scientific advancement but also to healthier environments, more sustainable technologies, and improved protection of human health.