INTEGRATED ANALYSIS OF SOCIOECONOMIC INEQUALITIES IN CONTAMINATED SITES: A CASE STUDY [1]

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Abstract. The study presents a prototype framework for integrated analysis aimed at assessing socioeconomic and demographic profiles in Sites of National Interest (SIN), applied to the Sulcis-Iglesiente-Guspinese SIN site (in south-western Sardinia). The developed model combines demographic, economic, educational attainment, employment data and is structured on two territorial levels: sub-municipal, through the aggregation of enumeration areas, and supra-municipal, through clusters of municipalities, to represent different scales of pollutant exposure. The findings support the creation of spatial profiles to assist territorial planning and policymaking aimed at reducing social and health inequalities.

1. Introduction and objectives of the study

Across the world, the remediation and management of contaminated sites represent a pressing challengefor environmental policy, public health, and territorial governance. These areas often present multiple issues where ecological degradation intersects with economic stagnation and social vulnerability, thereby amplifying existing inequalities (Pasetto *et al*., 2019). Contaminated sites therefore represent contexts of particular concern for public health and social cohesion, since exposure to pollutants frequently overlaps with socio-economic disadvantage. International research on environmental justice has shown that the most vulnerable communities are often those most exposed to environmental pressures, leading to significant health inequalities (Bullard, 2000; Brulle and Pellow, 2006). In Italy, the SENTIERI epidemiological project has documented excess mortality and morbidity among populations residing in Sites of National Interest (SIN), i.e. contaminated areas designated for environmental remediation (see Section 2), with particularly severe impacts on socially disadvantaged groups (Pirastu *et al*., 2013; SENTIERI VI, 2023).

[1] This paper has been jointly written by all the authors but §1 and §3 can be attributed to Daniela Vacca, §2 to Stefano Tersigni, §4 and §5.1 to Giovanna Pala, §5 to Adriano Cabras, §5.2 and §5.3 to Enrico Olla, §6 to Luigi Minerba, §7 to all authors. We sincerely thank Dr. Francesca Abate for her valuable assistance with the textual, critical, and methodological revision of the manuscript.

Within this perspective, this study aims to develop and test a prototype analytical framework applied to contaminated territories, combining demographic, social, economic, health, and environmental data[2]. The framework is designed to provide evidence supporting institutional governance and to generate indicators useful for assessing population exposure and informing territorial planning. From a spatial standpoint, an innovative operational approach is proposed for SINs, structured as a two-level geographical framework within each site: the sub-municipal level allows detailed evaluation of local dynamics and population exposure near pollution sources, while the supra-municipal level groups municipalities by spatial proximity and demographic relevance, forming statistically robust territorial units that support health and environmental governance (Vacca *et al.*, 2025).

The analysis focuses on the Sulcis-Iglesiente-Guspinese SIN, in south-western Sardinia, a historically mining- and industry- affected area that remains characterised by strong social and environmental vulnerabilities. The results reported provide the first findings of the study, aimed at building knowledge frameworks and producing multi-thematic information profiles.

The following sections present the context of SIN, environmental justice and inequalities, geographical levels of analysis, selected indicators, case study results, and future research prospects.

2. Sites of National Interest (SIN) and their management

In Italy, SIN are severely contaminated areas whose environmental damage has a direct impact on human health and ecosystems, requiring complex and particularly costly remediation processes[3]. Their management is entrusted to the State, given the significance of the environmental issues involved and the need for centralised coordination of interventions. Pollution in SINs generally results from prolonged industrial activity, uncontrolled waste disposal and environmental accidents, often dating back to periods when environmental regulations were absent or poorly enforced. The health and environmental consequences of pollution in SINs are numerous and serious: exposure to toxic substances, through inhalation, ingestion

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[2] This contribution is part of the institutional collaboration between Istat – Central Directorate for Environmental and Territorial Statistics (DCAT) – and the Department of Medical Sciences and Public Health of the University of Cagliari. The collaboration aims to carry out study on specific territorial areas, focusing on the interactions between environmental, health and socio-economic conditions.

[3] The main contamination sources are chemical/petrochemical plants releasing hydrocarbons, metals and persistent compounds, and steel/metallurgical sites with lead, chromium, nickel, arsenic and asbestos; illegal landfills add solvents, pesticides, pharmaceuticals and emerging pollutants; mining activities, which result in heavy metals and acids due to acid drainage; abandoned military and industrial sites, where explosives, fuels, asbestos and other hazardous agents are found.

(including through the food chain) and skin contact, is associated with the onset of chronic diseases, cancers, neurological and reproductive disorders. At the same time, significant damage to natural ecosystems is observed, including biodiversity loss, water contamination, and soil fertility reduction. The economic impact is also significant: property devaluation, restrictions on land use, loss of tourist appeal and high remediation costs are reported. The complexity of SINs also depends on their territorial extent (sometimes exceeding tens or hundreds of hectares), the variety and persistence of contaminants, the depth of pollution (which can reach aquifers) and the simultaneous presence of different contaminated environmental matrices (soil, subsoil, water and sediments).

The regulatory reference for the remediation of contaminated sites is Legislative Decree No. 152 of 3 April 2006, known as the "Consolidated Environmental Act", which in Article 252 assigns to the Ministry of the Environment and Energy Security (MASE), in agreement with the Ministry of Health, responsibility for the management of SINs, identified on the basis of environmental and health criteria.

3. Environmental justice and inequalities in contaminated contexts

The exposure of resident populations to environmental pollution in contaminated areas is unevenly distributed, often along a socioeconomic gradient, resulting in higher exposure among the most vulnerable communities. This phenomenon, defined as environmental injustice, emerges from the interaction of environmental, economic and institutional factors that lead to a higher concentration of contaminated sites in socially and economically disadvantaged areas, accompanied by a reduced capacity of exposed groups (Bullard, 2000; Brulle and Pellow, 2006).

In SINs, environmental injustice is expressed in the association between greater exposure to pollutants and socio-economic and health disadvantages, particularly for low-income and less educated populations living near contaminated sites (Martuzzi *et al.*, 2010; Pasetto *et al.*, 2019). Additional vulnerability factors, such as limited mobility and restricted access to health services, increase these risks. Economically disadvantaged communities are less likely to move away from polluted areas and often live in locations with poor health and social services, hindering the early diagnosis and management of exposure-related diseases. This situation is observed in some Italian SINs, where populations living near contaminated sites exhibit higher incidence and mortality for respiratory, cardiovascular, and oncological diseases (Pirastu *et al.*, 2013). The SENTIERI VI project (2023) has systematically documented these inequalities, highlighting higher incidence and mortality for the same diseases in SINs, particularly among socially disadvantaged populations. Environmental justice also involves limited participation of local communities in decision-making processes related to remediation and environmental risk management. Decisions are often made without adequate involvement of the most exposed populations, thus reducing the possibility of influencing mitigation strategies and improving living conditions.

In the Sulcis-Iglesiente-Guspinese SIN, the communities most exposed to environmental contamination also have high levels of social deprivation and poorer health outcomes (SENTIERI VI, 2023). This SIN is among the largest and most contaminated in Italy, affected by metallurgical, mining, and other industrial activities. From an administrative-territorial perspective, the SIN includes multiple Health Districts (HDs) across three Local Health Authorities (LHAs): specifically, the Carbonia, Iglesias, and Isole Minori HDs constitute the Sulcis-Iglesiente LHA; the Guspini HD belongs to the Sanluri LHA; and the Cagliari Area Ovest HD is part of the Cagliari LHA[4].

4. Geographical level of analysis

The geographical framework adopted for the socio-economic analysis of SINs is based on a two-tiered model, designed to identify and classify the areas of influence of contaminated sites. It consists of a sub-municipal level, which allows the identification of portions of municipal territory affected by contamination and provides a fine-grained analysis of population exposure near pollution sources, and supra-municipal level, which aggregates multiple municipalities into statistically robust and coherent units, capturing broader territorial patterns and supporting institutional planning (Vacca *et al.*, 2025).

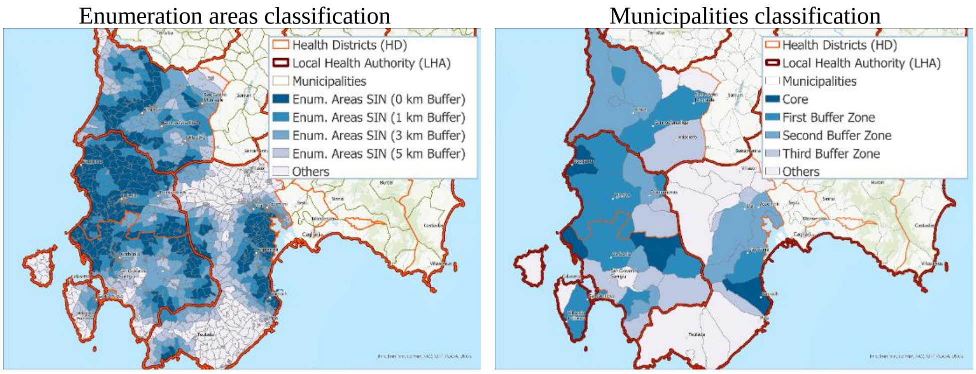
At the sub-municipal level, the territorial reference units are the 2021 Istat enumeration areas, providing the finest resolution available for the spatial interpretation of the resident population (Figure 1). To assess potential environmental impact, buffers of 0, 1, 3 and 5 km were defined around SIN perimeters. The underlying assumption is that the level of potential risk decreases with increasing distance from the contamination source. In this way, it is possible to estimate the "incidence of the population exposed to environmental risk", defined as the proportion of residents living within the buffer zones around SIN perimeter, an important indicator to assess the magnitude of the problem.

The construction of the supra-municipal level requires an additional step, based on a combined criterion of spatial proximity and demographic relevance. A municipality is included only if a certain proportion of its population resides within

[4] The Sulcis-Iglesiente LHA takes part in the One Health Citizen Science project, funded by the Ministry of Health, which assesses environmental quality, exposure, and health-social impacts in Italian SINs, promoting participation and environmental justice.

the defined buffers. Municipalities are then classified into five categories: Core (within the SIN, with at least 10% of the population), First buffer zone (from 0 to 1 km, ≥20% of the population), Second buffer zone (from 1 to 3 km, ≥30% of the population), Third buffer zone (from 3 to 5 km, ≥40% of the population) and Others municipalities (beyond 5 km). These classifications ensure consistency across governance levels (from enumeration areas to municipalities, HDs LHAs)-supporting planning and decision-making at every scale.

Figure 1 – *Sub-municipal and supra-municipal territorial level.*



Source: our elaboration on MASE and ISTAT data

5. Sources and indicators

The selection of indicators was guided by the need of building a coherent information framework, compatible with the availability of data. At the sub-municipal level, the use of enumeration areas from the 2021 Istat census allows for high spatial resolution, although the available information remains limited in scope. A more detailed and structured set of indicators, while still expandable, makes it possible to outline a profile of the analysed contexts. Among these, a key measure is the incidence of the exposed population, defined as the percentage of residents living within the SIN buffers and therefore potentially subject to environmental exposure**.** This measure provides a foundational context for interpreting the demographic and socio-economic profiles presented in the following sections, which focus on the Sulcis-Iglesiente LHA within the Sulcis-Iglesiente-Guspinese SIN.

The sub-municipal profile reveals a complex demographic structure, with notable differences across territories. In Carbonia HD, the ageing index is very high across all buffers, with a value of 306.7 in buffers 0 and 5, and reaching 362.9 in buffer 1, while the total dependency index consistently exceeds 64% (Table 1).

Table 1 – *Sub-municipal demographic profile by buffer –Sulcis-Iglesiente LHA, year 2021.*

Territories/buffer	Population	Pop_density	Families	Ageing index	Aged_depend _index	Tot_depend _index	% pop 0-14	% pop 75 +
Carbonia HD	**54,858**	**82.1**	**25,240**	**331.8**	**50.1**	**65.2**	**9.1**	**13.5**
Buffer 0	6,992	30.8	3,162	306.7	48.5	64.3	9.6	13.3
Buffer 1	15,996	116.6	7,461	362.9	51.9	66.2	8.6	13.5
Buffer 3	18,095	82.7	8,484	335.0	50.1	65.0	9.1	13.4
Buffer 5	10,353	121.0	4,556	306.7	49.8	66.1	9.8	14.0
Others	3,422		1,577	313.4	46.1	60.8	9.1	13.2
Iglesias HD	**44,687**	**73.9**	**20,568**	**294.9**	**43.2**	**57.9**	**9.3**	**12.3**
Buffer 0	3,666	9.4	1,718	301.5	43.9	58.5	9.2	11.3
Buffer 1	22,905	172.6	10,702	304.9	44.7	59.4	9.2	12.4
Buffer 3	12,695	229.1	5,851	282.4	40.6	54.9	9.3	12.2
Buffer 5	5,418	200.0	2,295	278.9	42.8	58.2	9.7	12.4
Others	3		2		-	-	-	
Isole minori HD	**19,541**	**280.8**	**9,714**	**333.1**	**51.6**	**67.1**	**9.3**	**15.4**
Buffer 0	961	274.1	440	242.2	40.4	57.0	10.6	12.8
Buffer 1	4,296	473.7	2,049	316.0	51.9	68.3	9.8	16.1
Buffer 3	5,287	200.0	2,491	363.2	52.7	67.3	8.7	14.5
Buffer 5	130	4.3	78	400.0	50.0	62.5	7.7	13.8
Others	8,867		4,656	335.4	52.1	67.7	9.3	15.8
LHA	**119,086**	**88.7**	**55,522**	**318.1**	**47.7**	**62.7**	**9.2**	**13.4**

Source: our elaboration on MASE and ISTAT data

In Iglesias HD, too, the values are high, but slightly lower: the ageing index varies from 278.9 (buffer 5) to 304.9 (buffer 1), while the total dependency index stands between 54.9% and 59.4%. The Isole Minori HD, on the other hand, shows greater variability. In buffer 3, the ageing index reaches its maximum (363.2), associated with a total dependency ratio of 67.3%, whereas in buffer 0 it drops to 242.2, indicating a younger demographic composition. Overall, these data suggest that proximity to the SIN does not entail greater demographic vulnerability, as observed differences may reflect other factors, such as settlement patterns, population density and and age structure.

At the supra-municipal level, a wider range of indicators allows for a more detailed territorial profile, although still partial. The selected indicators are distributed along two main dimensions: socio-demographic conditions, which include the age structure of the population, settlement density, natural and migratory balances and the presence of foreign citizens and economic conditions, with particular attention to the labour market and education (Table 2). The resulting profile allows identification of differences among the districts of the Sulcis-Iglesiente LHA in terms of ageing, population density, and family composition, as well as in employment opportunities and educational attainment.

These are elements which, although awaiting integration with the epidemiological profile currently being developed, already provide a valuable initial descriptive tool for understanding social inequalities and guiding interventions. The analysis of district profiles is the subject of the next paragraphs.

Table 2 – *Indicators at the supra-municipal territorial level.*

Themes	Indicators	Year	Abbreviations	Algoritm	Sources
Demography	Territorial surface	2021	Area (km2)	Area (km2)	Istat
	Population density	2024	Pop. dens.	Area (km2)/Pop.	Istat
	Resident population	2024	Population	Pop.	Istat
	Incidence of exposed population by buffer	2021	Exposure pop. Rate	Pop.in buffers/Total pop.*100	Istat
	Percentage change in resident population	2024/04	% Pop. change 24/04	Pop. 2024/Pop 2004*100-100	Istat
	Ageing index	2024	Ageing index	Pop. 65+ /Pop. 0-14*100	Istat
	Percentage of population aged 85 and over	2024	% Pop. 85+	Pop. 85+/Total pop.*100	Istat
	Natural rate per 1000	2024	Natural rate	Birth-death/Pop.*100	Istat
	Migration rate per 1000	2024	Migration rate	(Immigrants - Emigrants) / Pop.*1000	Istat
Economy	Declared income per capita (MEF)	2023	Income p.capita	Icome/Pop.	MEF
	Density of local units per 1000 inh.	2021	LU/1,000 inh.	Local unit/pop.*1000	Istat
	Density of employees in local units total	2021	Emp. in LU / 1,000 inh.	Emp. In local unit/pop.1000	Istat
	Density of local units per 1000 inh., Industry	2021	LU 1,000 – Industry	Industry Local unit/pop.*1000	Istat
	Density of employees in local units per 1000 inh., Industry	2021	Emp. in LU/ 1,000 – Ind.	Industry emp. In local unit/pop.*1000	Istat
Labour and Education	% population aged 25-64 with low education levels	2022	% 25–64 low edu.	Pop. 25–64 with ≤ lower sec./Pop. 25–64*100	Istat
	% population aged 25-64 with upper secondary education diploma	2022	% 25–64 with diploma	Pop. 25-64 with sec. diploma/Pop. 25-64*100	Istat
	% population aged 25-64 with tertiary education diploma	2022	% 25–64 with tertiary edu.	Pop. 25–64 with tertiary/Pop. 25–64*100	Istat
	Employment rate 25-64 years	2022	Employment rate 25–64	Employed 25-64/Pop. 25-64*100	Istat
	Activity rate 25-64 years	2022	Activity rate 25–64	Labor force 25-64/Pop. 25-64*100	Istat
	Unemployment rate 25-64 years	2002	Unemployment rate 25–64	Unemployed 25-64/Labor force 25-64*100	Istat

Source: our elaboration on MASE and ISTAT data

5.1 Carbonia Health District

The Carbonia HD covers an area of 725 km^2 and has a population density of 73.3 inhabitants per km^2. As of 2024, the area has a population of 53,103, 69% of whom are concentrated in the Core and First zones (Table 3). In the Core area, almost 67% of residents live near polluted sites (exposure pop. Rate 2021). Compared to the district average, the Core and Third areas are demographically stable, as evidenced in particular by the lower values of the 2024/2004 population change and the ageing index. From an economic and income point of view, the first two areas have the best profile, although the Core area is characterized by a robust economic structure, accompanied by the highest declared income in the district.

Employment and education data are also better than the district as a whole, although the Core area is weak in terms of tertiary education attainment. The Second buffer zone, on the other hand, has vulnerable socio-demographic and economic conditions, such as high environmental exposure, marked population decline, high ageing, low income, weak employment and critical educational levels, making it one of the most fragile and vulnerable areas of the system.

Table 3 – *Supra-municipal demographic profile by buffer – Carbonia HD.*

Indicators	Core	First buffer zone	Second buffer Zone	Third buffer zone	Others	Carbonia HD	Sardinia
Popolazione e territorio							
Area (km2)	124	238	70	262	31	725	24,099
Pop. dens. 2024	62.5	121.6	46.2	46.8	31.7	73.3	64.8
Population 2024	7,742	28,880	3,235	12,263	983	53,103	1,561,339
Demography, Economy, Labour and Education							
Exposure pop. rate 2021	66.9	55.6	86.5	80.2	100.0	65.6	38.0
% Pop. change 24/04	-11.2	-14.7	-13.1	-9.7	-11.8	-13.0	-4.7
Ageing index	348	414	400	363	422	390	281
% Pop. 85+	4.0	4.3	4.6	4.3	5.0	4.3	4.2
Natural rate	-0.9	-1.1	-1.3	-0.9	-0.7	-1.0	-0.7
Migration rate	-0.2	-0.4	0.2	0.1	0.2	-0.2	0.1
Income p.c. 2023	13,322	12,945	9,602	11,126	10,571	12,335	13,668
LU / 1,000 inh. 2021	52.7	58.7	39.8	49.3	38.2	54.1	76.1
Emp. in LU / 1,000 inh.	381.3	175.3	70.8	130.7	83.0	186.9	223.7
LU / 1,000 – Ind. 2021	5.6	2.9	2.4	4.1	4.9	3.6	5.2
Emp. in LU/ 1,000 – Ind.	198.0	12.8	5.7	15.2	18.4	39.9	26.4
% 25–64 low edu.	50.2	44.4	58.7	53.6	56.5	48.5	42.6
% 25–64 with diploma	39.3	41.3	33.1	36.0	33.3	39.1	38.2
% 25–64 with tertiary edu.	10.5	14.4	8.2	10.4	10.2	12.4	19.1
Employment rate 25–64	58.1	58.2	52.3	55.9	55.6	57.3	62.6
Activity rate 25–64	66.3	67.2	62.0	64.8	66.4	66.2	71.5
Unemployment rate 25–64	12.3	13.4	15.8	13.7	16.4	13.5	12.5

Source: our elaboration on MASE and ISTAT data

5.2 Iglesias Health District

The Iglesias HD covers an area of 605 km^2 and has a population density of 71.5 inhabitants per km^2 (Table 4). As of 2024, the area has 43,282 inhabitants, of whom almost 76% are concentrated in the Core and First zones. In the Core area, approximately 90% of the population lives in the area closest to the contamination sources (exposure pop. rate 2021). Compared to the district average, from a demographic point of view, the Third buffer zone shows relatively stable demographic indicators, with lower indicator values and a migration balance in line with the district average. The Core area presents critical demographic challenges, despite a positive migration balance. From an income point of view, the highest value is found in the First buffer zone with 13,268 euros. The Core and First areas have the most consistent productive structures in terms of the presence of local units and employees per 1,000 inhabitants, while the industrial structure is stronger in the Second and Third buffer zones. The district generally shows low levels of education, particularly in the Third buffer zone, characterised by a high proportion of people aged 20-64 with only middle school and a relatively low percentage of high school and university graduates. Employment performance is also weaker in the Core area, with an activity rate of 63.5%, employment at 55.2% and unemployment at 13.1%

Table 4 – *Supra-municipal demographic profile by buffer – Iglesias HD.*

Indicators	Core	First buffer zone	Second buffer Zone	Third buffer zone	Others	Iglesias HD	Sardinia
Population and territory							
Area (km2)	48	364	81	112		605	24,099
Pop. dens. 2024	21.0	87.1	71.1	43.0		71.5	64.8
Population 2024	1,015	31,737	5,732	4,798		43,282	1,561,339
Demography, Economy, Labour and Education							
Exposure pop. rate 2021	89.3	72.6	84.7	99.9		77.6	38.0
% Pop. change 24/04	-9.9	-12.3	-12.0	-8.6		-11.8	-4.7
Ageing index	355.9	363	332	311		352	281
% Pop. 85+	4.6	4.2	4.0	4.0		4.2	4.2
Natural rate	-1.3	-1.0	-0.7	-0.3		-0.9	-0.7
Migration rate	0.2	-0.1	-0.5	-0.2		-0.2	0.1
Income p.c. 2023	10,922	13,268	12,010	11,855		12,890	13,668
LU / 1,000 inh. 2021	66.5	57.7	52.9	47.7		56.2	76.1
Emp. in LU / 1,000 inh.	190.6	156.1	177.9	107.9		154.4	223.7
LU / 1,000 – Ind. 2021	4.7	4.2	5.6	6.1		4.6	5.2
Emp. in LU/ 1,000 – Ind.	15.7	19.6	32.8	23.9		21.7	26.4
% 25–64 low edu.	51.3	42.7	50.7	56.4		45.5	42.6
% 25–64 with diploma	38.7	41.7	36.9	32.9		40.0	38.2
% 25–64 with tertiary edu.	10.0	15.6	12.4	10.7		14.5	19.1
Employment rate 25–64	52.9	58.5	59.4	58.8		58.6	62.6
Activity rate 25–64	61.7	68.4	68.1	67.7		68.1	71.5
Unemployment rate 25–64	14.3	14.4	12.9	13.2		14.1	12.5

Source: our elaboration on MASE and ISTAT data

5.3 *Isole Minori Health District*

The Isole Minori HD covers an area of 170 km^2 and has a population density of 118.9 inhabitants per km². As of December 31, 2024, the area had 10,451 residents, with almost 55% concentrated in the First buffer zone. This buffer zone is the only part of the health district to have a population, and it is the smallest of the three Health Districts within the Sulcis-Iglesiente LHA. In the First buffer zone, almost 49% of the population lives within 1 km of polluted sites (exposure pop. rate 2021). The demographic profile is relatively critical, marked by a 10.6% population decline over the last two decades, a high proportion of elderly residents (85 years and older) and negative natural and migratory rates. Socio-economic conditions are also fragile, with an average per capita income of €11,711 and a weaker industrial structure compared to the rest of the area and Sardinia. Education and employment indicators highlight a high share of low educational attainment (46.2% with at most middle school diploma), few high school and university graduates, an activity rate of 63.5%, employment at 55.2%, and unemployment at 13.1%.

Table 5 – *Supra-municipal demographic profile by buffer – Isole Minori HD.*

Indicators	Core	First buffer zone	Second buffer Zone	Third buffer zone	Others	Isole HD	Sardinia
Population and territory							
Area (km2)		88			82	170	24,099
Pop. dens. 2024		118.9			105.5	112.4	64.8
Population 2024		10,451			8,666	19,117	1,561,339
Demography, Economy, Labour and Education							
Exposure pop. rate 2021		48.9			100.0	71.9	38.0
% Pop. change 24/04		10.6			6.5	8.8	4.7
Ageing index		382.0			378.4	380.4	281.4
% Pop. 85+		5.0			5.1	5.1	4.2
Natural rate		1.2			1.0	1.1	0.7
Migration rate		0.2			0.1	0.1	0.1
Income p.c. 2023		11,711			13,437	12,491	13,668
LU / 1,000 inh. 2021		56.3			73.9	64.2	76.1
Emp. in LU / 1,000 inh.		151.8			175.6	162.5	223.7
LU / 1,000 – Ind. 2021		4.2			5.7	4.9	5.2
Emp. in LU/ 1,000 – Ind.		13.1			17.6	15.1	26.4
% 25–64 low edu.		46.2			35.9	41.6	42.6
% 25–64 with diploma		38.8			47.2	42.5	38.2
% 25–64 with tertiary edu.		15.0			16.9	15.9	19.1
Employment rate 25–64		55.2			57.4	56.2	62.6
Activity rate 25–64		63.5			66.2	64.7	71.5
Unemployment rate 25–64		13.1			13.4	13.3	12.5

Source: our elaboration on MASE and ISTAT data

6. Research Prospects

The integration of epidemiological data is essential for a comprehensive assessment of environmental and health risks. In particular, the joint analysis of mortality and hospitalisations enables the identification of health outcomes associated with prolonged environmental exposure, providing a robust basis for regional health planning (SENTIERI VI, 2023). In the Sulcis-Iglesiente-Guspinese SIN, the data indicate a critical health situation: overall mortality, measured using Standardized Mortality Ratios (SMR)[5], is slightly higher than expected for both sexes (101 men, 103 women, Table 6). The most significant excess concerns respiratory diseases (SMR 147 men, 123 women), likely reflecting local exposures, including air pollution, fine particulate, and legacy industrial activities. Hospitalization data show stable rates for all natural causes, with a Standardized Hospitalization Ratio (SHR)[6] of 101 in men and 99 in women; however, significant

[5] SMR is calculated as the ratio of observed to expected deaths in population, adjusted for age and sex.
[6] SHR is calculated as the ratio of observed to expected hospitalizations in the population, adjusted for age and sex.

excesses are observed for respiratory diseases (SHR 111 in men and 109 in women) and urinary diseases (SHR 118 in men and 121 in women). Combining these indicators with socio-demographic information yields a multidimensional picture of risk, linking environmental exposures, health inequalities and social vulnerabilities, reinforcing the need for integrated tools for the management of contaminated areas (SENTIERI VI, 2023). The future goal is to update and integrate these epidemiological data with the new supra-municipal geography based on clusters of municipalities, in order to monitor exposure and health outcomes, supporting health and environmental planning, facilitating targeted interventions and coordinated management of areas at greatest risk.

Table 6 – *Mortality and Hospitalization in Sulcis-Iglesiente-Guspinese SIN- SMR and SHR, value for 100,000 inhabitants. Years 2013-2017.*

Mortality	**Male**		**Female**	
	OBS	**SMR**	**OBS**	**SMR**
General mortality	6,344	101 (99-103)	5,956	103 (100-105)
Diseases of the respiratory system	652	147 (138-157)	420	123 (114-134)
Hospitalization	**Male**		**Female**	
	OBS	**SHR**	**OBS**	**SHR**
All natural causes (excluding complications of pregnancy, childbirth, and the puerperium)	40,200	101(100-102)	39,620	99 (99-100)
Diseases of the respiratory system	6,228	111 (108-113)	4,840	109 (107-112)
Diseases of the urinary system	3,035	118 (114-121)	2,272	121 (117-126)

Source: SENTIERI VI Working Group, 2023

7. Conclusions

The adoption of a two-tiered geographical framework for the analysis of SINs allows for integrated and multi-thematic analysis, particularly useful for describing and assessing socio-economic, environmental and health inequalities in contaminated contexts. The application of this empirical approach to the Sulcis-Iglesiente-Guspinese SIN enabled the construction of fine-scale territorial profiles and the estimation of the environmental hazard gradient for the resident population.

It is also necessary to complete the information framework with additional epidemiological data and indicators of socio-economic deprivation in order to build an even more comprehensive and multidimensional model. This integrated approach will promote a better understanding of environmental and health inequalities and represent a transferable model for other SINs at the national level.

Future work will focus on developing integrated territorial information systems, updating epidemiological indicators, and promoting institutional alliances for participatory governance of at-risk territories.

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