10 Soils in Urban Areas

Franco Ajmone Marsan and Ermanno Zanini

10.1 Introduction

Soil is a crucial compartment of the urban ecosystem and, although frequently overlooked, it contributes, directly or indirectly, to the general quality of life of the citizens (Bonaiuto et al. 2003; de Hollander and Staatsen 2003; van Kamp et al. 2003; Chiesura 2004). With respect to natural or agricultural soils, in urban areas, the soil establishes distinctive relationships in space and time with the other components of the ecosystem, viz. air, water, biota and, most of all, humans. On the one hand, as an element of the landscape, it provides esthetical and recreational functions in parks and gardens and contributes to the preservation of biodiversity; on the other hand, urban soils often undergo rapid use changes which entail mixing with other anthropogenic materials that may modify its functioning and often end up with extensive sealing (Morel et al. 2005) (Fig. 10.1).

In addition, anthropic activities, such as traffic, heating, industry and waste disposal, often result in soil pollution (Ajmone Marsan and Biasioli 2010). Therefore, most of the major threats to soil conservation listed by the European Commission (2006) are active in urban environments.

The concern for soil quality is particularly strong due to the proximity of urban soils to humans which could enhance the effects of poor soil management. In 2010, more than 50 % of humankind, that is, around 3.5 billion people, was living in urban areas (Table 10.1). In Italy, this proportion had already been reached in 1950, and by 2010, more than 41 million people out of 61 million were concentrated in urban agglomerations (United Nations 2010).

Urban soils are considered in classification systems as *anthropogenic* or *technogenic* soils (Dudal 2004), but no specific categories are provided based on their location. Rather, it is the composition which guides their characterization, so the urban qualifier does not necessarily coincide with techno- or anthropogenic and vice versa. The World Reference Base includes them in the Group of the Technosols, whose soil properties are dominated by technical human activity in the form of artefacts or geomembrane or a pavement; subgroups are defined as either Ekranic (sealed), Linic (lined), Urbic (rubbly), Spolic (industrial wastes), or Garbic (organic wastes) (Rossiter 2007). An overview of the classification systems of urban soils was provided by (Lehmann and Stahr 2007). The International Committee for Anthropogenic Soils (ICOMANTH) (Galbraith 2004) is working towards the definition of specific classes for urban soils in the USDA classification system.

Despite this taxonomic endeavour, the application to urban soils has been sporadic as very few systematic studies have been conducted if compared with the knowledge that has been accumulating about agricultural, forestry and natural soils. As a matter of fact, the usual approach to soil survey and investigation, that is, used in open, non-urban areas cannot be applied due to a number of problems that complicate the inference process which is commonly used for rural areas.

A major drawback in urban soil studies is the high spatial variability of their chemical, physical and biological properties both in the horizontal and in the vertical direction. Recent research (Madrid et al. 2006; Wei and Yang 2010) reported a very high variability in some urban soils, even in the short range, not only of the general soil-quality indicators such as pH or cation-exchange capacity but also of the pollutants. Intense anthropogenic activity in the city environment adds to the natural spatial variability thus intensifying soil heterogeneity. Excavation, redistribution and mixing of the soil matrix and addition of extraneous materials are frequent in the urban and peri-urban areas as a consequence of the intensive use of the territory and the rapid land-use changes. Soil-forming processes are deeply modified or interrupted when sealing of the surface occurs and are partially resumed when built areas are dismantled.

F. Ajmone Marsan · E. Zanini (✉)
Università di Torino—DIVAPRA Chimica agraria e pedologia,
Via Leonardo da Vinci, 44, 10095, Grugliasco, TO, Italy
e-mail: ermanno.zanini@unito.it

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Fig. 10.1 Excavation of a soil for building a parking lot exposed a sealed soil

Table 10.1 Percentage of population residing in urban areas by major area and in Italy, 1950–2050 (United Nations 2010)

	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050
World	28.8	33.0	36.1	38.9	42.6	46.4	50.5	54.4	59.0	63.9	68.7
More developed regions	52.6	58.8	64.7	68.3	70.8	72.7	75.2	77.9	80.9	83.7	86.2
Less developed regions	17.6	21.8	25.3	29.4	34.8	40.0	45.1	49.8	55.0	60.5	65.9
Italy	*54.1*	*59.4*	*64.3*	*66.6*	*66.7*	*67.2*	*68.4*	*70.9*	*74.6*	*78.1*	*81.2*

Soil properties are then the result of complex processes that might be very far from the natural, more predictable ones (Fig. 10.2).

Another obvious feature of the built environment is the fragmented distribution of the areas where the soil is exposed because a large proportion of the surface of an urban area is sealed by constructions or roads. These areas have very variable size and are usually non-randomly distributed. This adds a constraint to the sampling design which would then be limited to the exposed surfaces and not necessarily representative of the entire urban area. The sampling coverage can be further distorted by the limited accessibility of the areas where soils can be studied for various reasons: private property, construction areas, no-traffic areas. In conclusion, the possibility of applying geostatistical techniques for the interpretation and mapping of urban soil data (Cattle et al. 2002; Wong et al. 2006) is very limited as they very rarely

Fig. 10.2 Soil compaction under a walking path in a public park

Table 10.2 Concentration of metals and other toxic elements in the soils of Italian cities

City	Soil type/use	Number of samples	Element	Concentration (mg/kg)			Reference
				Min	Max	Mean or median	
Rome	Park		lead	37	1357	330.8	Angelone et al. (1995)
			cadmium	0.03	1.9	0.311	
Naples	Park and garden		copper			20.1	Basile et al. (1974)
			lead			67.4	
			zinc			57.2	
Turin	Urban	30	arsenic	8	21	11	Biasioli and Ajmone Marsan (2007)
			chromium	140	480	233	
			cobalt	14	190	27	
			copper	33	290	94	
			lead	42	490	124	
			mercury	0.1	4.4	0.9	
			nickel	91	350	164	
			silver	0.1	29	2.5	
			zinc	30	460	170	
			cadmium	0.2	8.1	1.3	
Turin	Various	123	chromium	65	930	172	Biasioli et al. (2007)
			copper	15	349	87	
			lead	24	905	143	
			nickel	77	790	188	
			zinc	53	553	165	
Turin	Parks, roadsides	70	chromium	67	870	191	Biasioli et.al. (2006)
			copper	34	283	90	
			lead	31	870	149	
			nickel	103	790	209	
			zinc	78	545	183	
Naples	Flower beds	207	cadmium	0.1	6.9	0.6	Cicchella et al. (2003)
			chromium	0.8	149	15	
			lead	20	2052	204	
			palladium	8	110	12.7	
			platinum	1.6	52	4.2	
			zinc	35	3211	223	
Rome	Undisturbed	111	platinum(ng/g)	7	19.4	11.2	Cinti et al. (2002)
Naples		173	chromium	1.7	73	11	Imperato et al. (2003)
			copper	6.2	286	74	
			lead	4	3420	262	
			zinc	30	2550	251	

(continued)

Table 10.2 (continued)

City	Soil type/use	Number of samples	Element	Concentration (mg/kg)			Reference
				Min	Max	Mean or median	
Turin	Urban	25	mercury	0.21	0.9	0.47	Rodrigues et al. (2006)
Palermo	Green areas	70	chromium	12	100	34	Salvagio Manta et al. (2002)
			cobalt	1.5	14.8	5.2	
			copper	10	344	63	
			lead	57	682	202	
			manganese	142	1241	519	
			mercury	0.04	6.96	0.68	
			nickel	7	38.6	17.8	
			vanadium	21	124	54	
			zinc	52	433	138	
			cadmium	0.27	1.86	0.68	
Pisa, Livorno, Carrara	Parks, playgrounds, roadside, allotments	29	lead	30	1025	122	Bretzel and Calderisi (2006)
			zinc	45	337	107	
			copper	28	305	62	
			nickel	28	112	55	
Padua	urban	30	platinum (ng/g)	0.1	5.7	0.9	Spaziani et al. (2008)
Rome		16		7.0	19.4	10.6	
Viterbo		31		4.9	20.0	9.6	
Naples		15		4.7	14.3	8.4	
Palermo		14		0.2	3.9	0.7	

possess the qualities of a regionalized variable, viz. a continuous variation in space and some structure in its variation. An urban area is therefore a place where it is most unlikely that soil data exhibit some spatial dependence, that is, *where its values at locations close together are more similar than those further apart* (Webster and Oliver 1990).

All these limitations have certainly hindered the interest in the genesis and properties of urban soils except for those aspects more strictly related with their environmental quality: pollution and the transfer of pollutants to the adjoining compartments. Heavy metals and metalloids (Table 10.2) were in particular investigated in view of the numerous source of pollution within urban agglomerations.

10.2 Studies on the Environmental Quality of Urban Soils

Early studies in the urban area of Turin (Sapetti et al. 1974) had observed high Pb contamination in the urban and peri-urban zone. In the same year, Basile et al. (1974) had reported elevated concentrations of Cu, Pb and Zn in soils surrounding industrial plants and streets of Napoli. Analogously, Zanini et al. (1993) and Bonifacio et al. (1995) had observed high levels of Pb in the soils of an urban park in the city of Torino.

A first systematic study of heavy metals in soils was carried out in the city of Palermo (Salvagio Manta et al. 2002) where 70 samples were collected from the topsoil of green areas and parks. The results indicated that Pb, Zn, Cu, Sb and Hg were good tracers of anthropic pollution, whereas Mn, Ni, Co, Cr, V and Cd were inherited from the parent material. Vehicular traffic was the main source of diffuse pollution with the contribution of point sources of contamination. For the same city, Orecchio (2010) reported that the most abundant polycyclic aromatic hydrocarbons in the soils of the botanic garden were benzo[a]pyrene, benzo[b]fluoranthene, perylene, chrysene, fluoranthene and pyrene. The sum of the concentrations of 23 compounds, ΣPAHs, ranged from 947 to 18,072 µg/kg and were 2–3 times higher than the other urban soils and about 20 times higher than that of rural sampling locations.

Imperato and co-workers (2003) investigated the concentrations and chemical forms of Cu, Cr, Pb and Zn in the surface and sub-surface soils of gardens, parks, roadside fields and industrial sites of Naples and compared their results with historical data. They found that the soils have a mainly neutral or slightly basic pH, due to the presence of carbonates and that a coarse texture prevails. Copper, Pb and Zn largely exceeded the legislative limits for contamination, and Zn, in particular, resulted to have the most liable forms. Their concentrations had greatly increased since a study carried out in 1974, with higher accumulation in soils from roadsides thus indicating the vehicular traffic as the main source of these pollutants.

In a study that investigated specifically the soils within a former steel plant in the outskirts of Napoli, Adamo et al. (2002) found that disturbance of the soil profile by the industrial activities had been prominent due to mixing with extraneous materials. The contents of Cu, Co, Cr, Pb, Zn and Ni were above the legislation threshold, and their chemical speciation indicated that Cu and Zn were present in readily available forms. These Authors also observed some translocation of metals along the profile, associated with fine particles.

These results were confirmed by a similar study in the same location (Tarzia et al. 2002) that explored the industrial site at depth down to 5 m. By using Pb isotopes, it was observed an anthropogenic pollution together with a significant natural contribution from hydrothermal solutions of volcanic origin. This would have prevented any effective remediation action.

In Caserta, a study of the soils of the municipality reports high concentrations of Cu, Pb and Zn, as in Naples, together with high Sb and Hg, in the most densely populated and industrialized zone (Vitrone 2003).

These results for the Campania region were later confirmed by an extensive geochemical investigation by Cicchella et al. (2008). They analysed approximately 2000 topsoil samples from the urban areas of Avellino, Benevento, Caserta, Napoli, Salerno for 40 elements. These Authors found a positive correlation between high values of toxic elements (Sb, Cd, Hg, Pd, Pb, Pt, Cu, Zn) and the most densely populated areas, the high traffic flows, and with industrial settlements. By the use of isotopic data, it was possible to attribute the high concentrations of Pb in soils to the high traffic flows.

Twenty-one urban soils were sampled in the city of Ancona and its surroundings (Businelli et al. 2009). All the soils were calcareous—pH ranging from 7.9 to 8.4—and with a texture ranging from clay loam to sandy loam. The cation-exchange capacity varied from 7.4 to 35.7 $\mathrm{cmol}_{(+)}\ \mathrm{kg}^{-1}$, and the organic carbon (OC) from 17.6 to 88.5 $\mathrm{g\ kg}^{-1}$. The concentrations of heavy metal were compared with the limits established by the Italian Law (D. Lgs 152/2006) for public and private parks, gardens and residential areas. Copper, Cd and Cr concentrations were below the limits in all sites while Zn, Pb and Ni concentrations were found to be above the limits in 67, 29 and 5 % of the examined sites, respectively (Fig. 10.3).

Fig. 10.3 Soil excavation, transport and re-distribution is typical of an urban setting

A total of 29 samples were collected in the towns of Pisa, Livorno and Carrara in public parks, playground areas, roadsides and allotments (Bretzel and Calderisi 2006). The soil properties were very variable except for a pH which was always sub-alkaline. Among the metals analysed, lead showed the highest content and it was found in all roadside soils. Lead and zinc were correlated in all urban soils, suggesting a common origin of the two metals. The concentrations found by these authors, however, exceeded the legislative limits for contaminated soils except in few samples.

In the city of Roma a survey of platinum concentrations in urban and rural soils was conducted on the suspicion that catalytic converters of cars could have released this element in the environment and finally in the soils (Cinti et al. 2002). The Authors compared results of 2001 analyses with those obtained in 1992 and suggested that a possible increase in Pt concentration was underway. In addition, they observed a decrease in the concentration of Pb and attributed it to the phasing out of leaded gasoline.

Angelone et al. (2002) determined the concentration of Cd, Cu, Hg, Pb, Zn and Pt in the soils of the urban area of Naples. Their results indicated that Pb (mean 71, range 19–318 mg/kg), and Pt (mean 8.5, range <1–13.8 ng/g) concentrations were comparable with those found in other Italian urban soils while Zn, Cu, Cd and Hg were close to unpolluted soils. The relatively high concentration of Pb suggested that the main pollution source could be the vehicular emissions.

Similarly, Cicchella et al. (2003) analysed 195 urban and non-urban soils of the city of Naples for Pt and Pd. They found a large number of samples from the urban area with anomalous concentration of Pt (>6 μg/kg) and Pd (>17 μg/kg) and correlated those values with the major traffic flows.

More recently, Spaziani et al. (2008) reported the results of a study of platinum distribution in urban soils and dusts of five cities, from northern Padua, central (Rome and Viterbo) and southern (Naples and Palermo) Italy. They observed an enrichment in urban soils, with concentration ranges of 0.1–5.7 ng/g in Padua, 7–19.4 ng/g in Rome, 4.9–20 ng/g in Viterbo, 4.7–14.3 ng/g in Naples and 0.2–3.9 ng/g in Palermo. These results were related to vehicular traffic, because the concentrations decreased with the distance from the roads.

A comprehensive amount of data is available for the city of Turin. In 2006, Biasioli and co-workers compared soils within the city with those in the surrounding rural area. They observed that city soils had a higher pH (7.2) than the rural soils (5.6) and attributed this to the incorporation of extraneous materials such as bricks and construction debris that could increase the pH. This could also have influenced the particle size distribution as urban soils which show a coarser texture with respect to the surrounding area. The mean values of OC content are similar in urban and rural samples most probably for the low content of the latter.

While 58, 49 and 27 % of the urban soils were above the legislation limit for Pb, Zn and Cu, respectively, none of the rural samples was above the limit for these elements. Although Ni and Cr have a high natural background in the area, the difference between urban and rural shows a considerable contamination in the city soils. Ordering the samples with increasing distance from the city, an abrupt division between urban and rural soils was evident for Pb, Zn and Cu. The transport of pollutants from the city to the surrounding areas seems to be very low, as no trends with the distance were observed (Fig. 10.4).

Further investigations on Turin soils (Biasioli et al. 2007) confirmed that Pb, Zn and Cu are effective tracer of urban pollution while the association of Ni and Cr is due to the mineral composition of the substrate which is rich in serpentinitic minerals. In addition, the comparison of soil properties and metal content in the upper (0–10 cm) and lower (10–20 cm) layers clearly showed that the soil mixing and perturbation was such that no vertical trend was identified, in line with the expected high spatial variability of these soils.

The data of Turin were compared with those of Sevilla (Spain) and Ljubljana (Slovenia) and revealed that, regardless of the geographical location, climate and size of the urban areas, the *urban* factor—type and intensity of emissions and human influence on soils—is dominant in determining environmental quality of the urban soils.

Fig. 10.4 A mixture of various materials, including soil

A study on Hg concentration in the soils of the parks of five European cities (Rodrigues et al. 2006) reported a median value for Turin of 0.48 mg/kg of mercury in the topsoil but once again highlighted the high variability of concentrations both within each park and between cities. Short-range variability was found to be up to an order of magnitude over the distance of only a few 10 m.

The same variability was documented by a study on PAH contamination (Morillo et al. 2007). The soils in Turin had a concentration of PAH (ΣPAH) ranging between 148 and 3410 mg kg^{-1}, and only one sample could be considered as *non-contaminated*. The three most abundant PAHs were phenanthrene, fluoranthene and pyrene, and this, together with some molecular indices based on ratios of selected PAHs, suggested that the source of these pollutants was mainly motor vehicle exhausts.

A specific investigation on the soils of the urban parks of Turin for a broader variety of contaminants (Biasioli and Ajmone-Marsan 2007) revealed that the average contents of Co, Cr, Ni, Pb, Sn and Zn were above the legislation limits, but all thresholds were exceeded at least once for all the elements analysed except for Sb and Se. In particular, all the samples were above the limits for Sn, in 97 and 93 % of the samples for Cr and Ni, 67 and 53 % for Co and Zn, 37 % for Pb and V, 20 % for Cu, 13 % for Cd and Hg, and 3 % for As and Tl. The legislative limits were frequently exceeded also for the organic contaminants, and this was especially true for the most toxic molecule such as benzo[a]pyrene, indeno[1,2,3]pyrene, PCBs and PCDDs/DFs.

The high toxicity of the contaminants found in urban parks, where the proximity to humans is very high, enhance the concern for human health and reflects the environmental role played by soils in urban agglomerations.

10.3 Conclusions

A wide variety of properties is observed in the urban soils of Italy which make them a unique ecosystem, most often very different from the soils of the surrounding rural areas. The anthropogenic factor seems to prevail, in most cases, over the other factors of soil formation. This brings about an abnormal spatial variability of the soil characteristics and indicates pollution as the most common unifying property. Under these conditions, it appears inadequate or ineffective to use the traditional tools for the classification of soils as no useful information can be obtained. Land-use change is so rapid that a map of urban soils would become obsolete before it is ready to print.

A viable alternative is systems of numerical classification that can be organized to host other ecosystem parameters and pressure (such as population, proximity to green areas, traffic data) that actually defines the environmental quality of urban soils. Such systems (see e.g. Vrščaj et al. 2008), although they provide only point data, can be stored online and be updated in real time as new information becomes available.

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