GEOSCIENCES AND URBAN SPRAWL: THE CASE OF BUENOS AIRES METROPOLITAN AREA (AMBA), ARGENTINA

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ABSTRACT

Main environmental problems present in Buenos Aires Metropolitan area (AMBA) are studied. Since her foundation in 1580, Buenos Aires city has experienced a sostenible population grow, to reach her present 13000000 inhabitants. Main geoenvironmetal problems that pose a threat to Buenos Aires population are: floodings, water contamination (surficial and subterraneous water), soil deggradation (contamination, physical and chemical degradation and agricultural land loss), domicialiary and industrial waste disposal and sanitary fills, arids mining derived problems, expansive soils and atmospheric contamination. Present paper focus on geological and geomorphological aspects that controlled their occurence.

INTRODUCTION

In devoloping country cities ineffective urban land management resulted in soil, water and landscape degradation, occupation of hazard-prone areas and loss of green spaces and agricultural lands. In Buenos Aires Metropolitan Area (AMBA) lives more than 13 million inhabitants and have suffered an rapidly growing in this century, embracing less than 6000 square kilometers. This growing had lacked of any urban plan so negative impacts (over population and environment) arosed in last decades. Floodings, surficial and subterraneous water contamination, soil degradation (physical and chemical), arid-mining derived problems and waste landfills are eviromental main problems. An sytematic policy is desperatly need in order to solve and revert some of these negative features. The present contribution deals with AMBA main environmental problems, features, causes and impacts, with the objective of apport to strategy, policy and investment statutement. The AMBA is located in Pampean Plain beetween 34°-35°S and 57°45´-59° 15´W.

Region in which Buenos Aires is located have good environmental features that make it acurate for localation of a big city: absence of very dangeorous natural hazards, a very gently rolling relief and water, good agricultural soils and construction materials availability. Nevertheless, high rate last century city growing without minimmal land use plans and policies has resulted in an overwhelming pressure on natural envirronment and resources.

AMBA POLPULATION, GROW AND DISTRIBUTION

Since her second foundation, in 1580, til present, Buenos Aires has experienced a sustained growing. The AMBA is conglomerated rested on River Plate estuary, composed by the City of Buenos Aires (Federal capital of Argentina), the Gran Buenos Aires (divided in three concentric rings or belts "coronas", 1°, 2° & 3°), the Gran La Plata (capital of Buenos Aires province) and small satellites cities, like Campana, Zarate, etc. forming a semi circunsference of 80 Km of ratio. Argentina has a surface of 2800000 Km2, with a population of 33000000 inhabitants, wich more than 35% are located in the AMBA In 1991 the Gran Buenos Aires (GBA) had a population of 11323565 inhabitants, including Buenos Aires city population of 2955002 inhabitants. To southeast, in continuity, is Gran La Plata, with a population of 665103 inhabitants. Nowadays (1999), all AMBA certainly exceeded 13000000 of inhabitants. The city of Buenos Aires has a surface of 20000 ha and the GBA, 388000 ha. Untill 1850, the city ocuppied a surface of less than 35% of present City of Buenos Aires, with a population of less than 200000 inhabitants. AMBA growing if sustanain since foundation was differential in time and space. In 1895, Buenos Aires have reached a popualtion of 600000 (basically due to inmigration) and reached her presentdays popualtion practically in 1947. Main annual growing rate took place beetween 1869 and 1914, with an average of 4,8% annual. The GBA firt "Corona" expanded with an 8% rate in the same period, since then city growth migrated to second and third "coronas". Since XX century beginning less abble lands begun to be occupied. In mid-century, big housing construction plans made the situation irreversible (mainly bacuase of lower land prices of land in this sectors). Population density had increase since 1869 form average values of 21-200 hab./ha, to values of more than 400 hab./ha, with a medium value of 29 hab./ha for GBA (see table 1 a and 1 b).

CLIMATE

Regional climte is subhumid-humid (type Cfa, Mesothermal, with no dry season, according to modified Koppen clasification system), with average annual precipitation of 1200 mm and average annual temperature of 15°C. Even though there is not a dry season, rains show great variability. So heavy day rains with more than 150 mm could take place. Month with more probability of havy rains are february, march, april, may, november and december. Storms are cyclonic type, and take place mainly in march to may and augost to october meanwhile convective type storm are less frecuent and take place in summer months. Some big rains, that caused floodings, hav occurred in february of 1992 and 1998 with more than 42 mm in one hour and 73 mm in two hours respectivily. Anomauolous heavy rains occurred also the 26/1/85, with 192 mm in the day, the 31/5/85, with 184 mm and 25/3/88, with 102 mm. "El Niño"effect has resulted in an average increase of precipitation and a strong increase in amount of heavy day rains.

REGIONAL GEOLOGY AND GEOMORPHOLOGY

The zone is located in Pampa Ondulada morphostructural unit in Chaco-pampeana Plain geological province. Is a gently plain with roughly parallel NE-SW watersheds. To south, Pampa Ondulada is separated of Pampa Deprimida morphostructural unit by an extensive watershed that divides River Plate tributaries streams of Salado and Samboronbom rivers ones. In this divisory plain are located several small lakes in past deflation hollows.

Sediments outcropping in Pampa Ondulada are mainly brownish silt and fine sandy loess and fluvial reworked loess of Upper Pliocene-Pleistocene age of Pampeano or Pampiana Fm. His unit is composed of a lower member named Ensenadense or Ensenada Fm. and an upper member named

Juridiction	1869	1895	1914	1947	1960	1970	1980	1991
Buenos Aires city	187126	663854	1575814	2981043	2966634	2972453	2922829	2955002
Gran Buenos Aires	51134	149324	499263	1802693	3908943	5573619	7129447	8268563
AMBA*	242215	813178	2075077	4783736	6875577	8546072	10052276	11323565

Table 1 a : population grow of AMBA
* excluding gran La Plata and northen satellites cities

Juridiction	1869-95	1895-1914	1914-47	1947-60	1960-70	1970-80	1980-91
Buenos Aires city	4.99	4.65	1.95	-0.04	0.02	-0.17	0.10
Gran Buenos Aires	4.21	6.56	3.97	6.13	3.61	2.49	1.54
AMBA*	4.77	5.19	2.49	2.83	2.20	1.64	1.14

Table 1 b : annual population grow rate of AMBA
* excluding gran La Plata and northen satellites cities

Bonaerense or Buenos Aires Formation. The Ensenadense has a marine intercalation in his lower part, named Infraensenadense, belonging to a early Pleistocene marine ingression. Ensenadense appears beetween –20 and 8 m in the sustrate of larger part of AMBA, and could be observed outcropping in lower part of marginal old cliff. Boanaerense is dominant unit in all region, outcropping from 8 to more than 40 m height. Ensenadense and Bonaerense have several epigenetic and pedogenetic calcretes levels ("tosca") and paleosoils.
In valleys is located Lujan Formation, mainly greenish-grayish fluvial sands and silts, that filled up valleys. Realted to late Pleistocene and mid Holocene marine ingressions are Belgranense and Querandinese-Platense units. Querandinense are gray-blue plastic clays of estuarine-lagoon environment, outcropping below 5 m height, at the base of old cliff. Platense are sandy-shellish chenniers that belongs to regressive phase. In some places of studied region are less than one meter depth sandy sediments of aeolian orgin named aeolian Platense (Postampampeano or La Postrera Formation).
Regional sustrate of Pampa Ondulada are, from base to top, Cristalline Basement, granites and migmatites of Precambric ages, at 250 or more depth, Olivos Formation, red sandy-silty fluvial and loessic deposits of Miocene, Paraná formation, green clays belonging to Miocene great marine ingression and Puelche Formation, fluvial sandy sediments mixed with base of Pampeano.
Factors that have controlled lanscape evolution and main features in Pleistocene-Holocene times are: 1) sea level changes (ingressions-regresions sucesion), 2) thick loess and loess-like sediments deposition and 3) soil formation. Resulting of aeolian action, fluvial process and time limited litoral marine action three main Geomorphic Units (GU) could be differentiated. GU River Plate terrace and alluvial plain had originally evolutionated as a marine acretion plain, and since last regression is functional as an alluvial plain and fluvial terrace of River Plate. Its width varies bbetween 1 km to more than 10 km to south-east of GBA and Gran La Plata. In fact, in Buenos Aires city had practically desapeared because of landfills and Buenos Aires port, Aeroparque airpot and Universitary City building. Where it present, shows a plain relief with old tidal plains, stuarines plains and tidal channels with ocassional sandy-shellish litoral chenniers that where buildt by acretion beetween 6000 and 3500 years BP. This River Plate neighbouring sector is located below 5 m height, so is the most flooded affected area of AMBA region.

The Rivers Terraces and alluvial plains G.U. is developed in the numerous rivers and streams that drains to River Plate. Main are Matanza-Riachuelo, Luján and Reconquista rivers. The former drain a 2034 km2 basin and has 90 km lenght. This basin is totally included in urban area, so is deeply modified by diffrent antrhpogenic actions. Luján and Reconquista rivers are of similar magnitude and are also urbanizated rivers. In that three rivers alluvial plains and terraces lives more 3 millions inhabitants. River channels are deeply incised in alluvial plains (2-3 m) and genarlly have one terrace level. This geomorphic unit has a strong flooding potential. In Buenos Aires city area all streams are channalized and covered by avenues or streets (like Maldonado river). During last ingression main rivers' valleys acted as estuaries.
Dominant G.U. is Loessial Plain, characterized by a smooth relief, that become morr rolling near streams. To River Plate is marginated by an old litoral cliff, related to last marine ingression of mid holocene times. This cliff is erosionated in several places or strongly modified by urbanization. Nevertheless, to northern Buenos Aires city, in specially in northern GBA, vertical scarp could be recognized with more than 10 m of height. Loessial plains developed beetween 15 and 35 m heights. In southern sector of Buenos Aires city the erosion scarp is related to Matanza-Riachuelo river valley. This valley have more than 7 km wide in its mouth. Loessial Plain reappear near Quilmes and extends toward southern GBA an La Plata. For its features original occupation of Buenos Aires was largely in this land unit, practically until 1860.
The loessial plain show ocassional deflation hollows that were occupied by small water bodies and swamps. In Buenos Aires city this lows were modified by landfills in the beginning of XX Century. Some of they are parks and or squares. Calcretes levels developed in Pampean loess are frequently found at variable depths (2-3 m) in all region as well paleosoils (old argillic horizons). All these levels are barriers to infiltration.
Phreatic level varies from a geomorphic unit to other. In loessial plain is beetween 5 to 10 m depth, and in the others G.U. much more closer to surface, like in southern GBA, near River Plate where is at less 0,5 m depth or in Reconquista river valley at less than 1 m.
With respect to soils, dominates Mollisols. "Zonal soils", located in loessial plain are Argiudolls of typic, petrocalcic and vertic subgroups. In lower sectors of landscape, aquic regime is dominant, as well finer materials (fine silt and clay). In these places Haplaquolls, Natracualfs and Hapluderts are found. Independently of landform all region soils has moderate to poor

permiability (due to texture and pressence of argillic and calcic horizons), impliying slow infiltration. Soils in urban areas are strongly modified by antrhopogenic activities.

MAIN GEO-ENVIRONMENTAL PROBLEMS IN AMBA

Main geoenvironmetal problems that pose a threat to Buenos Aires population are:

a) floodings
b) water contamination (surficial and subterraneous water)
c) soil deggradation (contamination, physical and chemical degradation and agricultural land loss)
d) domiciliary and industrial waste disposal and sanitary fills
e) arids mining derived problems
f) expansive soils

Because of extension of present contribution focus is done on floodings, and only a brief description of others factors is done (see table 2).

a) Floodings in AMBA

Floodings are complex phenomena that included climatic, hydological, geomorphic, geological and social aspects. His complexity is frequently overestimated, an specially in the case of Buenos Aires city area. Magnitude and frequency of floodings are function of amount and rates of precipitation, surficial materials characteristics and landforms features, as well as land use and ocuppation.

Geological natural causes of floodings are low relief, a pooly integrated drainage (with lagoons and deflation hollows), slow infiltration due to soil features and surficial materials granulometry and near surface phreatic level. In Buenos Aires urbanization and structural actions developed in past in order to mitigate flooding impacts are by themeselves main cause of floodings in the region. Impermeabilization due to constriuction and channelization resulted in increase of runoff (to 90% or more). Drainage is strongly modified and stream runoff is affected by antropization. Particullarly road and trains bridges narrower enough that become dams and house building in alluvial plains.

In AMBA great floodings take place when heavy rains combine with strong south east winds ("sudesteadas") that produce a generalized raise of River Plate level. This raise plug natural drainage of rivers and streams so they overflow, floodings large parts of AMBA. For example River plate raised 4.4 m in 1940 (15-4-40) due to a "Sudestada" flooding large part of the city. Is important to remak that a part of AMBA is stablished beetween 4 and 6 m over sea level. Other remarkable River Plate raises were in 1989, with 4.6 and in 1993 with 3.90.

In GBA main floodings are related to Matanza and Reconquista rivers. Matanza river basin has a surface of 2000 Km2, with a total stream lenght of 510 km in 232 streams o different orders. Main course has a lenght of 61 km a has a meandriphorm habit. Matanza river has a annual average discharge of 7,02m3/seg a maximums of 1325m3/seg. Water height in lower course varies beetween 1,43 m and 6,16 m. Main tributaries are Morales, Cañuelas, Aguirre and Ortega streams. Lower course is rectified a is name Riachuelo. There was Buenos Aires first port during the conquest.

In Buenos Aires city, main floodings are related to channelized and covered Maldonado, Vega, White and Medrano streams. Athese streams were channelized not considering maximums values of runoff so they are efective only in relation with mediums rains and River Plate raises. Maldonado stream is 19 km lenght and has an average slope of 1m/km. Was channelized a covered by J.B. Justo avenue in 1937. Its terrace alluvial plain is 15 km wide a has a different of height of more than 2 m with respect sourranding loessial plain. In central zone of Buenos Aires city were several small streams that nowadays has desapeared.

Because of swiftness of River plate raise, great intensity of rains and runoff increase due to urbanization floodings in Buenos aires has flash floods characteristics. In Belgrano, Nuñez and Saavedra boroughs, are located Medrano (8 km), Vega (4,3 km) and White stream basins, covered by streets at present days. These streams frequently flooded sorrouindig areas. For example vega stream reached 1.2 m over street level (26-12-97).

b) Other geo-environemental problems

Buenos Aires population water supply is done by two ways. First by water public net and second by domicialiary (particular) provision by swells. The former sources are also two, directly from River Plate and from Puelche aquifer In AMBA more than 60% of water supply is by public service, of wich 90 % come from potabilization plant of River Plate waters. Private supply is done mainly from Puelche aquifer pumping. This regional aquifer is beetween 40 and 80 m depht. They are late Pliocene fluvial sands placd below Pampean loess sequence. A strong pressure is put on yhis level yet show high depression cones in different secors of AMBA. Contammination of water is also important by salinization, organic wastes or heavy metal polutants.

Only 50 % of total AMBA population is served by sewer net (in Buenos Aiores city more than 99%). Absence of sewer is one of main sources of surficial and subterraneous water contamination, particularlly in streams sourranding areas oa high phreatic level sectors. Small lagoons, swamps and watercourses show very high levels of contamination, by industrial wastes or domiciliary wastes. Specially, several industries drain theirs remanants directly to streams without processing them. Streams and rivers have values of ODB, metals (as Pb, Zn, Cd, Hg, etc.) and nitrates.

Until present abarcative AMBA soil contamination studies are absent, excepted a few localized studies in northern GBA and in La Plata city area. High hidrocarbures and heavy metals values has been determined for this sectores, some of they well beyong maximums allowed values by WHO. Main sources are, besides industrial emissions, oil destilleries, vehicles transit and landfills with not processed materials. Futhermore soil contamination is important because more than 50% of total AMBA vegetable consume is produced in proper area

Domiciliary and Industrial final waste disposal is probably main source of water and soils polutants in AMBA. Waste disposal is done by several enterprises but in general wastes are not processes before deposition. Location of waste disposal is also problematic, becuse land value is main variable at moment to choose places, not taking into account landform and surficial deposits features. So in AMBA places used for waste dsiposals are alluvial plains of reconquista an matanza Rivers an sectors of River Plate terrace and alluviall plains, all of this the less suitable areas of all AMBA region, beacuse their proximity to water bodies.

Ensenadense sediments are ML type (Unified Classification), and Intersenadense CL-ML.Bonaerense is more heterogeneous than Ensenadense,aand varies beetween CH to CL-ML. Lujanenseis CL and Querandi OL and OH.. All outcropping formations have variable bearing capacities as they deifferent aparameters show (Wl, and Wp, Iw, wet and dry density, cohession, internal rubbing angle and penetration N values).

Ensenadense and Bonaerense admit 2-3 Kg/cm2 variying with Wn (so pilote foundations are necessary), unless when calcretes are present, so exceeding 4 Kg/cm2. Querandinense (and sometimes fine lujanense sediments) has a Wm larger than Wl, so they are undersaturated (hydroplastic texture). They have a very low to null bearing capacity, with less than

Landscape Unit	Surficial Material	Main Soil type	Soil contamination susceptibility	Flooding potential	Slope stability	Expansive soil
Loessial Plain	ML CH & CL	Argiudolls Hapludolls	Variable	Low	High	Low to moderate
Terraces and Alluvial plains	CL & OL	Hapludolls Haplaquolls Udifluvents	High	High	Variable	Moderate
River Plate plain	OL OH	Haplaquolls Natraqualfs Hapluderts	High	High	variable	Moderate

Table 2: relevant degradation parameters in relation with landscape features and surgical materials

100g/cm2, son indirect foundations are always needed. Expansive soils are related to finer Lujanense sediments and to Querandinense clays. They appear in main rivers and streams alluvial plains and in River Plate terrace and alluvial plain. Expansive soils are also related to expansive clays of some Bt horizons of vertic Argiudolls that are widespread distributed in GBA area. House building in this type of materials always need replacement soils for proper foundation.

Mining of sands, clay for bricks and calcretes for road foundations are widespread distributed in AMBA region. These extractivity activities generally are done without minimal environmental protection practices and governamental control is weak or directly absent. For example abandoned quarries while inundated are dangerous for population. Also constituted a source of water contamination.

CONCLUSIONS

In Buenos Aires metropolitan area expantion, despite unquestionable role in environmental problems studies, Geociences were a negleted contribution excepting scarce cases. Lack of tematic mapping and different pouposes zoning appears as main deficiences in Geosciences contribution to enironmental balanced growing of Buenos Aires. To prevent further degradation, goverments should exert some degree of control over land use and development, achieving a balance beetween urban development and environmental protection.

Geoscientifics should became more involved in providing the information needed for solving environmental problems that arose in urban areas, particullarly in Megacities of developing countries. Governamental agencies, Universities and Science Research insititutions have to incorporate more urban areas-related aplicate and basic investigations to their plans in order to give the right information to proper implimentation of mitigation policies and plans.