Assessing Environment-Climate Impacts in the Nile Basin for Decision-Making

Farid El-Daoushy[184] and Wael M. Khairy[185]

Abstract

Assessing the environmental and climatic impacts in the Nile Basin is imperative for appropriate decision and policy making on national and regional levels. Tracer techniques provide basic spatio-temporal tools for quantifying past, and for predicting future, environmental and climatic impacts in whole Nile Basin. These tools allow the sustainable use of the natural resources through developing appropriate large-scale and long-term management and planning strategies. Radiotracers, for example, have diverse properties, unique sources and cycles in the environment. They provide powerful approaches to understand the behaviour of atmospheric processes, and the role of dry and wet-deposition on transfer of matter to the earth's surface. They are, also, useful for quantifying the functioning and metabolism in complex aquatic and land-water systems through appropriate definition of the spatio-temporal scales forcing their evolution and interactions with the environment and climate. They yield rich data on sources, pathways and flow-rates of hazardous matter within and between landscape units and at the critical boundaries with the lithosphere, ecosphere and the atmosphere.

Mitigation and adaptation strategies require records and observations supported by model and forecasting infra-structures that can simulate the impacts of coupled environment-climate changes both on local and landscape scales. Impacts of global warming are not straightforward to predict unless reasonable scales can be used to compile and collate the diverse climatic and environmental data. Coordinated studies and observations of complex river-, lake-catchment, land-water and delta-coastal systems can provide a wide-range of information on human and climate impacts through using radiotracers as common time and space indicators.

Coupling water management in the Nile Basin with environment-climate policy

[184] Ångström Laboratory, Uppsala University.
Box 530, S-751 21 Uppsala, Sweden.
Tel: + 46 (018) 471 3569; Mobile: + 46 (070) 4250076; Fax: + 46 (018) 471 3524
E-mail: farid.el-daoushy@fysik.uu.se

[185] NBI, Nile Water Sector, Ministry of Water Resources and Irrigation.
9 El Mokhaim El Daem St., Naser City, Cairo, Egypt.
Tel: +202 2 261 1197; Mobile: +201 24798846; Fax: +202 2 402 5966
E-mail: w.khairy@nws.gov.eg

In this paper we will describe a general scientific and technical approach for the sustainable use of the Nile Basin water and land-water resources through stronger coupling between the different sectors and users (Figure 1). The suggested research is highly inter-disciplinary and inter-sectorial and is based on assessing the impacts of all the interacting sectors on the natural resources of the Nile Basin. The approach given here is focused on surface-based facilities (including field, remote, and automatic) for in-situ measurements though coordination with satellite- and radar-based tools would be necessary for optimisation of the necessary monitoring/research activities. We have to keep in mind that atmospheric, aquatic and life sciences have always been and will continue to be observation-driven. Modelling is, however, complementary for predicting future trends and replacing expensive and unnecessary observations/measurements.

Level (1)

International Interaction and Trans-national Coordination/Management								
Burundi	Congo	Egypt	Ethiopia	Kenya	Rwanda	Sudan	Tanzania	Uganda

Level (2)

National Interactions Between Water Sector and Rest of the Economy								
Industry	Transport	Energy	Environment	Water	Health	Agriculture	Tourism	Other

Level (3)

Precipitation/ Flood	Surface-water	Ground-water	Potable water	Hydro-power	Naviga-tion	Sewage/ Sanitation	Irriga-tion	Coastal water

Level (4)

Monitoring, Planning and Management	
Supply Management	Demand Management

Figure (1). Management and interactions in the water sector. In "Levels (2 & 3)" extensive impacts from other sectors on water exist. Dynamic and tight linking between Levels (2 & 3) and levels (1 & 4) is needed by sound scientific and technical solutions.

Coordinating the scientific, technical and human capacity on the Nile Basin level offers a Policy Instrument "PI" that facilitates establishing and updating water treaties, directives, guide-lines, laws and regulations (Table 1) both on national and regional levels. This "PI" will link levels (2 & 3) with levels (1 & 4) in Figure (1) through counteracting the limitations (Table 1) in the decision-making process (Baron et al., 2002) and thereby improving and enhancing the criteria of the involved actors to achieve their objectives.

→ Decision Making Process for Sustainable Water Resource Management Path →

Actors	**Criteria**	**Level**	**Policy Instrument**	**Limitations**
Multinational	Economic		Finance, Technology	Uncertainties,
	Performance	Level (1)	Transfer, Treaties,	Cost,
International	Welfare		Directives/Guidelines	Technology,
				Envir
Impact,				
Commercial		Level (2)	Laws, Regulations,	Lack of
	Resources			analytical
Governmental			Guide-lines, R & D,	tools/skills,
	Sustainability	Level (3)		Weak of
Water Utilities			Ecomonic/Prices	institutions,
	Quality			Insufficient
Consumers		Level (4)	Timing, Requirements	funding,
	Information		(e.g. permission, rules)	Lack of
Public Groups	Others		Public Information	interest

Table (1). Hierarchy of decision making for sustainable water management. Observe the direction of decision actions is moving from the left of the table to the right of the table.

This "PI" will, also, act as a transfer-of-knowledge platform for research and higher education in order to follow the international developments and to structure and build up an African R&D Networking of relevance for the Nile Basin. Based on existing knowledge and with consideration to future environment-climate threats we have to set up a scientific and technical agenda for protecting the Nile Basin and its population from local and major disasters. This is critical and challenging for the African countries but is IMPERATIVE and URGENT. Water in the Nile Basin by being key natural resource with vital role in economy, not only for industry and production but also for livelihood of humans, needs to be efficiently managed on several levels (Figure 1) and with consideration to the complicated hierarchy of the decision-making machinery (Table 1).

Shortly after World War II science and technology gradually shifted towards inter-disciplinary and inter-sectoral research both on basic and applied levels. This was natural, but yet necessary, for safe and secure implementation of many industrial and technical solutions. Meanwhile environmental issues became a priority and experiences from global disasters, e.g. nuclear weapons tests, acidification, eutrophication and global warming, have caused critical thinking about the role of science and technology in modern societies. Previous disasters arose from large gaps between understanding and implementation (Munasinghe, 2008) and from severe fragmentation in management and decision-making policies (Figure 1 and Table 1). Climate threats are already here and sustainable solutions require extensive interaction between various sectors. Appropriate applications of the solar energy and other renewable energy sources, for example, can allow clean use of the water resources and introduction of life in vast unpopulated areas, e.g. in the Nile Basin countries. In this context, "PI" will serve as a general platform for implementing strategic solutions with consideration to the increasing pressures on the use and production of energy, productivity of land and stability in the supply of food and protection against environmental and climate threats.

Among important functions of "PI" is facilitating the national and regional planning and management of water and land-water resources through establishing appropriate Key Environments "KE" to identify and define Key Performance Indicators "KPI" for the sustainable use of water by the public and private sectors in the Nile Basin. Tracer tools will give the necessary data on existing pollution cycles that endanger the sustainability of water and land-water resources in the Nile Basin. They will help creating quantitative routines to follow the goals and performance of various sectors in relation to the negative impacts of waste on environment and health in the Nile Basin countries.

Measures for strengthening the interaction between the water sector and other sectors, on sustainable basis, will be established with focus on assessing the impacts of all sectors on the Nile Basin through:

(1) Bench-marking of the performance of each sector regarding pollution emission and the use of water and land to achieve the national and Nile Basin goals for the sustainability of the natural resources and the protection of human health on national and regional levels, and with consideration to International Competitive Standards.

(2) Support the overall competitiveness of the water sector through implementation of sustainable instruments and approaches that define "KPI" standards for the use and protection of the natural resources in the Nile Basin while enhancing the performance, production, safety and effectiveness of the labour within each sector.

(3) Marketing "KPI" through: (a) dedicated information to the customers on sustainable issues of production and technology; (b) demographic analysis of individuals to become customers; (c) demographic analysis for enhancing turnover through identification of weaknesses and redefinition of profitability for the users in terms of the ecological values and quality of life in general.

(4) Linking, implementing and harmonizing the Nile Basin "KPI" strategies to suit an effective coupling between the water sector and all other sectors through defining and measuring the progress towards organizational and national goals, and to assist in describing a course of action of the water sector towards other sectors. In this context the large-scale and long-term impacts will be quantified, through valid statistical approaches to counteract and mitigate future climate threats on the Nile Basin e.g. diseases, biodiversity, flooding, shortage of water, salination, erosions,

storms, ... etc. .

ENVIRONMENT-CLIMATE IMPACTS IN THE NILE BASIN: SCIENTIFIC AND TECHNICAL ISSUES

Global change and climate change are dealt with by systematic classification of the environment into main compartments (Figure 2). Such dynamic changes are detailed on various spatio-temporal scales by following the physical, chemical and biological processes and interactions in the compartments (Rosswall, et al., 1988). Environmental compartments allow tracing the natural effects and the human impacts from source to sink by combinations of natural and artificial tracers that originate along with the induced changes either directly or indirectly. Environment-climate change studies, and their coupled interaction, have many applications in management and protection policies. Radiotracers, of natural and artificial origins, are elegant tracers with central importance in many earth and environmental studies. They provide bases for establishing temporal scales ranging from hours, days and months, years and centuries, and up to millennia and hundreds of thousand years. These time-scales provide reference framework for tracing the spatial changes forced by processes spanning from micro- and local scales, to regional and global scales (Rosswall, et al., 1988). In climate change and related atmospheric-surface studies we are dealing with hierarchically structured interactive processes of at least several hundred kilometres and with time-scales of seasons up to a century or so. For surface areas down to one kilometre or so, the changes/processes involved can have lower temporal scales from days up to decades. For larger spatial scales one has to account for longer time-scales, in such cases more critical space-time parameters have to be considered. Complex systems, e.g. Lake- and river-catchment, require assessing dynamic processes in several sub-compartments including the surface-boundaries between them, e.g. the atmosphere, the hydrosphere and the lithosphere (El-Daoushy et al., 2001). These studies require representative datasets on the origin and behaviour of several tracers and markers that can simulate the impacts of environment-climatic changes in these systems (El-Daoushy et al., 2000).

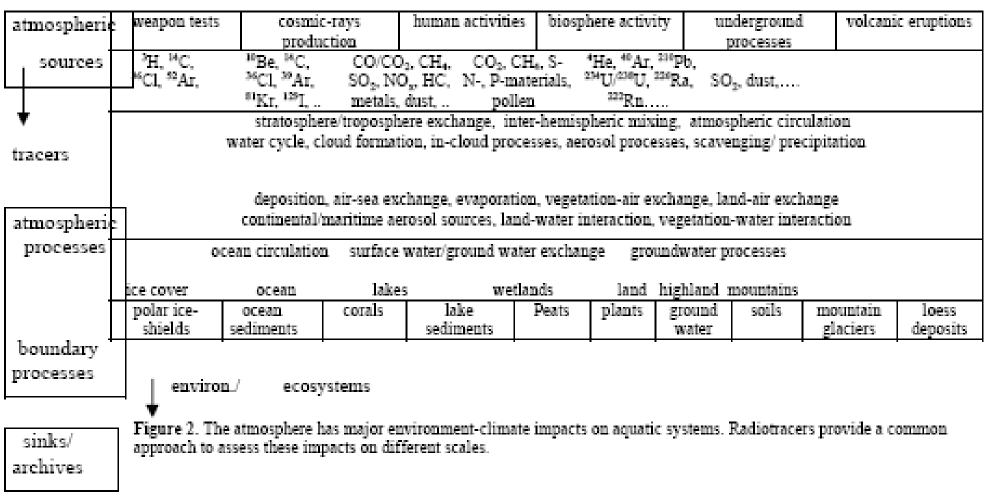

Figure 2. The atmosphere has major environment-climate impacts on aquatic systems. Radiotracers provide a common approach to assess these impacts on different scales.

In aquatic mass-balance studies, processes in the atmosphere, hydrosphere and the catchment have to be quantified, parameterised and modelled for assessing the consequences of different impacts. The role of groundwater interactions with the land and the biosphere is equally important because of the newly emerging threats on water quality from deep mining and the disposal of waste in underground repositories.

Modelling and quantifying the impacts of the atmospheric pollution (Table 2) on surface-water, for example, require proper knowledge on atmospheric radiotracers, e.g. ^{14}C, ^{10}Be, ^{7}Be, ^{210}Pb, ^{137}Cs, $^{239+240}Pu$ and ^{241}Am. Such tracers allow assessing the input, fate and impacts of atmospheric emissions (Table 2), e.g. aerosols, particulates, heavy metal, acidification and greenhouse gases, on short-term effects of air and water quality and long-term impacts on aquatic systems on decades, centuries and up to millennia. The atmospheric sources of natural radiotracers are known and relatively steady in time, this makes them suitable source-functions to test and validate a wide-range of models. Atmospheric radiotracers are, therefore, elegant reference tools for understanding the environmental, climatic and radio-ecological effects in river-, lake-, peat-land and coastal systems in contrasting climates. In the deep disposal of industrial and mining waste, where the ecological impacts have to be followed on much longer time-scales up to hundreds of thousands years, the primordial radio-nuclides (e.g. U/Th-series) are of great interest. U/Th-series have particular importance to study and simulate groundwater interactions with the bedrock and the long-term impacts on coupled geo-ecosphere systems (Figure 2). Understanding the geo-chemistry of the U/Th-series is crucial in the developing and validating the models, e.g. capabilities, reliability and resolution, used in assessing the consequences of the disposal of human waste on the whole ecosphere.

The atmosphere. Atmospheric processes (Figures 2 and 3) influence the behaviour of aerosols in much the same way as the atmospheric radiotracers. Parameterisation and quantification of aerosol formation, attachment and scavenging (Table 2 and Figure 3) can be done by proper compilation of reference atmospheric datasets of several key radio-nuclides. These studies are crucial for testing and validating General Circulation and Atmospheric Trajectory Models. The temporal scales forcing the behaviour of the atmospheric aerosols, pollutants and associated radiotracers can be given as follows:

(1) Short-term changes. Wet: snow/rain (Crutzen & Lawrence, 2000; Knies et al., 1994) and dry precipitation: dust/sand (Papastefanou et al., 2001; Lugauer et al., 2000), and local/regional meteorology and variability in emission sources of aerosols and pollutants (Table 2) are important factors influencing the short-term attachment, scavenging and deposition in the atmosphere (Kim et al., 2000). Short-term changes are, also, sensitive to the location of the site, i.e. urban, coastal, continental or mountain regions (Chester et al., 1993).

(2) Seasonal changes. Regional meteorology and weather forces seasonal changes in frequencies and intensities of wet-dry precipitation, moisture-cloud conditions, and thunderstorms. Precipitation-deposition studies of aerosol-tracers are important to parameterise cloud, rain and snow scavenging/removal by following the temporal evolution of individual rain/snow events (Kane et al., 1994; Ishikawa et al, 1995). Reloading of aerosols occurs by rapid mixing with surrounding air. Reload of ^{7}Be, ^{210}Pb and Ca, for example, in continental regions is similar to the average reload time of aerosols. Washout, rainout and the influence of Saharan and soil dust on aerosol chemistry (Papastefanou et al., 2001; Lugauer et al., 2000), the buffering

capacity and chemical loads, at the level of cloud formation is, however, not yet well understood.

AEROSOL/POLLUTANT	PROCESSES AND MODEL REQUIREMENTS	PARAMETERS TO BE STUDIED/REFINED
Persistent Organic Pollutant (POPs)	Emissions	Source-receptor relationships
	Atmospheric transport (Advection, diffusion)	Resolution, seasonal & long-term variability
Acidifying & eutrophying pollutants (NO, SO_4, SO_3,..)	Chemical composition (formation, transformation, gas/particle partition)	Size distribution, primary/secondary aerosols, man- made/biogenic carbon
	Gaseous exchange with underlying surfaces (vegetation, soil, water)	Atmospheric/surface interaction (emissions, diffusion, ..)
Particulate/alkaline matter (PM_{10}, $PM_{2.5}$, ..)	Eroded/desert dust, re-suspension	Dust events, re-suspension
	Dry/wet deposition	Dry/wet deposition
Heavy metals (Pb, Hg, Cd, ..)	Atmosphere-lake-river catchment Ex-change/transfer-functions	Interactive atmospheric near-surface parameters

Table (2). Global aerosols/pollutants, their processes and parameters forcing coupled environment-climate changes. Datasets and transfer-functions of associated tracers help understanding these processes and simulating their impacts in complex ecosystem.

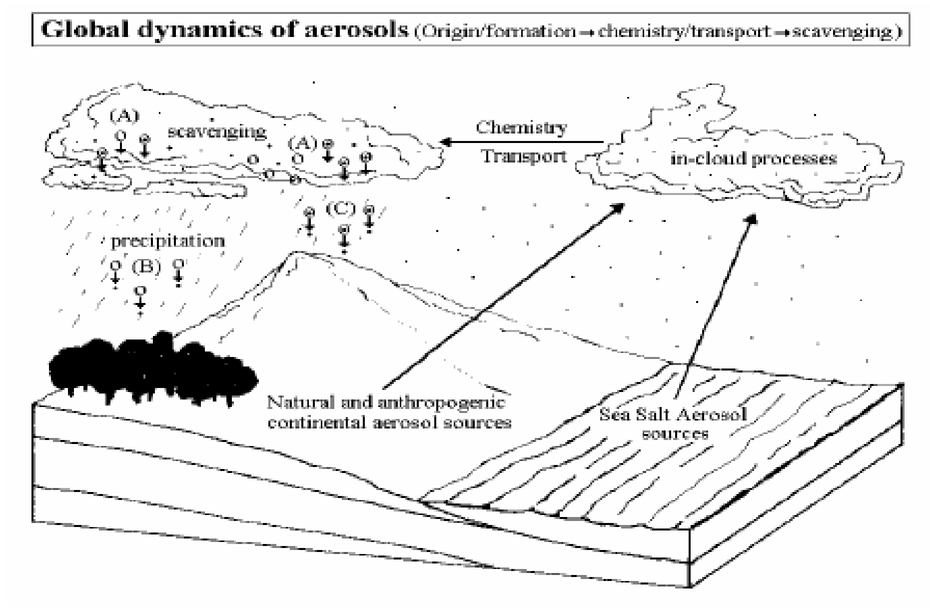

Figure (3). Aerosols emission, including dust/sand, and scavenging by cloud and wet precipitation. (A) rain-out, (B) wash-out, (C) rain-out and wash-out. "." mean an aerosol, and "o" mean a water drop. Since radio-nuclides created in the atmosphere follow the atmospheric aerosols, they can provide input-functions to parameterize aerosol dynamics and to quantify the cycles of the atmospheric pollution in the environment.

(3) Long-term changes. Frequency and intensity of thundershowers, excessive rainfall and outstanding dust events are driven by large-scale meteorology and climate and have strong influence on tropospheric scavenging. This is reflected in increasing 210Pb deposition velocity in Southern Germany in the past two decades (Winkler & Rosner, 2000). It is, also, closely related to a decrease of 210Pb-concentration and an increase of 210Pb-deposition at ground. This behaviour is explained by increasing thundershowers and excessive rainfall events. However, both 210Pb and 7Be levels, in Central Greenland, have been decreasing in the past century (Dibb, 1992; Nijampurkar and Clausen, 1990). Shifts in global circulation resulting from climate change introduce changes in the global flow of air masses, radiotracers and other atmospheric species.

Environmental radioisotopes with global dispersion have transport routes that correlate well with analogous atmospheric species since aerosols act as general host carriers. The two main atmospheric scavenging processes of aerosols are dry and wet removal (Figure 3). These processes are very much different and occur independently and/or simultaneously. The main motor of wet removal is the water cycle, while the dry removal is forced by the global flow of insoluble aerosols, e.g. sand, dust and minerals.

Surface water systems: Freshwater ecosystem structure and function are tightly linked to their catchments. In classical studies surface water bodies were dealt with separately. This, however, is rather suitable for short-term and small-scale studies of environmental changes. Large-scale and long-term effects in riverine networks, lakes and wetlands, by being landscape units, are greatly influenced by terrestrial processes and exchange with groundwater. Sustainability of these systems requires that they should fluctuate within a natural range. Flow regime, sediment, organic-matter inputs, thermal and light conditions, chemical and nutrient loads, and biotic assemblages are basic properties defining the major features of productivity and biodiversity of freshwater ecosystems. Managing these systems involve multi-scale dynamic processes and coupled socio-economic needs. Short-term and small-scale studies, i.e. piecemeal approaches, cannot solve the problems confronting these systems. Large-scale and long-term studies should involve a political agenda, also, for a sustainable development route (Baron et al., 2002).

Lakes: Lakes are transient systems and biological reactors with internal and external interactions. Sediment archives of lakes provide full records on the environment and climate impacts on the functioning and metabolism of these surface water systems. The classical applications of ^{14}C, ^{210}Pb and ^{137}Cs within global change involve studies of lake sedimentation and historical documentation of the consequences of man-made activities on lake ecosystems, e.g. anthropogenic pollution and land-use. These studies are still of major interest, e.g. variability in sedimentation and its physico-chemical nature (i.e. settling, scavenging, bioturbation, slumping, focusing, land erosion/land slide), also for historical monitoring and rehabilitation of the natural cleaning capacity of lake systems.

Lake studies require using atmospheric functions (El-Daoushy et al., 2001) of radiotracers to model and quantify the role of internal and external processes on transfer and accumulation of matter. Atmospheric tracer records in sediments are compared with atmospheric input-functions, e.g. historical records of the atmospheric inputs for ^{210}Pb, ^{7}Be, ^{10}Be, ^{137}Cs, $^{238-240}Pu$ and $^{241}Pu(^{241}Am)$, to maximise the value of sediment archives for quantitative studies of the delayed effects. Good control of sedimentation processes requires, for example, tight intervals of radioisotope measurements and additional stratigraphic markers in order to get reliable flux-data at the required resolution (Jensen et al., 2002). Compilation of data from sediments and water-bodies, e.g. sediment-traps, allow to parameterize the internal settling, accumulation and resuspention in lake water-bodies, e.g. through isotope-particle studies of the transfer parameters of pollutants.

<u>**Lake-catchment systems:**</u> Interactions in lake-catchment systems (Figure 4) are multi-scale processes and require reliable and operational spatio-temporal records that satisfy the involved processes and scales. Advances and difficulties in using radiotracers to assess and model the modern global and climate changes are very well illustrated in studies of complex environmental systems, e.g. lake-catchments (El-Daoushy et al., 2001). In these studies the functioning and metabolism forcing lake-catchments are classified into "within-system" and "between-system" interactions. Reference radiotracer data-sets, e.g. the atmospheric functions, are very useful for constructing the mass-balance of the material flow through the application of Compartment models (El-Daoushy et al., 2001). They are, also, essential for the parameterisation of various internal and external transfer processes in lake systems. In this context, the spatio-temporal records of the distribution of matter in the systems and the involved scales have to fulfil the representativity requirements, i.e. with respect to: (1) the spatial variability in the atmospheric input-functions of radio-tracers; (2) the spatial variability in the sub-compartments on the landscape scale; (3) the temporal changes in the delay mechanisms causing the mobilisation of matter from interacting compartments, e.g. the catchment and the groundwater. Few examples of lake-catchments are given here. However, possible applications in river-catchment, river-delta and river-coastal systems will be introduced especially what regards the complex interactions in these systems.

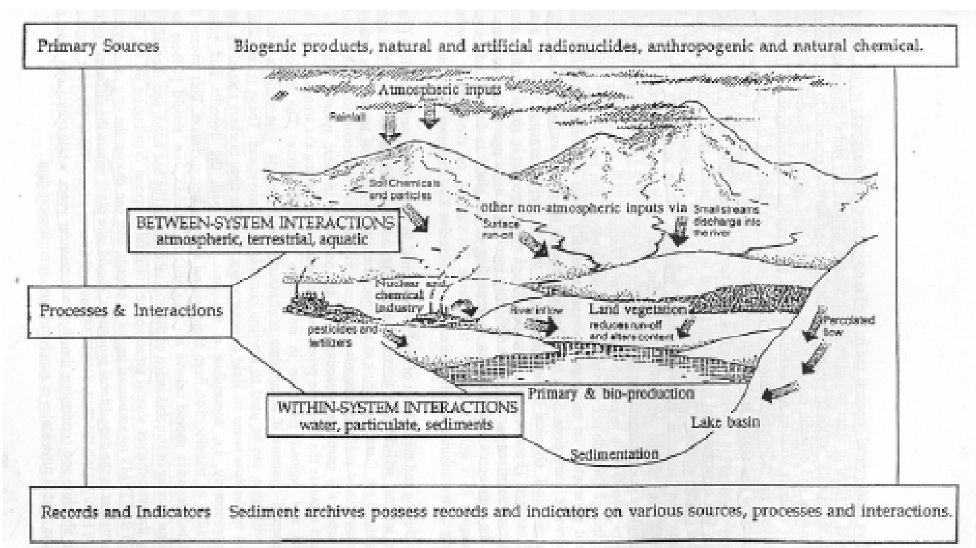

Figure (4). Lakes provide important data on environment-climate change where "within-system" and "between system" interactions can be detailed using multi-tracers. Lake-catchment systems exist at different latitudes/altitudes and can be imbedded in forested/ cultivated areas or associated with rivers, deltas and marine coasts. Diversity of lakes allows a variety of uses to study environment-climate impacts on land-water systems.

Rivers, deltas and river-coastal systems: The final fate of surface water is the sea "He who does not know the way to the sea, must follow the river". This makes rivers natural erosion-drivers. Soil erosion is among major environment-climate problems causing the loss of fertile land and an accelerating dispersion and mobilisation of anthropogenic pollutant and nutrients from catchments (forested, agricultural and anthropogenically-disturbed land) especially through river and lake systems. Soil erosion can be due to natural forcing processes or due to land-use practices and mapping of erosion over large areas can reflect its causes. Several approaches are used to estimate long-term sediment and contaminant export to aquatic systems due to climate change and human activities. There is an increasing shift from erosion monitoring to erosion modelling (Brazier, 2004), which is also the case in other environment-climate protection sectors. Though much quality data exist to describe erosion by water, e.g. in the UK, there are few datasets that can provide the necessary details with which the model performance, capabilities and resolution can be evaluated. The paradox between data collection and compilation to improve models, and erosion models to replace data collection and compilation, must be addressed for modellers and experimentalists, at the same time, if full use of high quality datasets and improvement of models is to be made. There will be always need for monitoring since models in general are site-sensitive, this is especially critical when description of the spatial heterogeneity of soil loss is required.

Quantification of soil erosion can be made by direct methods, e.g. plot studies, over-flight with field survey, and ^{137}Cs and ^{210}Pb survey. Plot and field survey provides an insight into soil erosion over the period of monitoring while ^{137}Cs-data gives rates of erosions for longer periods (Walling and Quine, 1991; El-Daoushy and Eriksson, 1998). The ^{210}Pb-method provides better long-term averages because of longer half-life time, continuous atmospheric delivery of the ^{210}Pb and stability against chemical-mobility. ^{210}Pb and ^{137}Cs are considered to be the most simple and straightforward approach for erosion studies. Soil erosion from catchments by water through indirect approaches (Figure 5) can be inferred from lake sedimentation (El-Daoushy and Eriksson, 1998).

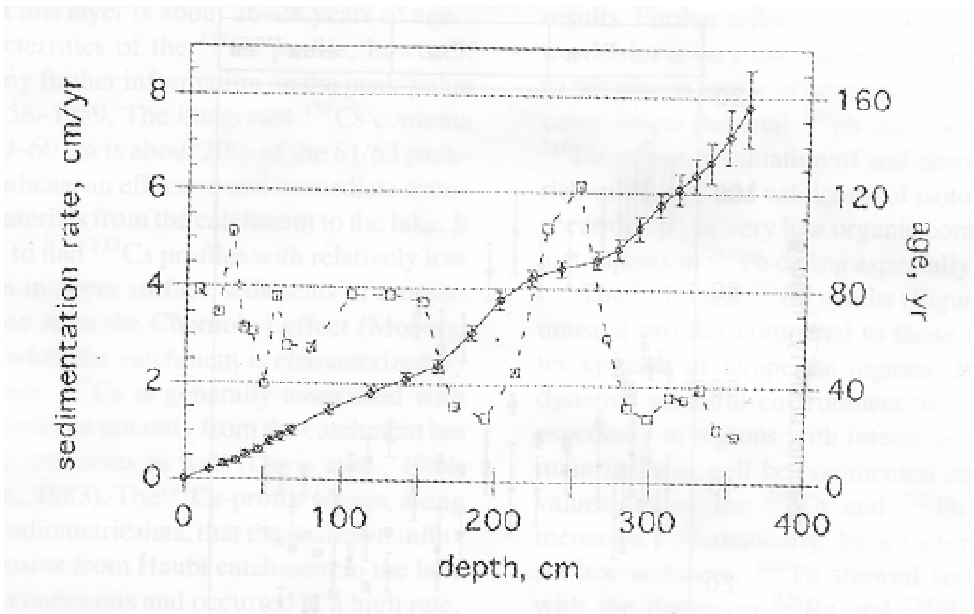

Figure (5). The chronological changes of the sedimentation rates in Lake Haubi showing the intensive erosion in a severely degraded area in Kondoa Irangi Hills, central Tanzania.

The transfer of eroded soils from a severely degraded area in Kondoa Irangi Hills, central Tanzania, caused great changes in the sedimentation rates (Figure 5) of Lake Haubi. Soil erosion studies, in lake-catchment systems require compilation of representative and reliable radiotracer datasets by comparisons of data from natural and artificial traps[4]. The proximity of Lake Haubi to the equator and the relatively high and dynamic sedimentation regimes in this lake required the use of multi-tracer approaches, e.g. U/Th-tracers, ^{210}Pb, ^{226}Ra, ^{137}Cs and ^{40}K, and sensitive techniques to resolve these difficulties. This example illustrates the unique properties of lakes to assess soil erosion because of human, environmental and climatic effects in arid and semi-arid regions. Erosion in river-delta-coastal systems, in river-catchments and around river-systems can be used to give indirect data on the temporal changes of regional land-use, environment and climate impacts. This information is difficult, if not impossible, to get by other means.

Coastal marine systems: ^{210}Pb and ^{137}Cs are used to study recent volumetric changes in salt marsh soils (Kim et al., 2004) due to organic decomposition, compaction and de-watering, which are closely related to contemporary weather and climate conditions and post-formation, e.g. diagenetic and aging processes. Resolving contemporary and post-formation processes depends on finding appropriate temporal indicators. The most intense rates of change in soil volume are neither in deep nor old sediments, i.e. more than 1000 yrs, but within the first several hundreds of years after accumulation. ^{210}Pb and ^{137}Cs dating appears to allow extrapolation backwards/forwards in time and thereby can extend ^{14}C chronologies to sub-recent deposits where ^{14}C has major problems and limitations. Volumetric changes in salt marsh soils are of special interest for sedimentation studies, geochemistry of salt marsh, historical monitoring of heavy-metals and radio-nuclides. In Delaware (Kim et al., 2004) salt marshes, for example, the sedimentation rates were similar to the local sea-level rise, about 3 mm/yr. Salt-marsh assemblages of modern diatom with distinct elevation zones suggest that the diatom distribution in salt-marsh is a direct function of elevation with the duration and frequency of sub-aerial exposure as the most important controlling factors (Horton et al., 2006). This diatom-based transfer function for the east coast of North America was used to reconstruct former sea levels and demonstrated a sea-level rise of c. 3.7 $mm.y^{-1}$ over the past 150 years. Submergence of coastal marshes in areas with relative sea-level rise exceeding rates of marsh sedimentation, or vertical accretion, is a global problem. Using ^{210}Pb-dating it was estimated that, since the 1950s, more than 2000 ha of wetland have been lost in the fluvial-deltaic systems of the Texas Gulf coast (White et al., 2002).

Radioisotopes are, also, used in studies of long-term dispersion of pollutants and excess nutrients in river-estuarine systems and their dispersion and accumulation in coastal marine/oceanic areas. These long-term and large-scale environment-climate changes are related to previous global threats during the second half of the 20th century and the newly expanding economies (Ip et al., 2004; Sanders et al., 2006). Uses of radioisotopes, e.g. ^{210}Pb and ^{137}Cs, to study river-marine systems are imperative to understand the large-scale and long-term impacts of land-use on complex delta-coastal systems. These multi-scale processes require much more data and knowledge to arrive to quantitative approaches for predicting the regional environmental consequences.

Historical monitoring of coastal-lagoon sediments (Robert et al., 2006) show that they are very suitable for high-resolution studies where assemblages of minerals and microfossils reveal succession of events in accordance with human activities and climate change. Estuaries, however, have diverse modern functions by being sites of port, industrial, urban and recreational activities and they are also important for many forms of animal life (Ridgway and Shimmield, 2002). Contaminations delivered from terrestrial environments can affect estuarine ecosystems through fine-grained material transported from land. Half-lives of ^{210}Pb and ^{137}Cs, by being suitable to study accumulation rates of sediments and major constituents in marine coasts, allow quantifying the specific characteristics of the sea floor, e.g. patterns of primary production, lithogenic material, near-bottom homogenisation and degradation of organic matter. Appearance of these nuclides in suspended matter of rivers indicates recent inputs to near-shore areas. Impacts of atmospheric pollution on the functioning and metabolism of coastal lakes, e.g. disappearance of fish due to acid rain can be assessed by tracer techniques (El-Daoushy, et al., 2001). Environment-climate changes have other remarkable impacts on the ecosphere such as the damage of photosynthesis in forest and marine systems.

Popular summary: There is a continuous flow of matter in the different parts of aquatic and ecological systems, just like in the human body. Understanding the functioning and metabolism in these systems depends to large extent on understanding the flow of matter in these systems: what are the important flows? How large are these and how quick? Which factors regulate them? This knowledge gives the necessary background to forecast how these systems would respond to various changes in pollution and climate.

An effective method to gain knowledge on these flows is to use radio-nuclides. Through their property to decay in regular manner they can be used as "clocks". Because of this, studies of radio-nuclides can trace not only the dispersion of different compounds in space but also in time. The diversity of radio-nuclides in the environment, in terms of their origin (stratosphere, troposphere, hydrosphere), chemical (reactions under different conditions) and physical (decay rates and modes) identities, allows to study different transport and accumulation processes on the earth's surface especially what regards assessing the impacts of humans on nature.

The Nile Basin has complex and dynamic flow of matter (for example nutrients and pollutants) with local, regional and global interactions. Resolving the natural and human components of these interactions, in terms of space and time, is imperative for implementing sound planning and management policies. As for other parts of the world, radiotracers provide elegant tools for identifying and quantifying environment-climate impacts in the Nile Basin. Examples on previous global applications of the radiotracers are given the references and will be further reviewed and demonstrated in this talk. The contrasting landscape and climates of the Nile Basin, in combination with multi-tracer approaches, will give important data for the sustainable management of its land-water resources and for understanding the impacts of climate phenomena on the global environments. Through correlating radiotracer data with the behaviour of stable elements and compounds, under different environment-climate regimes, new knowledge on the flow of matter in complex land-water systems, e.g. the Nile Basin, will be gained.

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