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THE NONPOINT SOURCE IMPACTS OF PERI-URBAN SETTLEMENTS IN SOUTH AFRICA: IMPLICATIONS FOR THEIR MANAGEMENT

G. C. Pegram*, G. Quibell** and M. Hinsch***

* Pula Catchment Support, 110 Herbert Baker Street, Groenkloof, Pretoria, 0181, RSA

** Carl Bro International, Copenhagen, Denmark

*** Department of Water Affairs and Forestry, P.O. Bag X313, Pretoria, 0001, RSA

ABSTRACT

South Africa is currently experiencing rapid urbanization, much of which is in under-serviced and informal settlements. This has resulted in significant nonpoint source related water quality problems in these settlements. Although contamination of water resources is a physical process, which is related to the settlement character and service levels, the institutional and socio-economic conditions in the settlements largely govern its manageability. Understanding the settlement characteristics that exacerbate or mitigate water quality problems is therefore necessary for the identification and selection of appropriate management solutions. This paper outlines the key physical, institutional and socio-economic factors that contribute to water quality impacts from peri-urban settlements, and explores the implications of these characteristics for management of the nonpoint source impacts. © 1999 Published by Elsevier Science Ltd on behalf of the IAWQ. All rights reserved

KEYWORDS

Developing countries; nonpoint source management; socio-economic causes; unsewered communities; urban sources.

INTRODUCTION

South Africa, like most developing countries worldwide, experiences significant water quality problems associated with peri-urban residential settlements. These problems are often nonpoint source dominated. While contamination of water resources from peri-urban settlements is a physical process, which can be managed, these processes have their roots in the social, cultural, economic and institutional conditions of the settlement itself. These are not easily managed, especially by those responsible for water quality management. This situation is exacerbated by limited resources for water quality management and settlement development, which implies the need for innovative and cost-effective solutions.

Effective management of water quality impacts from peri-urban settlements requires a sound understanding of the severity and causes of the problems. This paper presents an overview of the nonpoint source related water quality impacts of peri-urban settlements in South Africa. It is based on a review of South African studies which have attempted the quantification of priority water quality impacts from peri-urban settlements. It also highlights the causal physical, institutional and socio-economic factors, that should be

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considered when formulating strategies to manage these impacts. Therefore this paper is of great relevance to water quality managers and practitioners in other developing countries, who are dealing with the problems of rapid urbanization.

THE CHARACTER OF PERI-URBAN SETTLEMENTS IN SOUTH AFRICA

In the context of this paper, peri-urban settlements in South Africa are assumed to include the informal settlements in and around urban areas, as well as the formal residential areas on the urban periphery. The physical, social, economic and administrative characteristics of these settlements vary considerably, both between and within a settlement type. This variation results in different attributes and mechanisms causing a range of water quality impacts from peri-urban settlements.

Peri-urban informal settlements are generally dense (25-150 dwellings/ha) and unplanned, with rudimentary services and a low socio-economic base. They are often associated with severe water quality impacts, due to the high rates of contaminant generation per unit area and limited waste management systems. These settlements are also characterised by limited community affordability for services and often limited local authority capacity and resource for management.

Formal peri-urban residential areas are planned settlements, which generally have medium to high service levels, with medium to high population densities (5-75 dwellings/ha). However, the services often do not function very well, due to poor management by the local authority and/or overcrowding of the settlement beyond the service design capacity due to urban land shortages. This results in serious water quality problems, which are compounded by inappropriate use of services, due to convenience, ignorance or vandalism. The socio-economic levels of these settlements tend to be higher than informal settlements and some capacity and resources are available to the local authorities.

THE WATER QUALITY EFFECTS OF PERI-URBAN SETTLEMENTS

The appropriate management response to water quality problems from peri-urban settlements must reflect the nature of the problem, both in terms of its causes within the settlement and its effects on the receiving water environment. The causes and effects of water quality problems from these settlements are directly related to certain key settlement attributes. Therefore, peri-urban settlements should be holistically characterized in terms of these attributes (indicators), in order to formulate appropriate, effective and sustainable interventions for integrated management of the water quality effects. The four main components of this characterization are dealt with in the remainder of this paper, namely:

- water quality problems in the receiving water environment;
- the physical attributes which determine the causes of these water quality problems;
- the institutional factors that restrict the effective management of these problems; and
- socio-economic factors, which cause or worsen the physical or institutional problems.

The following water quality problems are the management priority in peri-urban settlements in South Africa, based on the severity of the settlements' contribution to these problems. Table 1 provides a summary of the ranges of *E. coli* concentrations, as well as nutrient and sediment loading rates from different types of settlements, based on reported South African literature values (Pegram *et al.*, 1999).

- *Microbiological* contamination associated with faecal pathogens, causes acute localised impacts in surface or ground water, with severe health impacts on those users who rely on the resource directly. In peri-urban settlements, it is generally related to inadequate water supply and sanitation infrastructure and/or direct contamination of the water resource by animals or livestock.
- *Nutrients*, mainly phosphorus and nitrogen, cause eutrophication through accumulation in regional surface water bodies, while nitrates can cause groundwater contamination with human health impacts. Nutrient loads from peri-urban settlements are largely related to inadequate water supply and sanitation infrastructure, and poorly managed stormwater washoff.

• Litter, cumulated, inadequate, infrastructure

• Sediment, aquatic, garden, for advertisement

• Habitat, construction, Africa, the attitude

Tab

Formal

Peri-urban

Rural

Other problems demanding quality protection thus not expected

The causes to the production receiving water institutional environment

Water quality which are not service provided

- Sanitation, nutrient, structure
- Grey water, contamination, associated
- The water, a major (particulate)
- Stormwater, on the large source problem

- *Litter*, which includes household solid waste (and in some cases animal carcasses), causes acute and cumulative ecological, aesthetic and health problems in surface water bodies, and is entirely related to inadequate solid waste management. However, it also contributes to the failure of other services and infrastructure, thereby exacerbating other water quality problems.
- *Sediment* settles in reservoirs and rivers, thereby affecting storage capacity, water treatment and the aquatic habitat. It is associated with stormwater washoff from poorly vegetated areas, including roads, gardens, croplands and livestock grazing. Particulate matter also provides a major delivery mechanism for adsorbed substances and can thus exacerbate other problems.
- *Habitat destruction* of the instream and riparian environment is caused by human, animal and construction activity in the riparian zone, and is included as a water quality problem in line with South Africa's new water policy. Degraded habitats also exacerbate other water quality problems by reducing the attenuation and assimilation of contaminants.

Table 1. Average observed ranges of contaminant concentration and loading by settlement type

	<i>E.coli</i> (#/100ml)	Phosphorus (kg/km ² /a)	Sediment (ton/km ² /a)
Formal residential - well managed	<10 ³	150-500	10-100
- poorly managed	10 ⁴ -10 ⁷	150-500	10-100
Peri-urban informal settlements	10 ⁴ -10 ⁷	100-300	50-500
Rural villages	10 ² -10 ⁴	< 50	50-500

Other problems may be associated with physical properties (i.e. temperature, colour and odour), oils, oxygen demanding substances, metals, salinity, or hazardous substances. In most cases, these lower priority water quality problems will be addressed through management of the causes of the high priority problems, and are thus not explicitly addressed in this paper.

THE PHYSICAL CAUSES OF THESE WATER QUALITY PROBLEMS

The causes of water quality contamination from peri-urban settlements may be separated into those related to the production of contaminants at the source, and those mechanisms which govern their delivery into the receiving water environment. These conditions may be caused or exacerbated by socio-economic and institutional conditions, but the starting point in understanding water quality problems is the physical environment.

Water quality problems from peri-urban settlements are primarily caused by infrastructure and services which are not adequate for the settlement characteristics (particularly density), are poorly managed by the service provider and/or are incorrectly used by the community, as indicated below:

- *Sanitation* system failure is the dominant cause of microbiological contamination and a major cause of nutrient loading to surface and ground water resources. It is largely due to limited, overloaded or structural failure of the infrastructure.
- *Grey water* (in the broadest interpretation), can be a major source of nutrient load and microbiological contamination to surface or ground water resources. The level and functioning of water supply and the associated drainage infrastructure has significant impact on this contamination.
- The water quality impacts (particularly gross matter) associated with *solid waste* disposal and littering is a major problem in areas with poor (either inadequate or unreliable) waste management services (particularly urban informal and township settlements).
- *Stormwater* washoff is one of the key delivery pathways for all contaminants which have accumulated on the land surface, and thus the stormwater drainage system has a significant influence over nonpoint source problems.

- The *construction* phase of settlement and infrastructure development can contribute significantly to sediment loads and habitat destruction.
- *Livestock* is a factor in transitional informal settlements on the periphery of urban areas, where they may cause faecal contamination and habitat destruction.
- *Crop cultivation* is a relatively minor contributing factor to water quality problems, generally associated with more rural informal settlements, causing sediment yield and habitat destruction.
- Disposal and washoff of *backyard industrial wastes*, is a relatively minor factor, except in the denser peri-urban settlements.
- *Atmospheric deposition* of substances is only really a factor in peri-urban informal settlements due to burning of coal, wood and paraffin for heat and light.

The production of waste from peri-urban settlements has two components, namely generation and availability. These are largely related to the population and level of services, but may be exacerbated or mitigated by socio-economic and institutional factors. Per capita contaminant generation rates tend to increase with increasing affluence and better services, while the contaminant availability tends to decrease with higher levels and improved functioning of services.

The South African case studies of water quality impacts from peri-urban settlements, have indicated that inadequate or ineffective sanitation, waste disposal and water supply services are the main causes (sources) of surface water quality problems. This becomes more apparent as the "assimilative capacity" of the environment decreases as settlement density increases. Storm washoff, sewer and stormwater system failure and waste water runoff are the primary delivery pathways.

Infiltration of contaminants from inadequate sanitation and waste water disposal are the main causes of groundwater contamination. However, this is not to negate the impacts of instream and riparian activity and the storm washoff of sediment and accumulated matter, which also play a major role in water quality problems from peri-urban settlements.

Siting of peri-urban settlements and *layout* of associated residential activities are key factors exacerbating or mitigating delivery. This is largely due to the greater possibilities for assimilation and/or management of contamination during delivery from sources located away from the riverine environment.

THE INSTITUTIONAL ENVIRONMENT

Most water quality problems from peri-urban settlements can be managed, through appropriate planning, development and operation of these settlements and the associated services. However, this can only be achieved if water quality management is a priority of government agents or the affected communities, and if there is adequate capacity, resources and support to initiate and sustain interventions. Thus the possibilities for management are generally constrained by the institutional environment associated with peri-urban settlements, as highlighted by the following:

- Local, provincial or national authorities may not accept responsibility for managing the water quality impacts of settlements, because of ignorance or lack of political will.
- Service delivery is currently the prime objective of the South African government, thus many authorities do not prioritize and address environmental water quality related issues, because it is viewed as relatively less important or is perceived to be a potential threat to development.
- Even in cases where water quality management is a priority, action is not taken, because authorities are not willing to pay for untested solutions or there is lack of knowledge of available solutions.
- Where actions are taken, successful implementation is inhibited by a lack of information or inappropriate planning, implementation and monitoring.
- Interventions may also take the form of legislation, but the application of this legislation may not be effective, because it is inappropriate, poorly formulated or not enforced.
- The capability for intervention by authorities is related to the finances available to them. For local authorities, service delivery to address the massive backlog is constrained by poor credit rating, low rates and tax base and non-payment or illegal use of services.

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- The capacity of local authorities to provide services and/or implement water quality management interventions is further constrained by limited human and equipment resources.
- The fragmentation of planning and environmental responsibility requires significant co-ordination between local, provincial and national government in the spirit of collaborative governance, but this is seldom implemented and the historical experience is limited.

THE SOCIO-ECONOMIC CONDITIONS

The social and economic environment in a settlement is generally the underlying cause of the physical problems, as well as contributing to the institutional problems. This is supported by the assertion that the water quality impacts of peri-urban settlements can be effectively managed (both technically and administratively), if there is adequate funding and community support. Problems are generally related to the following factors:

- People are invading and settling undeveloped land, largely due to over-population of existing settlements, internal growth and rural-urban migration, the massive backlog of land, infrastructure and services and insufficient allocation of land, infrastructure and services to meet the demand.
- Formal and serviced areas are being settled beyond the design capacity of the provided services, because there are limited areas with easy access to employment opportunities, inadequate land and housing is being made available to meet the demand and owners need extra income.
- Even where the capacity of the services is adequate, incorrect or inappropriate use of the services by the settlement inhabitants contributes to their failure, due to ignorance, convenience, the derivation of some benefit or vandalism.
- Formal and informal channels of communication are not effective at raising the awareness of environmental health issues.
- Illegal use of services has negative impacts on the administration of settlements, and is caused by limited availability, inability to pay or expectation of free delivery for services.
- In addition to illegal use of services, people are not paying for services provided, due to poor affordability, historical expectations, inadequate services and political agendas.
- The functioning and acceptance of some local authorities by the communities has been severely inhibited by a lack of credibility and legitimacy related to political motives, high expectations and inadequate community participation in decisions.
- People cannot or will not modify behaviour patterns which impact negatively on the aquatic environment, because there is no alternative, they are ignorant or have limited "ownership" of their areas.

As with the entire urban spatial planning processes, these factors cannot be addressed directly by the water managers, because they are dependent upon national and provincial economic and social development strategies and processes that are the responsibility of other government authorities. However, the management of the water quality impacts from peri-urban settlements needs to take cognizance of these factors, in order for it to inform and influence other processes that are targeting the socio-economic or institutional environment of peri-urban settlements. Furthermore, the constraints imposed by these conditions must be taken into account when selecting technical solutions, otherwise their sustainability is doomed.

IMPLICATIONS FOR WATER QUALITY MANAGEMENT

In summary, water quality problems from peri-urban settlements are primarily caused by infrastructure and services (i.e. sanitation, solid waste disposal, water supply and stormwater drainage), which are:

- not adequate for the settlement characteristics, in terms of physical conditions or density;
- are poorly managed by the service provider, in terms of operation and maintenance; or
- are incorrectly used by the community.

The adequacy of different service levels is dependant upon the dwelling density, its siting relative to the receiving water environment and the natural physical features of the settlement area. These will either exacerbate or mitigate the impacts of the services.

On the other hand, the causes of service failure are generally related to the socio-economic conditions and institutional arrangements in peri-urban settlements. The socio-economic factors directly contributing to water quality effects from peri-urban settlements are generally associated with inadequate services or result in the misuse of services, due to:

- no physical or economic alternative;
- ignorance of the environmental impacts;
- convenience; or
- benefit gained by negative actions or vandalism.

Socio-economic factors are usually related to historical, political or economic conditions and are expressed through the relationship between communities and government authorities, which inhibits the latter's ability to perform adequately. These may include:

- settling of unserviced land or densification above service capacity;
- non-payment for or illegal use of services; and
- neglect of the environmental and health consequences of actions.

The institutional factors affecting conditions in peri-urban settlements which have an impact on the water quality effects may be summarised as:

- authorities do not accept responsibility;
- other issues have higher priority;
- inappropriate interventions;
- ineffective legislation; and
- inadequate institutional capacity and resources.

Management of the water quality effects from peri-urban settlements therefore requires an integrated approach to the causes of contamination. It is not adequate to only address one component of the problem, but rather all causal factors must be targeted simultaneously in order to break the "cycle-of-pollution" between the socio-economic, institutional and physical elements of peri-urban settlements. This requires the identification of a system of management measures, which are technically, economically, socially and institutionally achievable interventions for managing water quality problems, including:

- *legislation* to control and enforce interventions;
- *institutional arrangements* reflecting authorities' roles and responsibilities;
- *financing mechanisms* to assist implementation of other interventions;
- *consultation* to ensure community acceptance and ownership of interventions;
- *community action* in terms of partnerships and organic community-based projects;
- *structural engineering* interventions in the physical environment;
- *environmental protection* to improve natural ecosystem functioning and assimilation;
- *operation and maintenance* of services and infrastructure to control contamination;
- *education* to alter perceptions, raise awareness and utilise public censure; and
- *capacity building* of personnel within organs of state.

Appropriate measures should be selected in terms of their effectiveness, resource requirements, institutional responsibility, sustainability and acceptability, taking cognizance of the need for an evolving strategy in the short, medium and longer terms. Measures should be chosen to address the key physical, institutional and socio-economic factors causing the water quality problem in a particular settlement.

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It is clear that integrated management of the water quality effects of peri-urban settlements will require interventions outside the jurisdiction of water managers. This requires that water managers make use of *direct intervention* to implement or fund a management measure, *regulation* through control and enforcement under the water law, *cooperative governance* entailing collaboration with other organs of state and *influence* of institutions and communities through advocacy and education.

THE CASE FOR SETTLEMENT CHARACTERIZATION

Settlement characterization provides an objective way to guide the identification of the priority problems and their key causes, thereby indicating the types of intervention that may be most appropriate in a particular situation. Based on the preceding discussion, this characterization may be built around the following general groups of questions. However, answering these questions will require the evaluation of indicators, reflecting the settlement attributes discussed above, which have not been outlined here due to space constraints. They are dealt with in DWAF (1998).

Water quality problem

- What are the priority water quality effects (health, ecological, water treatment)?
- What are the associated water quality problems?
- Where are the critical receiving water resources (ground or surface water)?

Physical settlement character

- Which services or activities are associated with these problems?
- Are the service levels adequate for the settlement density?
- Are there planned changes in the settlement (greenfield development or upgrade)?
- Are there other factors that exacerbate or mitigate the impacts of these services (e.g. slopes)?
- Are the services being effectively operated and maintained?

Institutional arrangements

- Are local institutions mitigating, neglecting or worsening these water quality impacts?
- Is there institutional capacity and will to engage these problems?
- Is there capacity to mobilise water quality management intervention?
- Is there capacity to sustain and consolidate water quality management intervention?

Socio-economic conditions

- Is the settlement stable in terms of influx of people and leadership?
- Can community support be obtained for water quality management intervention?
- Can the use of services be enhanced or can abuse be curtailed?
- Is there payment for services and can this be improved?

Particular types of management interventions are associated with the answers to these questions, and this provides the linkage between the characterization and the identification of appropriate management solutions.

CONCLUSION

Although the ultimate goal for water quality (and municipal) managers may be the provision and operation of high levels of service for all peri-urban settlements, limited resources and capacity will prevent this in the short term. Thus water managers have to strategically collaborate with other responsible institutions to achieve this end, while ensuring that innovative low-cost management interventions and intermediate service levels are implemented where possible. The identification and selection of appropriate management solutions should be based on the characterisation of the water quality problems in a settlement, and the causal physical, institutional and socio-economic factors.

The 21st century will see rapid urbanisation in developing countries and the explosion of mega-cities. Most of this will be in peri-urban settlements, housing the poorest sections of society. This paper has outlined some of the major nonpoint source related water quality problems associated with these types of settlements

and has explored their causes. Based on this assessment, the water quality impacts from peri-urban settlements are likely to become the greatest nonpoint source problem in the next century. Further investigation of best management practices (BMPs) which are appropriate for managing the physical, institutional and socio-economic causes of nonpoint source contamination from peri-urban settlements in developing countries is urgently needed and must become a research priority if these issues are to be addressed.

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