# Evaluation of water pollution risk of Muskeli oya –Kehelgamu oya watershed by watershed unit approach

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ABSTRACT: Watershed approach is widely used by many developed nations as a very effective tool in water quality management. The paper outlines application of watershed unit based approach to evaluate water pollution risk in Kehelgamuoya Muskelioya watershed, a typical case demonstrating issues of watershed degradation due to extensive anthropogenic influence. In this approach characterization of water pollution risk was based on that criteria that higher watershed naturalness result water quality closer to baseline levels (low water pollution risk) and increased human pressure portraying deterioration of water quality (high water pollution risk) from the baseline levels. The results reveal that densely populated areas and tea plantations pose both human and agrochemical pollution risk on ambient waters. This together with adhoc waste management in unplanned/ landlocked town centers and poor community health & sanitation appear to have increased nutrient pollution and fecal pollution risks. The tested drinking water sources showed levels of nitrates above baseline levels in all cases and 65% of the samples having fecal coliform counts very much higher than baseline levels. The potential risk of water borne infections due to these could be high as this water reaches consumer without treatment. Water quality comparison between water draining through reservoirs and that of natural streams provide clear evidences on the role of reservoir system as a pollutant recipient. The paper highlights the strength of watershed unit approach in evaluation of water pollution risk, its effectiveness as a management tool and also the long-term viability as an evaluation tool due to the fact that attributes for evaluation came mainly from existing local data bases.

## 1. INTRODUCTION

Watershed approach is widely used by many developed nations ( ref 4) as a very effective tool in water quality management. The approach considers natural and human factors and determines the relative significance of their influence on water resource health. The local water quality management efforts in the country are mainly project based and generally limited to monitoring water quality with poor integration of vital information such as land use, demography, ecology etc in to the system. Moreover, water quality data gathered under such projects has a limited validity in management point of view due to vagueness of measurement boundaries. Lack of a systematic water quality management system even on the major rivers of Sri Lanka poses local river systems under a serious risk of water pollution. The upper reach Kelani River basin demarcated by the Muskeli oya and Kehel gamu oya (K_M) watershed is a typical case demonstrating issues of watershed degradation due to extensive utilization of water resources for multiple purposes however, without a symmetric watershed assessment to determine status of degradation.

Having identified the significance of the watershed approach in the management of local water resources a ***project on developing a water resource health assessment framework for upper Kelani river watershed was sponsored by the United Nations Development Program***. The tasks under this project were executed in 2010-2011 by a team of scientists in the Environmental Division of National Building Research Organization. The paper outlines application of framework in characterization of water pollution risk of K_M watershed using watershed unit approach.

## 2. THE SALIENT WATERSHED FEATURES

The upper Kelani watershed is located within the **administrative boundaries of Ambagamuwa Divisional Secretariat Division,** Nuwaraeliya Distirict, Central Province and is defined by the sub watersheds of Maskeli Oya and Kehelgamuwa Oya draining a total area of approximately 315 sqkm. The natural geomorphologic features characteristics with gorges, steep slopes and flats in the drainage basin and plenty of water resource enriched with more than 3000mm mean annual rainfall have made the opportunity to develop a cascade of five hydropower reservoirs popularly known as K-

M complex. The watershed harbors precious wild life reserve; the peak wilderness wild life reserve of which many parts still remain pristine. The land mass of the watershed is greatly exploited for tea plantations which is integrated with expansion of plantation based human settlements resulting a range of land degradation and pollution issues such as soil erosion, landslides, agro chemical pollution, depletion of stream flow, deterioration to water quality and reservoir sedimentation etc. Centralized water supply is not feasible due to mosaic terrain morphology and hence domestic water supplies are scattered in places where up- hill feeding stream can be used as source of drinking water. These streams and springs are tapped to establish multitude of community water supplies to satisfy domestic water demand for scattered settlements and isolated townships such as Hatton, Maskeliya, Norton, Norwood etc. In these supplies treatment for the most stringent water use: i.e. drinking water is limited only to town supplies whereas all other receive untreated water posing consumer population on water borne health related risk. Absence of a watershed/ water resource health evaluation system for this watershed has left a situation where trends of pollution, extent damage to water resource health and related risks in a black box.

## 3. THE OBJECTIVES

- Develop the conceptual framework for watershed unit based evaluation system

- Assess the integration potential of local information sources in to watershed unit based decision support system

- Evaluate the degree of water pollution risk of K_M watershed by watershed based approach with comprehensive use of existing information sources.

## 4. METHODOLOGY

The methodology covers

- Development the conceptual framework
- Delineation of system boundaries (watershed and Data)
- Selection of input information and integration in to the decision support system
- Analysis of information
- Characterization of water pollution risk

### *4.1 Development of watershed unit based system*

The **watershed unit approach** is based on input/analysis of attributes (information) under three categories which best represent watershed health status. i.e. watershed naturalness, the level of human influence and the water resources health. The characterization of water pollution risk was based on the criteria that higher naturalness result water quality closer to baseline levels and increased human pressure portraying distortion of water quality from the baseline levels, i.e. deteriorated water resource health. Fig 1 depicts the conceptual framework of the watershed based evaluation system developed for the K-M watershed. The information falling under above three categories were mostly chosen from the local information sources and then they were systematically analyzed either qualitatively or quantitatively to evaluate their relative influence on interpretation of the water pollution risk.

| **Pollution risk evaluation categories** |
|---|
| **1- Watershed Naturalness** |
| Natural vegetation cover, catchment hydrology, land features ( landform, terrain soil, geology etc) |
| **2. Human process/influences** |
| **Demographic characteristics and urbanization**- Demographic-( Population distribution, density and growth) & urbanization |
| **Watershed sanitation**: human waste disposal , solid waste management, hazardous waste management systems, Industrial waste management |
| **Stream alterations** (river morphology changes) |
| Agrochemical use, soil erosion, reservoir sedimentation |
| **3. Water resource health** |
| Drinking water safety & ambient water quality |
| Water sanitation & Incidence of waterborne infections |
| **Water related disasters** (floods, drought, water scarcity, water borne epidemics, toxic pollutants in water |

Fig 1 Categories for watershed unit based water pollution risk evaluation framework

*4.2 Delineation of system boundaries*

In the use local information effectively the key criteria to be satisfied is the ability to delineate data boundaries within the watershed boundaries. As the local data are available on administrative boundaries the task was approached, first by delineating the watershed boundary and then overlaying administrative boundaries over the watershed boundary. For this task GIS software; Arc view 3.3, geospatial hydrologic model extension: HEC-Geo HMS and 1:50 000 scale digital contour layers with 20m isolines was used. The administrative boundary of the K_M watershed is the Ambagamuwa Korale Divisional Secretariat, which has a total of 67 GN Division and of which 54 fall almost fully within the K_M watershed successfully satisfying 80% overlap.

*4.2 Information sources ( attributes) used as input data*

Among a range of indicators widely used in interpretation of water resource health the study chosen indicators that qualify directly or indirectly to represent the three categories indicated in the evaluation system (fig 1) however, subjected to the fact that their availability in local information sources with reasonable reliability. The Survey Department Digital Maps, Divisional Resource Profiles, Ceylon Electrify Board power generation data and Health & Sanitation Data of Medical Health Office of the Paradeshiya sabas served as local information sources. As most of the local information sources relevant to demographic features and health- sanitation were available at Grama Niladhari (GN) level, GN spatial boundaries were also over laid on the watershed boundary. This was followed by depicting relevant data within the GN unit. The water quality data of the main stream network although is a vital information requirement was not available for this watershed. Therefore NBRO conducted a monitoring to capture water quality in the main stream network representingt different developments and land uses. The selection of sampling locations also considered “evaluation of influence of cascade of hydropower reservoirs in quality of water draining the reservoir system compared to the water channeling through streams (environmental flows) ”.

Accordingly, analysis and characterization of water pollution risk was focused on under mentioned areas

- Influence of population pressure on the water pollution risk
- Effect of land use character
- Pollution risk on the drinking water sources
- Impact of cascade of hydro power reservoirs on the water quality
- Water pollution risk and the incidence of waterborne infections

## 5 RESULTS & DISCUSSION

### *5.1 Influence of population pressure on the water pollution risk*

The total population within the watershed is about 200,000 (2010 census) with the ethnic composition of 76 % Estate Tamils, 20% Sinhalease and 4 % others mainly Muslims. Majority of the Tamil population is clustered in line houses in tea plantations where sanitary conditions are very much bellow the required sanitation level. High population density was observed in Kehelgamu oya Upper reach and Muskelya area (fig 2). Concentration of population was also observed in town centers; i.e. towns of DIkoya, Hatton, Norwood, Norton, Bagawanthalawa and Muskeiliya. The field observations revealed that the town centers are land locked, unplanned and developed along stream/reservoir banks restricting further expansion. The water bodies serve as recipients of town wastewater with situations of direct sewage disposal demonstrating a potentially very high water pollution risk. The town center could be highlighted as red spots of emission sources posing serious water pollution risk.

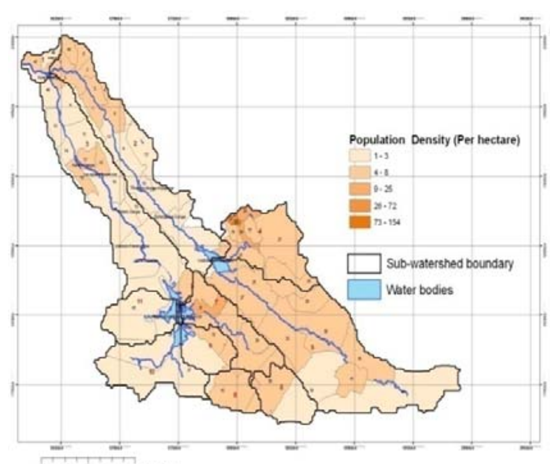


Fig 2 Population density distribution within the watershed

The potential water pollution risk in areas with higher population density is comparable with distribution of fecal coliform counts, the indicator parameter for feacal pollution, in stream waters. Streams draining catchments with higher population concentration (Dik oya and Hambantota Oya) have reported fecal coliform counts several folds higher than the baseline level, i.e. 35 /100ml , a stream draining Laxapana forest reserve. In contrast a river system draining Dikoya and Hatton towns have reported counts as high as 430/100ml. Also, the fecal coliform counts were as high as 590 and 859 at two locations along the Hambantota oya which drains Bagawanthalawa and Norwood towns. Refer Fig 2 & fig 3. Some raw water sources of community water supplies also demonstrated even higher feacal and total coliform levels in which the reported fecal coliform counts have reached the levels as high as 4000/100ml (fig 5). Such high levels could be possible due to the fact that upstream land of many community water supplies are inhabited with estate settlers

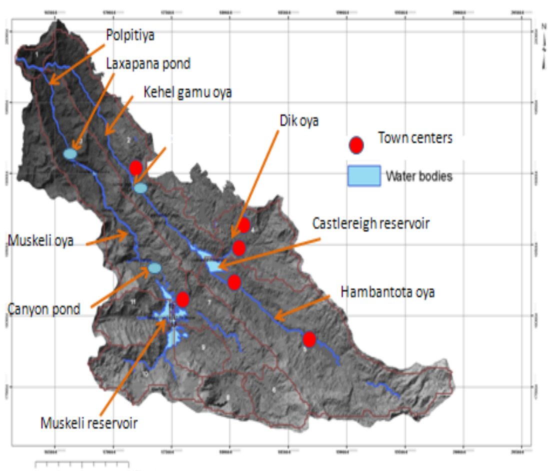


Fig 3 Hydrological setting and the distribution of town centers in the K_M watershed

*5.2 Effect of Land use character*

The major land uses in the study area are tea plantations, forest and home gardens. The tea plantation represents about 60% of the land use where as forests represent 30% and home garden and other land uses about 10%. The results reveal high water pollution risk in streams draining from land uses under heavy anthropogenic influence compared to undisturbed land uses i.e. natural forests. The streams draining natural forests represent baseline levels of water quality in the watershed. Accordingly a representative stream in the Laxapana forest reserve demonstrated pristine water quality with fecal coliform counts as low as 35/100ml, Total coliform counts at 50/100ml, low Nitrate (NO3) levels 0.04mg/l N, very low Total Phosphorus (TP) levels 0.01mg/l as P, turbidity 1 NTU, dissolved oxygen at saturation, i.e. 8.4mg/l and conductivity as low as 10um /cm. Levels closer to background has been demonstrated by the Kehelgamu oya lower reach which drain relatively undisturbed catchment compared to other ,Table 1.

Table 1 Land use character and the NO3, NH3 and TP concentrations in the surface water streams.

| **Major land use** | **Natural Forest-Laxapana forest** | **Tea/plantation settlements (Bagawanthalawa)** | **Tea / plantation settlements/ urban ( Hatton, Norwood, Dikoya)** | **Total catchment drain (Polpitiya)** | **Disturbed forest/Home gardens (Kehelgamu oya lower reach)** |
|---|---|---|---|---|---|
| NO3-N mg/l | 0.04 | 0.3 | 0.24-0.26 | 0.20 | 0.04 |
| NH3-N mg/l | 0.1 | 0.09 | 0.06-0.16 | 0.20 | 0.3 |
| TP –P mg/l | 0.01 | 0.04 | 0.05 | 0.04 | 0.05 |
| Fecal coli forms no/100ml | 35 | 850 | 430-- 590 | 10 | 80 |

In this watershed the tea plantation land use is integrated with the estate settlements and hence the water pollution risks of streams in tea plantation land uses are both agrochemical

and human origin and follow a closer pattern with population distribution. The table 1 bellow depicts levels of indicator parameters for nutrient and fecal pollution in streams draining

through different land uses. The NO3 and TP content in the tea plantation landuse appear to be very much high compared to baseline levels indicating nutrient pollution risk in the planta tion land use. The results also show high feacal pollution levels compared to baseline levels suggesting un managed human waste disposal and fertilizer input as responsible sources for high nitrate levels and feacal coliform counts in stream water. The field observations revealed that fecal pollution risk is closely linked with the poor water sanitation and hygiene patterns of the plantation sector community.

*5.3 Pollution risk on the drinking water sources*

Representative parameters namely; Nitrate concentration and Fecal coliform counts were used as indicators of agro chemical pollution and pollution due to human waste. The level of indicators in the drinking water sources were evaluated against baseline levels. The nitrate values in all drinking water sources were higher than the baselines level (0.04mg/l), (fig 4) whereas feacal pollution indicator bacteria i.e. feacal coliform counts in more than 65 percent of the samples were very much higher than the baseline level i.e. 35 colonies /100ml, (fig 5) indicating influence of both agrochemicals and feacal pollution of drinking water sources.

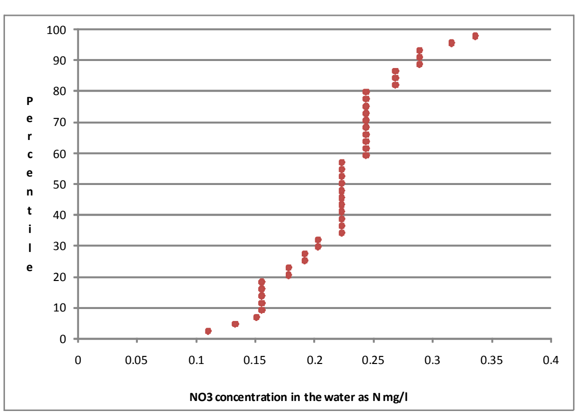


Fig 4 Percentile distribution of nitrate levels in the source water of community water supplies

As majority of these waters are supplied directly with out any treatment they do not comply with respective national standards for indicator bacteria for fecal pollution which should be maintained zero in drinking water supplies at the consumer end.

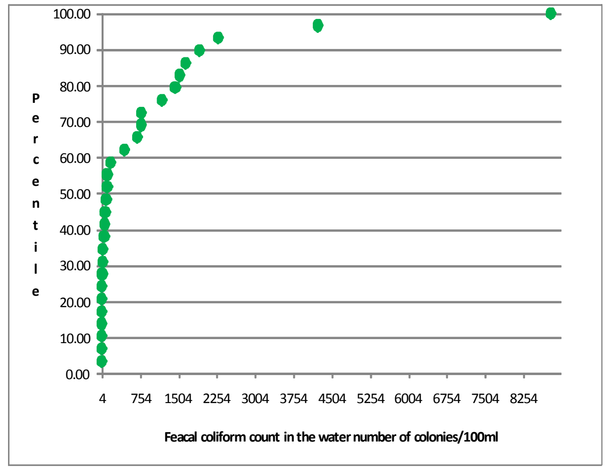


Fig 5 Percentile distribution of fecal contamination levels in the source water of community water supplies

*5.4 Water pollution risk and the incidence of waterborne infections*

Consumption of feacaly contaminated water poses a threat of water borne infections. Evaluation of data on the incidence of waterborne infections (fig 6) show a gradual decrease in number of patients infected with water borne infections such as Dysentry, Diarrhea and Viral Hepatitis.

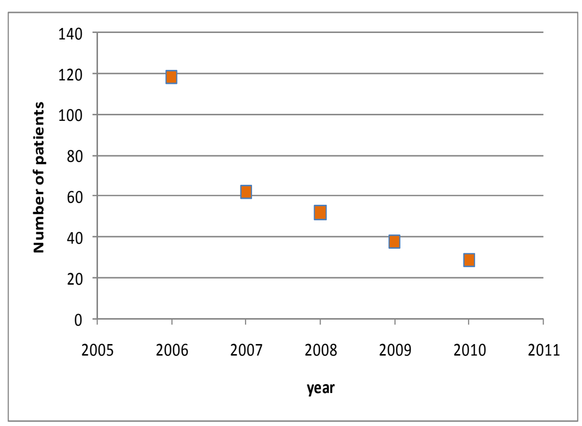


Fig 6 Temporal distribution of waterborne infections

According to the MOH office records (ref 3) the reasons for the decline in number of patients over the time are due to several factors such as improved awareness on sanitation, medical facilities and people's trend in attending to private clinics of which the number of patients seeking medical care in the private clinics are not accounted in the MOH records.

However, compared to total resident population in the watershed the infected number of patients amount only to 0.015% indicating very low levels of risk on waterborne infections opposed to pollution risk on the drinking water sources.

### *5.5 Impact of hydro power reservoir cascade on the catchment water quality*

The fig 7 and table 2 present the drainage pattern and water quality characteristics of five cascade reservoirs/ponds respectively. Of the total water intercepted by the catchment about 60% is extracted for hydropower generation. This water leaves the watershed at the Polpitiya and the water quality at this point represent the water flowing through the hydropower reservoir complex. As water in the upper reaches of the Kehelgamu oya sub watershed is diverted to Laxapana pond at Norton pond the water quality at the draining point of the Kehelgamu oya is represented fully by stream water in the lower reach of Kehelgamu oya (fig 3 & 7).

In the water quality picture nitrogen based pollutants (NH3 & NO3) show an increasing trend along the reservoir system while P and E-Coli levels show a trend of recession. The most appropriate limnological explanation could be that the reservoir cascade acts as recipients for pollution. I.e. the Nitrogen pollutants appear to be converted to final from of NO3 and entering the aqueous phase while P settles in the sediment layer in which reservoirs act as P traps. Along the reservoir cascade feacal pollution indicator bacteria are subjected to decay resulting counts as low as natural baseline levels at the lower reaches of the watershed.

The water quality comparison between water draining through reservoirs and that of Kehelgamu oya provide clear evidence on role of reservoir system as a pollutant recipient (Table 2).

Table 2 Water quality in the Cascade of hydropower reservoirs

| Major land use | Muskeliya resevoir ( upper catcment) | Castlereigh Reservoir ( upper catchment ) | Norton reservoir ( middle catchment ) | Canyon pond (middle catchment) | Laxapana pond (lower catchment0 | Polpitiya (Total reservoir drain) | Kehelgamu oya lower reach |
|---|---|---|---|---|---|---|---|
| NO3-N mg/l | 0.85 | 0.072 | 0.1 | 0.14 | 0.2 | 0.20 | 0.04 |
| NH3-N mg/l | 0.03 | 2.9 | 0.01 | 0.16 | 4.0 | 0.20 | 0.3 |
| TP–P mg/l | 0.08 | 0.08 | 0.08 | 0.14 | 0.04 | 0.04 | 0.05 |
| E coli no/100ml | 220 | 760 | 520 | 640 | 10 | 10 | 80 |

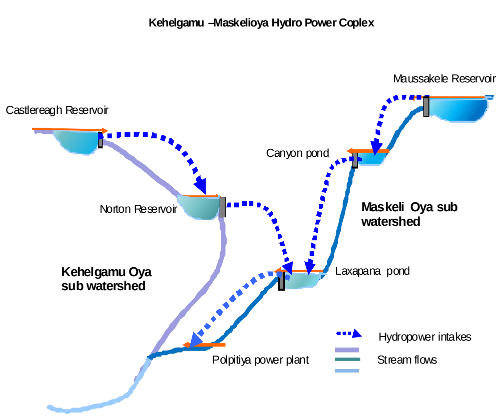


Fig 7 Kehelgamu-oya Muskeli oya Hydro power complex

## **7.** CONCLUSIONS AND RECOMMENDATIONS

The study portrays effectiveness of the watershed unit approach in water resource health evaluation, highlight effects of human influence on the water quality, the focuses on water pollution risks management and moreover, the utility value of existing/local information sources in the characterization of water pollution risk. The approach demonstrates a higher long-term viability as attributes for evaluation came mainly from existing local data bases. However, the water pollution risk interpretations could not use full scale of attributes given in the conceptual framework due to limitations encountered with respect to reliability of local information sources suggesting "through proper information management systems at local watershed level, the reliability of the approach could be greatly improved”


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