Chapter 4
Monitoring the Effects of Anthropogenic Activities on Water Quality: Von Bach Dam, Namibia

J. J. Sirunda and J. P. Msangi

Abstract This chapter is based on research carried out to examine the effects of human activities on the quality of water flowing into Von Bach Dam, the water in the dam as well as water flowing out of the dam during different seasons. The specific objectives of the study were to determine water quality at different points around the Von Bach Dam during different seasons of the year. The study involved bacteriological testing, turbidity determination and temperature variation within the water body. Other tests carried out include dissolved oxygen content and pH levels. Bacteriological analysis showed high presence of *E. coli* which is a strong indication of pollution emanating from human activities. High values for soil and other organic matter were found to be the major contributing factors in raising the dam water turbidity which was responsible for algal blooms in the dam. The pH of the water during summer and winter did not indicate potential harmful effects to human health as these were within the limits of the NAMWATER standards for drinking water.

Keywords Eutrophication · Anthropogenic activities · Inflow and outflow discharge · Turbidity · Coliform bacteria · *E. coli* · Dissolved oxygen · PH levels

Introduction

Namibia is the second driest country in Sub-Sahara Africa and water scarcity is the norm for most of the country. Surface water is almost non-existent with the exception of the five trans-boundary rivers marking its political boundaries with

J. J. Sirunda (✉)
Water Quality and Environmental Services, NamWater, P Bag 13389, Windhoek, Namibia
e-mail: SirundaJ@namwater.com.na

J. P. Msangi
WELER Consulting Services, PO Box 98138, Pelican Square, Hochland Park, Windhoek, Namibia
e-mail: jpmsangi@iway.na

J. P. Msangi (ed.), *Combating Water Scarcity in Southern Africa*,
SpringerBriefs in Environmental Science, DOI: 10.1007/978-94-007-7097-3_4,

Botswana, Angola, Zambia and South Africa. These include Kwando-Linyati-Chobe, Okavango, Kunene, Zambezi and the Orange Rivers. Most of the other rivers are ephemeral carrying water only during and soon after the rains.

Namibia has great temperature variations, the average annual temperature along the coast being less than 16 °C, about 18–20 °C in the central area, 20–22 °C in the south, and more than 22 °C in the northern-eastern parts. However during the hottest months (i.e., October–February), the temperature at the coast remains less than 20 °C, it rises to over 30 °C in the centre, over 36 °C in the southern and over 32 °C in the northern-eastern parts of the country.

In Namibia, annual rainfall varies across the country, where the coastal areas on average receive less than 50 mm per year, the southern part 50–200 mm per year, the central parts 200–400 mm per year and the northern part receives 400–550 mm per year (Mendelsohn et al. 2002). The eastern Caprivi receives the highest average rainfall of about 650 mm per year while some areas in the central part like Tsumeb receive 510 mm per year, Otavi 540 mm per year, and Grootfontein 550 mm per year. Most parts of the country receive rainfall during the summer months (November–March) with the exception of the south–western corner of Namibia which receives winter rainfall during June–August.

The country is characterized by very high evaporation losses (southern areas 2380–2660 mm per year; north-eastern parts 1680–1820 mm per year and less than 1680 mm per year along the coastal area. The highest rates occur during October–January (Mendelsohn et al. 2002).

Overview

This chapter is based on research carried out to examine the effects of human activities on the quality of water flowing into Von Bach Dam, the water in the dam as well as water flowing out of the dam during different seasons. The specific objectives of the study were to determine water quality at different points around the Von Bach Dam including inflow and outflow points at different depths. The study set out to compare quality of water collected at different points in order to determine the effects of human activities on the water quality of the dam. The main research question of the study was to determine the season during when human activities affect the water quality of Von Bach dam the most. Therefore the study involved bacteriological testing, turbidity determination and temperature variation within the water body. Other tests carried out included dissolved oxygen content and pH levels. Three sampling stations were selected randomly: one for testing inflow discharge, one for assessing effects of intense human activities and the last one for assessing the outflow discharge. A total of thirty eight (38) water samples were collected at different depths during winter and summer months.

The driving force behind the choice of Von Bach dam is the fact that there are very few fresh water sources available to meet the ever increasing demands of the country’s growing population and industrial activities. These few sources are also at risk from pollution resulting from uncontrolled waste dumping, poorly managed agricultural lands, industrial effluents and air borne pollutants. Von Bach Dam, located on Swakop River seven kilometers from Okahandja, town is the main source of fresh water for the largest town and capital city of the country, Windhoek. The dam is a recreation facility which also serves as a water source not just for Windhoek but also for the nearby Okahandja town.

Von Bach Dam has a capacity 48.5 Mm^3. It is a popular venue for aquatic recreation for activities such as water skiing, yachting, windsurfing, boating as well as angling. At Von Bach Dam there are bungalows and camping facilities on the south eastern banks of the dam. Wild animals including kudu provide added attraction. The catchment area of Von Bach Dam, used mainly for livestock farming and small-scale crop cultivation to produce food for family and friends, has seasonal rivers which cut off villages such as Ovitoto during the rainy season when they are in flood.

Anthropogenic activities which take place in a catchment area are assumed to affect the quality of the water in rivers and storage dams. Human activities are considered to be the highest contributing factor in water pollution of water bodies all over the world. In any given river basin, human activities emanating from different sources affect water characteristics particularly those taking place in the upper catchment area.

Overall assessment of drinking water system should take into consideration any historical water quality data that assists in understanding sources of water characteristics and drinking water system performance both over time and following specific events like excessively high rainfall. The efficiency in managing water resources and potentially polluting human activities in the catchment will influence water quality downstream as well as groundwater aquifers.

Turbidity of the water is important in quality monitoring because this is related to cleanliness (aesthetically) of the water. Turbidity is caused mainly by high concentrations of biota such as phytoplankton and sediments. Waters with low concentrations of total suspended solids are clearer and less turbid than those with high total suspended solids. Turbidity as a water quality parameter affects the aquatic system as it can alter light intensities in a water column thus potentially altering potential rates of photosynthesis and the distribution of organisms within the water column. Lowered rates of photosynthesis may in turn affect the levels of dissolved oxygen available in a water body, thus affecting large organisms such as fish. Sedimentation increases the turbidity of water in a reservoir (dam). Some sediments originating from the catchment's top soil following bad cultivation practices introduce nutrients into the river and eventually into a reservoir, dam or lake and thus affect primary producers in the plankton by reducing light penetration to the lower layers. Eventually this alters the composition of benthic communities.

Dissolved oxygen analysis is a key test in water pollution and waste water treatment process control since it is a key determinant of survival of most aquatic organisms. It is vital in the process of cellular respiration and without sufficient dissolved oxygen most aquatic life would not survive. Some organisms require high amounts of dissolved oxygen than others. Aquatic plant populations, rainfalls, rocks on the river bed, time of day, water velocity and water temperature are contributors to total dissolved oxygen. It is documented that dissolved oxygen in a water body should not exceed 110 % of the concentration of oxygen in the air because at certain concentrations it could be harmful to aquatic life.

Water pH in a body of water is affected by the age of the water body because of the chemicals discharged into it over time by communities and industries. Most lakes and dams/reservoirs are basic when they are first formed and become acidic with time due the buildup of organic materials. Surface waters receive a variety of organisms discharged in municipal wastewater effluents, industrial wastes and agricultural activities. Water temperature affects and accelerates the growth of adapted organisms in the water body. Microbial growth is not only keyed to bacterial strains that quickly adjust to limited nutrient sources, but also to water temperature.

Coliform bacteria are used as indicator organism in assessing the quality of the water and the presence of these bacteria indicates that pollution has occurred which can be associated with fecal contamination from man or other warm blooded animals (Gronewold and Wolper 2008). The characteristics of these bacteria include all aerobic and facultative anaerobic gram-negative, non-spore forming, rod-shape bacteria. This bacteria ferment lactose to produce a dark colony with a metallic sheen. The sheen may cover the entire colony and may appear only in the central area or on the periphery.

Testing water for all possible pathogens is complex, time-consuming, and expensive. However it is relatively easy and inexpensive to test for coliform bacteria. There are three different groups of coliform bacteria; each has a different level of risk. Total coliform, fecal coliform, and *E. coli* are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. *E. coli* is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform and if it appears that total coliform is present, the sample will also be tested for either fecal coliform or *E. coli*, depending on the lab testing method.

Reviewed Literature

Nowadays most river basins are to some extent subjected to the effect of the human economic activity (Ismaiylov et al. 2007). The changes in their runoff can be caused by both a direct impact on it and changes in the conditions of its formation resulting from an impact on the physiographic conditions (topography, soils, vegetation, etc.). It is generally true that a minimum quality of surface water must be ensured in order to maintain property self-purification (Rump and Krest 1992). In this report it is stated that the degree of pollution always parallels changes in the ecological situation.

Water quality in adjacent streams or upper or lower reaches of the same stream typically exhibit similar trends (Chang 2008). In this study Chang shows that the spatial patterns of nutrient concentrations confirm the influence of urban land cover on stream water quality. He stated that, watersheds that have been disturbed by deforestation and urbanization are less able to process these pollutants because of a reduction in microbes and processes that naturally work to immobilize nutrients. He reports that, some forms of nitrogen or phosphorus show elevated concentrations as flow rises due to a flushing effect.

The environmental state of water bodies is affected not so much by particular chemical elements as by complexes of elements that are simultaneously present in water and bottom sediments (BS) (Klenkin et al. 2008). Their research found out that the comparative assessment of BS pollution in different regions of aquatic ecosystems and the investigation of sources of the increased anthropogenic pollution are only possible with the compensation for differences in the granulometric composition of BS. River water runoff is regarded as the most available resource that renews every year (Magritskii 2008). Magritskii suggested that this property of river water makes it most significant for practice as compared with water resources that renew more slowly or groundwater that renew annually.

In his analysis, Magritskii found out that, the effect of economic activity on the river basins of North European and Asian parts of Russia is much weaker. He stated that the rate of intensification of sulfate reduction in water bodies is a sign of a stronger anthropogenic impact on the environment and natural water bodies. On the other hand, other researchers including Chicherina and Leonov in their work dated 2008, state that the rate of sulfate reduction (SRR) is a representative characteristic allowing one to control anthropogenic pollution and eutrophication processes in water bodies (Leonov and Chicherina 2007).

The productivity growth of a water body is affected by an increase in phosphorus release from bottom sediments (Martynova 2008). According to Martynova it is believed that the main reason for the increase of the internal phosphorus load in a eutrophic water body is the expansion of the area under anaerobic sediments, from which phosphates absorbed by iron compounds under aerobic conditions are released. Additionally, biogenic substances (N and P compounds), which are present in natural waters, play a very important role in the processes taking place in streams and largely effect the chemical composition and physical properties of water (Samarina 2008). In this report it is stated that on one hand, the need to restrict eutrophication requires the identification of links between biogenic substances flow formed at the watershed and on the other hand, the dynamics of the water body eutrophication.

According to the study conducted by Samarina in (2008), the destruction of high-molecular organic compounds of natural and anthropogenic origin intensifies the contamination of a water body and disturbs the normal vital activity of animal and plant organisms. In this study, it is stated that, analyzing the anthropogenic factors resulting in the appearance of phosphorus and different mineral forms of nitrogen in the streams in industrially developed areas of Central Chernozem region, the following factors could be identified: the intense development of national economy, accompanied by an increase in the number of settlements in the region, points to an abrupt increase in the amount of domestic and industrial effluents, as well as uncontrolled washes off from settlements and industrial zones within the watershed area. Meanwhile in his study conducted in 2007, Jing Zhang argues that industrialization and urbanization along the coastal population centers have brought great changes in the land cover and natural material fluxes from watersheds to receiving bays and estuaries.

Generally, the temperature of the water under treatment is another factor to consider in the operation of a sedimentation basin (Goula et al. 2008). It is stated that, usually, a wastewater treatment plant has the highest flow demand in the summer, whereas when the water is colder, the flow in the plant is at its lowest. As ecosystems with slow water circulation, lakes and reservoirs (dams) have similar formation and development regularities (Martynova 2006). Martynova argues that, as compared to natural lakes, reservoirs have larger catchment area and higher rate of water circulation; they are subjected to a higher pollutant load and have a higher capacity of retaining all sorts of human-induced contaminants.

Elsewhere, the environments receiving runoff from urban areas have been reported to experience an increase in their concentrations of suspended sediments, nutrients and metals (Pecorari et al. 2006). According to them, rivers, lakes and other water bodies are frequently located in urbanized areas and such waters are not only used for recreational purposes, but usually act as collectors of diverse types of effluents. Pecorari et al. stated that traditionally, few limnologists have paid attention to the effects of urbanization on the ecology of these impacted aquatic systems. However, it is a well-known fact that urbanization causes great changes in the hydrology, geomorphology and water quality, which can be stronger than the impacts caused by other uses of the land such as agriculture and forestation.

Data Collection and Analysis

Non-probability sampling techniques were used, where the probability of any particular member of the population being chosen is unknown. The selection of sampling units is arbitrary as researchers rely heavily on personal judgment. In this study, the sample size was selected in such a way that it represented the characteristic of the total population. Nineteen (19) water samples were collected on each trip, the first samples were collected during winter (June 2008) and the second samples were collected during summer (September 2008).

Water samples were collected at each of the three selected stations, two at each depth using a niskin bottle with a depth finder and an attached weight. Water from the *niskin* bottle was poured into sampling bottles (glass bottle 250 ml) and the sample bottles were labeled before they were stored in the cooler box at a temperature below 10 °C. Samples in the cooler box were taken to the laboratory where they were refrigerated at a temperature below 10 °C and analyzed within

Table 4.1 Average bacteria density for summer season

Station	Depth (m)	Heterotrophic plate count (CFU/1 ml)	Total coliform (CFU/100 ml)	Fecal coliform (CFU/100 ml)	*E. coli* presence/ absence
Inflow	0	2026.5	146.7	184.3	Present
Ski club	0	736	30.7	1.7	Present
Outflow	0	362.5	27.3	0.7	Present
	9	373.5	*79*	1.3	Present
	18	395	36.7	0.7	Present
Total average		778.7	64.1	37.7	

24 h to test for total coilforms, fecal coilforms, and pH. Parameters such as, dissolved oxygen, turbidity and temperature were measured and recorded in the field. To measure Temperature and Dissolved oxygen, an oxygen meter was used after calibration and a secchi disk was used to determine turbidity.

The data was subjected to statistical analysis using a two way-ANOVA. This analysis revealed that there was a significant difference in temperature readings at all the stations in both winter and summer at 5 % significance level. The analysis also revealed that the water temperature readings were significantly different at 5 % significance level. Dissolved Oxygen level analysis revealed that there was no significant difference in dissolved oxygen levels for winter and summer months.

Collected data on turbidity, pH and heterotrophic counts bacteria at all the three stations were also subjected to statistical analysis using ANOVA. The analysis showed that there was no statistical difference in turbidity of the dam water at all stations during winter and summer at 5 % significance level. Similarly, no statistical difference in pH of the water was recorded for all the stations for winter and summer months at 5 % significance level and that the heterotrophic plate bacteria count were the same in both winter and summer. Statistical analysis for total coliform counts bacteria from all the stations were not statistically different from each other at 5 % significance level.

However, statistical analysis of fecal coliform counts revealed that there was a marked difference on samples collected from the three stations during winter and summer at 5 % significance level. Samples from the inflow water station for both winter and summer contained *E. coli* while the water for the other two stations showed presence of *E. coli* only during summer months (Table 4.1).

Heterotrophic Plate Count Bacteria (CFU/1 ml)

The average density of the heterotrophic plate counts bacteria are shown in Tables 4.1 and 4.2. The winter results show that the average density was higher at the Ski Club station at 0 m depth compared to the Inflow and Outflow stations at

Table 4.2 Average bacterial density for winter season

Station	Depth (m)	Heterotrophic plate count (CFU/1 ml)	Total coliform (CFU/100 ml)	Fecal coliform (CFU/100 ml)	*E. coli* presence/ absence
Inflow	0	850	87.7	9.7	Present
Ski club	0	1400	70.3	1.7	Present
Outflow	0	750	118	0	Absent
	9	450	102	4	Present
	18	350	116.3	4.3	Present
Total		760	98.9	3.9	

the same depth. On the other hand, in Table 4.2 the average heterotrophic plate count bacteria were higher at the Inflow Station at 0 m depth.

The inflow station in Table 4.2 shows higher total coliform counts bacteria compared to the other two stations. The temperature differences during winter and summer affects the average total coliforms as indicated in the two tables where the total coliform counts are more in winter than in summer. Despite the low temperatures in winter, the population of bacteria is one to one and half orders of magnitude than in summer. The Inflow station had a higher count of fecal coliforms in both winter and summer. The total average of coliform counts was higher in summer than in winter giving an inverse proportion relationship between total coliform and fecal coliform. *E. coli* was confirmed at all stations during summer at all depths except at the Outflow during winter.

As expected the water temperature was higher during summer than during winter at the Outflow Station, however the rate of decrease with depth was faster in summer than during winter (Fig. 4.1). The water temperature at the Inflow and Ski Club Stations showed low variations with depth and as such had no significant bearing on the water of Von Bach dam.

The Outflow Station recorded higher levels of dissolved oxygen at the surface water in summer than in winter. The dissolved oxygen dropped rapidly with depth during the season. Comparatively, in winter the water dissolved oxygen decreased more slowly with depth than during summer (Fig. 4.2).

The effect of water temperature on bacteria counts was clearly demonstrated by the bacteria average density which was much lower at the surface during summer compared to the winter season when there was a rapid increase of bacteria count with depth. This supports the fact that the higher the temperature the lower the bacteria replication process (Dolgonosov et al. 2006).

The Outflow Station experienced rapid drop of dissolved oxygen with depth during summer and a more gradual drop during winter. This difference can be explained by the fact that low surface water temperatures in winter supports fast growth in bacteria in all depths as compared to summer scenario when temperatures are high at the surface but drop rapidly with depth thus supporting fast growth of bacteria at greater depths (Fig. 4.3). The dissolved Oxygen levels at the

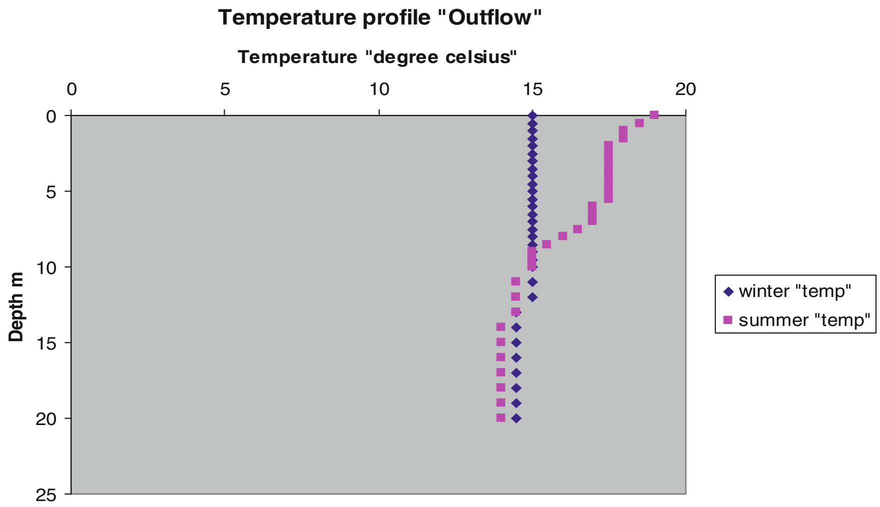

Fig. 4.1 Winter and summer temperature profile at the outflow station

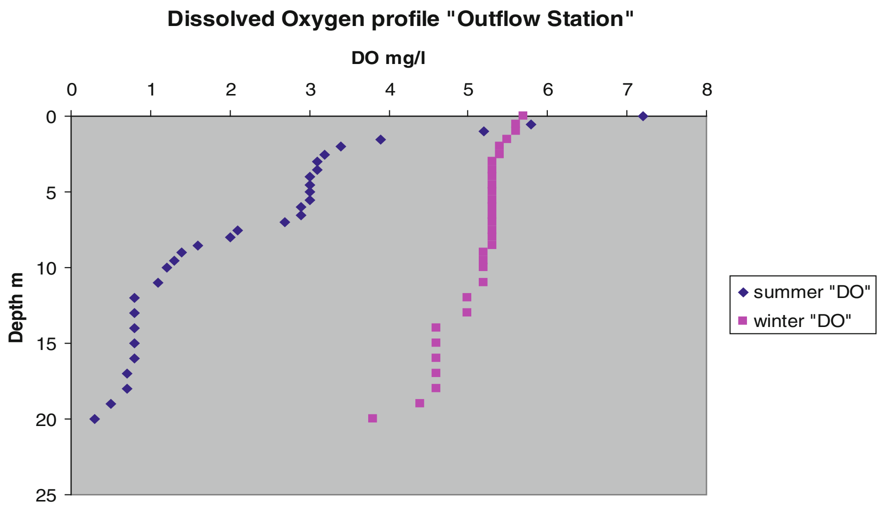

Fig. 4.2 Winter and summer dissolved oxygen at the outflow station

Inflow and Ski Club stations in both summer and winter showed fewer constant variations with depth (Figs. 4.3 and 4.4).

Turbidity levels were higher at the Inflow Station during winter than other stations. This was caused mainly by in flowing water from the catchment area which suffers from overgrazing and is characterized by high losses of top soil loosed by continuous trampling by large herds of livestock. This high sediment

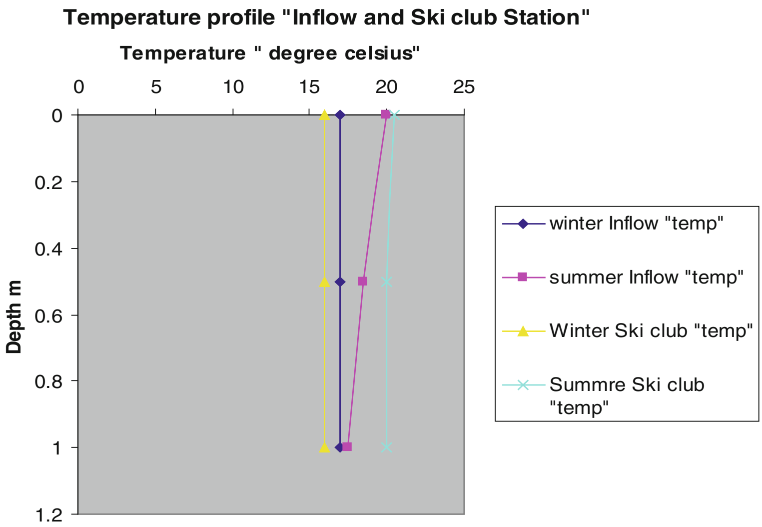

Fig. 4.3 Summer and winter temperature profiles at the inflow and ski club stations

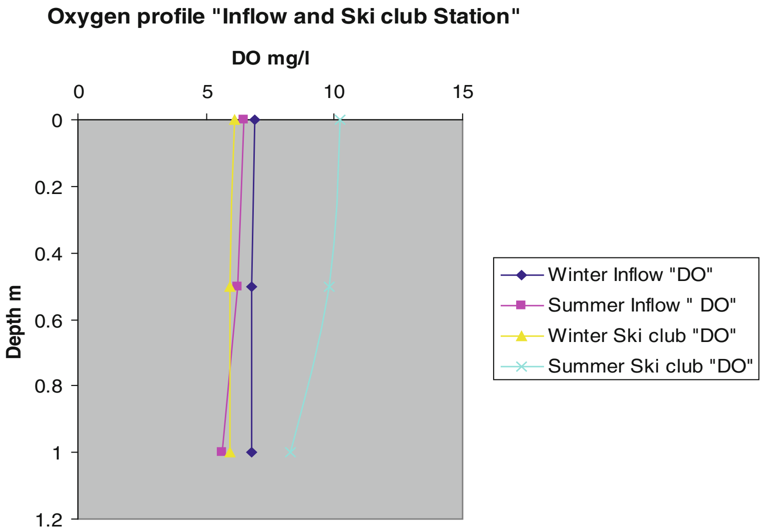

Fig. 4.4 Summer and winter oxygen profiles at the inflow and ski club stations

concentration can be linked with the low counts of coliform bacteria at the Inflow Station because when the level of turbidity increases, the water loses its ability to support a diversity of aquatic organisms. Water turbidity has a direct relationship with temperature and dissolved oxygen because when turbidity level is high, the suspended particles absorb more heat from the sunlight and lead to an increase in water temperature which results in lower dissolved oxygen in the water. Hence the higher the turbidity the lower the bacterial counts.

The water turbidity level was higher during winter at the inflow station as the secchi disk's color disappeared at 31 cm deep compared to that of summer when the color disappeared at 46 cm deep; a difference of 15 cm. The Outflow Station showed turbidity content at 72 cm and Ski Club showed turbidity at 87 cm while during summer the turbidity content was observed at 38 and 50 cm at the Outflow and Ski Club stations respectively.

The pH values of the water at the Inflow Station in winter and summer were constant while at the Ski Club and Outflow Stations some variations were observed. This is explained by the effluents from the residential and resort bungalows at the Ski Club Station.

According to water classifications based on NAMWATER standard guidelines for drinking water, water at the Ski Club Station is fit for human consumption during all seasons. However water at the Inflow Station is fit for human consumption during summer because the bacterial counts were in group B and C (Appendix 4.1).

Discussion

The major sources of microbial pollution to the dam water emanate from human and warm-blooded animal excrements that enter into water bodies with municipal wastewaters and drains from cattle farms and areas polluted by manure (Dolgonosov et al. 2006). Heterotrophic plate count consists of diverse groups of microorganisms that have wide range of metabolic capabilities and culture requirements and constitute a wide range of risks to public health (Lechevallier and Mcfeters 1985). The growth of many heterotrophic is more pronounced than the coliform subset of this population, often providing abrupt surges in density during summer (Geldreich et al. 1977). Heterotrophic plate counts bacteria cause health risk in patients who are in hospitals, clinics as well as at home. Some species and strains of Psedomonas, Bacillus and sarcina suppress coliform bacteria detection in water; this suppression is due to the increase in heterotrophic plate counts bacteria. Fecal and total coliform bacteria are indicators of potential fecal pollution and water-borne pathogenic threats to human health.

In this study, high coliform bacteria counts recorded at the Inflow Station during both seasons is an indicator of pollutants gathered by rain water from the catchment area and delivered to the streams flowing into Von Bach dam. The presence of the bacteria at the other two stations can be explained by the discharge from the resort bungalows and directly from the people who swim and bathe in the water body. Animals who are watered directly from the dam could also be a contributor to this direct pollution through their droppings.

Studies done elsewhere have demonstrated that there are low population of microorganisms in summer and autumn which can be due to phytoplankton blooming bringing about an increase in pH values. Raised pH values suppress vital activity of bacteria flora (Dolgonosov et al. 2006). The observed high pH value (close to 10) at both the Ski Club and the Outflow Stations in summer confirms this observation documented in the report by Dolgonosov et al. Combined with high temperatures and high turbidity, such an occurrence could have contributed to the low summer coliform counts at the two stations at 0 m depth. *E. coli* was confirmed at the Inflow Station in both seasons and at the Ski Club Station during summer.

Bacterial count for heterotrophic plate counts, total coliform, and fecal coliform shows high counts in summer at the Inflow Station with lower content of turbidity than it was in winter with highly turbid water. This shows that, turbidity plays a very important role in bacterial growth and they are inversely related. According to the study conducted by Martynova in 2006 it was confirmed that the higher the plankton production (and the higher the rate of its destruction in the water column, which lags behind the increase in the productivity), the higher the rate of organic matter accumulation, and, respectively, the higher the sedimentation rate. The high population of coliforms in winter could be explained by high release of organic matter at the catchment surface because of decay of dead plant material accumulated in summer and delivered by surface waters into the estuary. This observation is well indicated in this study, whereby coliform counts at the Inflow Station was high in summer compared to the counts during winter. The reason could be that, the decay of dead plant material was taking place in summer while the water has already reached the inflow station from the catchment area. During winter the outflow station was inundated by dead plant material and since the decay process is very slow in winter, few counts of coliform (fecal and total) were found.

Dissolved Oxygen is used by bacteria during the decaying process of organic matter in the aquatic system. Dissolved Oxygen is also produced during the photosynthesis process by phytoplankton in the aquatic system as a by-product. Possible increase in organic matter in the Von Bach dam could be through soil losses resulting from poor agricultural practices in the catchment area, land clearing for building structures around the dam and through direct disposal of organic matter by people frequenting the dam to engage in recreational activities. The consequences of these activities may have contributed towards lowering oxygen levels in the dam water. Elsewhere, it has been documented that aquatic ecosystems changes were brought about by the changes in the relative contribution of major water pathways and biotic concentrations originating from human activities in the watershed (Zhang 2007).

Turbidity which depicts clear state of the water is mainly caused by the sediment released from the catchment area and from activities around the dam. This sediment carries nutrients into the water body resulting in rapid bacteria growths. On the other hand, an increase in the pH of water lowers the growth of microorganisms such as bacteria. The rise in pH values is caused by the increase in organic material within the water body because when these materials decompose, carbon dioxide is released and the carbon dioxide combines with water to form carbon acid. Even though the acid formed is weak, large amount of this can lower the water pH. Dumping of chemicals into the water by individuals, industries and communities in the watershed can affect the water pH as well. Chemicals contained in shampoos can affect the water quality; these chemicals are frequently used by residents occupying holiday bungalows around the dam and those using the ablution facilities of the recreational infrastructure. Daily visitors to the dam can also contribute to this through dumping. This explains the variations of the pH values at the Ski Club and Outflow Stations throughout the two seasons against the constant pH values at the Inflow Station over the two seasons.

Conclusions

Natural waters become polluted when the polluting material upsets the natural balance of microorganisms, plants and animals living near or in the water body or makes the water unsafe for human consumption or for recreation. In this article, Chan et al. also stated that natural water may contain a wide variety of microorganisms; in fact it is not unlikely that one might find representatives of many of the major categories of microorganisms in a specimen from such sources. Therefore monitoring the water quality overtime being it seasonal, monthly or even weekly may give conclusive evidence on the quality of the water.

In this study on Von Bach Dam, the bacteriological analysis of fecal coliform indicates that there is pollution emanating from human activities since the results from some of the water samples tested for *E. coli* confirmed the presence of these microorganisms. It is assumed that water at these stations was contaminated by human activities both in the catchment area and around the dam. However, it should be noted that, not all the fecal coliform counts were from human and animal intestines as it was observed in the entire confirmation test for *E. coli* where some of the samples were negative results (brown and orange color). The higher detection of coliform bacteria at the Inflow Station could be attributed to the increase in nutrients load coming into the dam from the catchment area.

Heterotrophic plate count is not sensitive to human activities, as this test is for diverse groups of microorganisms but the water with higher level of heterotrophic plate count when consumed can cause illness or spoil food. The results from this test indicated that, the water at all the stations were of little risk to human health, since the counts were within the limits stipulated by NAMWATER as of little risk to human health. The pH of the water during summer and winter did not indicate potential harmful effects to human health because the pH levels results were within the limits of the NAMWATER standards for drinking water. Organic matter and soil sediments reaching the dam from the catchment area and from construction around the dam were the main indicators of anthropogenic activities affecting the water quality in Von Bach Dam.

Organic matter in the dam affects aquatic organisms by altering the temperature and dissolved oxygen levels upon which the aquatic organisms depend on for growth. Soil sediments and the organic matter values were found to be the major contributing factors in raising the dam water turbidity. Chemicals from shampoos and other cosmetics used by frequent visitors to the dam for recreational activities were found to be responsible for the elevated pH values particularly during summer months.

Recommendations

While this study generated some useful data which pointed to an indication of possible pollution to Von Bach Dam, it is recommended that for effective assessment of the impacts of anthropogenic activities on the dam water, more intensive testing should be carried out where more sampling stations would be established and more water samples collected using more sophisticated and accurate instruments that will afford higher precision.

It is also recommended that NAMWATER as the managing agent charged with providing potable drinking water to the country's population, should carefully address the dangers of waste water disposal particularly that which contain chemicals found in cosmetics. Over time these chemicals would accumulate to be a major threat to the balance of the aquatic ecosystem. These imbalances may affect the water quality in the long run so as to increase water purification costs.

Furthermore, it is recommended that more effective disposal methods of refuse from building construction around the dam should be put in place so as to prevent accumulation of shrubs and grass in the dam water which then lowers the amount of light penetrating the water body which deprives the light and energy required by phytoplankton for photosynthesis; it also increased the temperature of the surface water.

Lastly, it is recommended that periodic cleaning to remove debris should be instituted. Debris and organic matter reaching the dam from the catchment area accumulates at the Outflow Station which raises nutrients load that is likely to lead to an increase in the growth of phytoplankton. Rapid phytoplankton growth leads to algal blooms which affects the appearance of the water and kills aquatic organisms by preventing light penetration to the benthic layer of the water body. Debris affects the aquatic ecosystem by altering the pH of the water, temperature, dissolved oxygen, light intensity and turbidity. Thus filtration structures should be installed just above the inflow points to minimize the quantity of debris entering the water body from the catchment area.

Appendix 4.1: Water Classifications Based on NAMWATER Standard Guidelines for Drinking Water

The classification Consists of four groups:
Group A Water with an excellent quality
Group B water with good quality

Group C Water with low health risk
Group D Water with high risk, which is unsuitable for human consumption.

Summer standards

Stations (summer)	Inflow				Ski club				Outflow			
Limits to groups	A	B	C	D	A	B	C	D	A	B	C	D
pH	8.6						9.6				9.3	
Turbidity (Secchi cm)	*	*	*	*	*	*	*	*	*	*	*	*
Dissolved oxygen (mg/l)	*	*	*	*	*	*	*	*	*	*	*	*
Temp (°C)	*	*	*	*	*	*	*	*	*	*	*	*
Heterotrophic plate count (cfu/1 ml)			2027			736				362.5		
Total Coliform (cfu/100 ml)	Beyond limits						30.3			24		
Fecal Coliform (cfu/100 ml)	Beyond limits					1.7				0.7		
E. coli (presence or absence)	*	*	*	*	*	*	*	*	*	*	*	*

Star (*) indicate water quality parameters which are not in NAMWATER standard guidelines

Winter standards

Stations (winter)	Inflow				Ski club				Outflow			
Limits to groups	A	B	C	D	A	B	C	D	A	B	C	D
pH	8.5				8				7.5			
Turbidity (Secchi cm)	*	*	*	*	*	*	*	*	*	*	*	*
Dissolved oxygen (mg/l)	*	*	*	*	*	*	*	*	*	*	*	*
Temp (°C)	*	*	*	*	*	*	*	*	*	*	*	*
Heterotrophic plate count (cfu/1 ml)		850					1400			750		
Total Coliform (cfu/100 ml)			87.7				70.3		Beyond Limits			
Fecal Coliform (cfu/100 ml)			9.67			1.67			0			
E. coli (presence or absence)	*	*	*	*	*	*	*	*	*	*	*	*

Star (*) indicate water quality parameters which are not in NAMWATER standard guidelines. Water at the ski club station meets the NAMWATER standards in all seasons because all the measured parameters fall in groups which are less health-risk to human beings. The inflow station water was also less risky to human health because the bacteria counts were in groups B and C

References

Chang, H. (2008). *Spatial analysis of water quality trends in the Han River basin, South Korea*. (Vol. 42(13), pp. 3285–3304). Boulevard: Elsevier. Department of Geography, Portland State University. Retrieved July 09, 2008, from http://login.oaresciences.org/whalecom www.sciencedirect.com/whalecom0/science?_ob=MImg&_imagekey=B6V73-4S92THT-4-N&_cdi=5831&_user=6181540&_orig=browse&_coverDate=07%2F31%2F2008&_sk=999579986&view=c&wchp=dGLbVzW-zSkWW&md5=7d1c307918bdf5695981d891a4c366b2&ie=/sdarticle.pdf

Dolgonosov, B. M., Korchagin, K. A., Messineva, E. M. (2006). *Model of fluctuations in bacteriological indices of water quality, Vodnye Resursy*. (Vol. 33(6), pp. 637–650). Springer: Retrieved August 08, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/r6086x40v384h164/fulltext.pdf

Goula, A. M., Kostoglou, M., Karapantsios, T. D., Zouboulis, A. I. (2008). *The effects of influent temperature variations in a sedimentation tank for portable water treatment—A* *computational fluid dynamics study*. (Vol. 42(13), pp. 3405–3414). Thessaloniki: Elsevier. Retrieved July 16, 2008, from http://login.oaresciences.org/whalecomwww.sciencedirect.com/whalecom0/science?_ob=MImg&_imagekey=B6V73-4SHF4D0-1-N&_cdi=5831&_user=6181540&_orig=browse&_coverDate=07%2F31%2F2008&_sk=999579986&view=c&wchp=dGLbVzz-zSkzV&md5=e6c9c89599f967bd71809a330a36be08&ie=/sdarticle.pdf

Geldreich, E. E., Nash, H. D., Spino, D. (1977). *Characterizing bacterial population in treated water supplies: A progress report*. Kansas City: AWWA Water quality.

Gronewold, A. D, Wolpert, R. L. (2008). *Modeling the relationship between most probable number (MPN) and colony-forming unit (CFU) estimates of feacal coilform concentration*. (Vol. 42(13), pp. 3327–3334). Retrieved July 16, 2008, from http://login.oaresciences.org/whalecomwww.sciencedirect.com/whalecom0/science?_ob=MImg&_imagekey=B6V73-4S98TTJ-1- &_cdi=5831&_user=6181540&_orig=browse&_coverDate=07%2F31%2F2008&_sk=999579986&view=c&wchp=dGLbVzW-zSkWW&md5=67a61f5bc9843de78c2937caafe0c3d2&ie=/sdarticle.pdf

Ismaiylov, G. Kh., Fedorov, V. M., Nezhad, S. D. (2007). *Assessment of possible anthropogenic changes in the runoff of the Syr Darya river on the basis of a mathematical model*. (Vol. 34(4), pp. 359–371). Vodnye Resursy: Springer. Retrieved August 26, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/g7082h23244m3663/fulltext.pdf

Klenkin, A. A., Pavlenko, l. F., Korpakova, I. G., Studenikina, E. I (2008). *Characterization of the Azov Sea bottom sediments by the degree of present pollution with a complex of most hazardous toxicants*. (Vol. 35(1), pp. 88–92) Vodnye Resursy: Pleiades Publishing. Retrieved July 09, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/v181r714831t6340/fulltext.pdf

LeChevallier, M.W. and McFeters, G.A. (1985) Interactions between heterotrophic plate count bacteria and coliform organisms. Appl. Environ. Microbiol. Vol. 49, 1338–1341.

Leonov, A. V., Chicherina, O. V. (2007). *Sulfate reduction in natural water bodies*. (Vol. 35(4), pp. 417–434). Moscow: Springer. Retrieved August 06, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/w4xl32r8345k0922/fulltext.pdf

Magritskii, D. V. (2008). *Anthropogenic impact on the runoff of Russian Rivers emptying into the Arctic Ocean*. (Vol. 35(1), pp. 3–16). Moscow: Pleiades Publishing. Retrieved July 09, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/t321x7p668688875/fulltext.pdf

Martynova, M. V. (2006). *Production-destruction processes in water and the accumulation of matter on the beds of lakes and reservoirs*. (Vol. 33(6), pp. 670–676). Vodnye Resursy: Springer. Retrieved June 24, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/j15962m00141n85k/fulltext.pdf

Martynova, M. V. (2008). *Impact of the chemical composition of bottom sediments on internal phosphorus load*. (Vol. 35(3), pp. 339–345). Moscow: Springer. Retrieved August 06, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/d845q1644660x34t/fulltext.pdf

Mendelsohn, J., Jarvis, A., Roberts, C., Robertson, T. (2002). *Atlas of Namibia: A portrait of the land and its people*. Windhoek, Namibia: Ministry of Environment and Tourism.

Pecorari, S., Jose de Paggi, S., Paggi, J. C. (2006). *Assessment of the urbanization effects on a lake by zooplankton*. (Vol. 33(6), pp. 677–685). Vodnye Resursy: Springer. Retrieved August 20, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/a75r34n8682632p5/fulltext.pdf

Rump, H. H., Krest, H. (1992). *Laboratory manual for the examination of water, waste water and soil* (2nd ed.). New York: VCH.

Samarina, V. P. (2008). *Spatial and temporal variability of biogenic substances in the oskol river water*. (Vol. 35(3), pp. 346–352). Vodnye Resursy: Springer. Retrieved August 06, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/l4u345t03481456w/fulltext.pdf

Zhang, J. (2007). *Watersheds nutrient loss and eutrophication of the marine recipients: A case study of the Jiaozhou bay, China*. (Vol. 7(6), pp. 583–592). Netherlands: Springer. Retrieved July 27, 2008, from http://login.oaresciences.org/whalecomwww.springerlink.com/whalecom0/content/080870q526263m16/?p=6fdadef055df4c549bc60e2bb2a0b071&pi=1