LITERATURE REVIEW

A Review of the possible impact caused by wastewater on a wetland habitat.
A case study: Anse Intendance, Mahé, Seychelles

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1. Background information on Anse Intendance

The Anse Intendance beach and wetland region on Mahé, Seychelles, are considered areas of high biodiversity. The beach is deemed one of the most important nesting grounds for sea turtles on Mahé (Somers et al. 2020), and is also a popular destination for swimming, sunbathing, and surfing, by tourists and locals alike. The wetland holds a significant amount of biodiversity, deemed one of the most crucial wetlands in the whole of Seychelles, due to it being a reproductive site for critically endangered terrapin species (Somers et al. 2020). The outlet of the wetland to the sea is also a popular swimming spot for young children and infants, who are not able to venture into the sea (personal observations).

The Anse Intendance beach

The Anse Intendance beach is regarded as one of the world's most renowned beaches (Duvat 2008). Along with its picturesque beauty, the beach hosts nesting populations of both Hawksbill (*Eretmochelys imbricata*) and Green (*Chelonia mydas*) turtles, and is considered one of the beaches with the highest sea turtle nesting activity on Mahé, making significant the potential impact of disturbances on this beach (Somers et al. 2020). The beach crest vegetation along Anse Intendance is particularly important for these species as it provides the necessary coverage and shelter during nesting. Hawksbill turtles have a nesting season, starting in September and ending in March, while Green turtles are known to nest all year-round (Mortimer 1984). Nesting Hawksbills generally emerge with the high tide, regardless of time of day, while nesting Green turtles emerge only at night (Mortimer 1984). Both species of turtle use the entire length of Anse Intendance beach for nesting (Somers et al. 2020).

The Anse Intendance wetland

Wetlands in general are known to exhibit high rates of plant and tree growth; the dense vegetation provides food and shelter for different animal and bird species (Kokkal et al. 2007). Migratory birds often build their nests in the dense vegetation of wetlands for breeding, rearing, or feeding of their young (Nayak & Bhushan 2022). Among the different wildlife, fishes, mammals, amphibians, and reptiles have found their home for food, shelter, and reproduction within wetlands (Nayak & Bhushan 2022).

The wetland at Anse Intendance is home to indigenous, rare, and migrant species of reptiles, birds, fishes, and amphibians (EIA Report 2020). Many of these are classified as rare and threatened species, and are considered to be 'species of special concern' or 'Key Biodiversity Area (KBA) species (EIA Report 2020). In fact, during the biodiversity assessment carried out as part of the EIA process, 15 species of special conservation value were inventoried (EIA Report 2020). These are highlighted in Table 1 below.

Table 1: A list of species of special conservation value that were identified during the biodiversity assessment during the EIA process (Table adopted from the actual EIA Report, 2020)

Habitat-type	Group	Scientific name	Common name	Status	KBA
Woodland	Reptiles	*Ailuronyx seychellensis*	Bronze-eyed Gecko	Native	Yes
Wetland	Fishes	*Anguilla bicolor*	Freshwater Eel	Native	Yes
Wetland	Birds	*Ardea purpurea*	Purple Heron	Migrant	Yes
Beach	Reptiles	*Chelonia mydas*	Green turtle	Native	Yes
Beach	Reptiles	*Eretmochelys imbricata*	Hawksbill turtle	Native	Yes
Woodland	Birds	*Falco araea*	Seychelles Kestrel	Native	Yes
Wetland	Birds	*Ixobrychus sinensis*	Yellow bittern, Maka zonn	Native	Yes
Wetland	Crustacean	*Macrobrachium equidens*	Kanmaron pitakle	Native	Yes
Wetland	Crustacean	*Macrobrachium lar*	Kanmaron gran lebra	Native	Yes
Wetland	Birds	*Nycticorax nycticorax*	Black crown night heron	Native	Yes
Wetland	Fishes	*Pachypanchax playfairii*	Golden panchax, Gourzon	Native	Yes
Woodland	Plants	*Pandanus balfourii*	Vakwa bordemer	Native	Yes
Wetland	Retiles	*Pelusios castanoides ssp. intergularis*	Seychelles Yellow bellied mud terrapin	Native	Yes
Wetland	Retiles	*Pelusios subniger ssp. parietalis*	Seychelles Black Mud turtle	Native	Yes
Wetland	Amphibian	*Tachycnemis seychellensis*	Seychelles Treefrog	Native	Yes

Amongst the prominent wildlife at Anse Intendance are the freshwater turtles. There are two species found within the wetland: the endemic Yellow-bellied *(Pelusios castanoides ssp. Intergularis*) and endemic Black Mud turtles (*Pelusios subniger ssp. Parietalis*), both listed as Critically Endangered on the IUCN Red List (Gerlach 2008b, c). Although freshwater turtles have been protected in Seychelles by the Wild Animals and Birds Protection Act since 1996 (GOS 1994), their overall population trend is declining, mainly due to habitat loss and degradation from drainage and development (Sommers et al. 2020; Gerlach 2008a). Of note, very few terrapin populations are known to be actively reproductive in the wild (Somers et al. 2020). Both species found within the Intendance wetland have been documented to be reproductive (Somers et al. 2020), proving the necessity to provide stringent protection to this specific area.

Monitoring and conservation work done by the Marine Conservation Society, Seychelles (MCSS), indicate that in 2020, there was a population estimate of 123

Yellow-bellied terrapins and 170 Black Mud terrapins within the Anse Intendance wetland (Somers et al. 2020). An additional 63 terrapins (both Black Mud and Yellow-bellied) from the Anse Royale populations were temporarily translocated to the Anse Intendance wetland at the request of the Ministry responsible for Environment (MACCE) between 2017 and 2018 (Somers et al. 2020). This was done as a precautionary measure while wetland rehabilitation works were undertaken in the Anse Royale wetland (Somers et al. 2020). These 63 individuals were not recaptured before the closing of the Banyan Tree and Wildlife Conservation and Rehabilitation Centre, and their current recapture and translocation status is unknown (Somers et al. 2020).

Besides being considered to hold significant amounts of biodiversity, wetlands also provide many essential ecosystem services such as carbon sequestration, flood control, groundwater recharge, nutrient removal, toxic retention, and biodiversity maintenance (Maltby 2009; Vymazal 2011). While being essential habitats, they are also ecologically sensitive. In fact, in Seychelles, wetlands are considered the most severely threatened habitat, having been reduced to a fraction of their pre-human settlement cover (Somers et al. 2020). Therefore, considering these factors, development in and around wetland areas should recognise the value of these habitats to threatened species during critical life stages, and should be designed to cause as little harm and disturbance; they should instead promote the presence of these species (Somers et al. 2020).

2. Background information on the development project

In 2018, the Banyan Tree Seychelles Resort ownership changed hands, and extensive renovation works were planned for the Resort (EIA Report 2020). The proposed works required authorisation from the Ministry of Environment (MACCE), in accordance with the Environment Protection Act (EPA), Act 18 of 2016. In accordance with the Environment Protection (Impact Assessment) Regulations (S.I. 39 of 1996), Clause 5(1) a Class I Environmental Impact Assessment (EIA) was required. To undertake the EIA process, Hill View Resorts (Seychelles) Limited (HVRSL) appointed DJ Environmental Consultants (“DJEC”) (Lead Environmental Assessment Practitioners) and Mr. Ian Charlette (Local Environmental Assessment Practitioner) as the independent environmental consultant for the Project (EIA Report 2020). This EIA Report forms part of the environmental approval process.

The EIA process is designed to determine the possible impacts the proposed development may have on the environment, to recommend mechanisms to enhance the positive impacts and to minimise the negative impacts (EIA Report 2020). Specialists were appointed to undertake specific studies to determine the impacts of the development on the environment, including a biodiversity assessment of the area (EIA Report 2020).

3. Possible impact within the Anse Intendance wetland caused by wastewater discharge

Since development/ renovation of the Hotel (ex-Banyan Tree) commenced in 2020, there have been various suspected breaches of the EIA Report, which was prepared by DJEC for HVRSL in November 2020. An expert opinion by Ebrahim (2023) was produced to outline several of these suspected breaches. One such breach included the suspected unauthorised discharge of wastewater into the wetland at Anse Intendance.

Within this literature review, I will be focussing on the potential threat/destruction that may have been caused to the wetland and wildlife at Anse Intendance, based on water samples taken and analysed.

Two separate water samples were taken within the Anse Intendance wetland, by two separate individuals, at different times of the year, and analysed by two separate labs. Sample 1 (Figure 1) was collected and analysed in June 2023, while Sample 2 (Figure 2) was collected and analysed in August 2023.

FINAL CERTIFICATE OF ANALYSIS

COA N°:	780223-0
COA Date:	27/06/2023
Page	1 / 1

Customer: H2O International Cape Town
Order N°:
Client Reference N°:
Project N°: CT 23-025394

Analysed By Swift Silliker (Pty) Ltd t/a Mérieux NutriSciences
7 Warrington Road, Claremont, Western Province, South Africa

Phone: +27216838436 Fax: +27216834695
E-mail: za.customercare@mxns.com

Received from H2O International Cape Town

Work Space 6, The Powder Mill
5 Sunrise Circle, Ndabeni, 7405, Cape Town, South Africa

E-mail: chris@h2ocapetown.co.za

To: Le Mesurier Trading cc
Mr. Chris Le Mesurier
Work Space 6, The Powder Mill
5 Sunrise Circle Ndabeni
7405
Cape Town
South Africa

SAMPLE DESCRIPTION

Lab Sample Ref #: CT 23-025394-001 **Sample N°:** 4918993 **Test Date:** 21/06/2023
Category Detail: Water **Sample Condition:** SEALED **Date Received:** 21/06/2023
Product Description:** Vlei water From Mahe Island Seychelles

ANALYTICAL RESULTS

Tests	Analysis Start Date	Results	Units	Limits *[Target value]*
☑ **Coliforms** METHOD: SWJM 48	22/06/2023	200000	cfu/100ml	Result <= 10 cfu/100ml
☑ **Faecal Coliforms** METHOD: SWJM 56	22/06/2023	60000	cfu/100ml	Not Detected cfu/100ml
☑ **Escherichia coli** METHOD: SWJM 45	22/06/2023	60000	cfu/100ml	Not Detected cfu/100ml
☑ **TMA** METHOD: SWJM 35	22/06/2023	30000	cfu/ml	Result <= 1000 cfu/ml

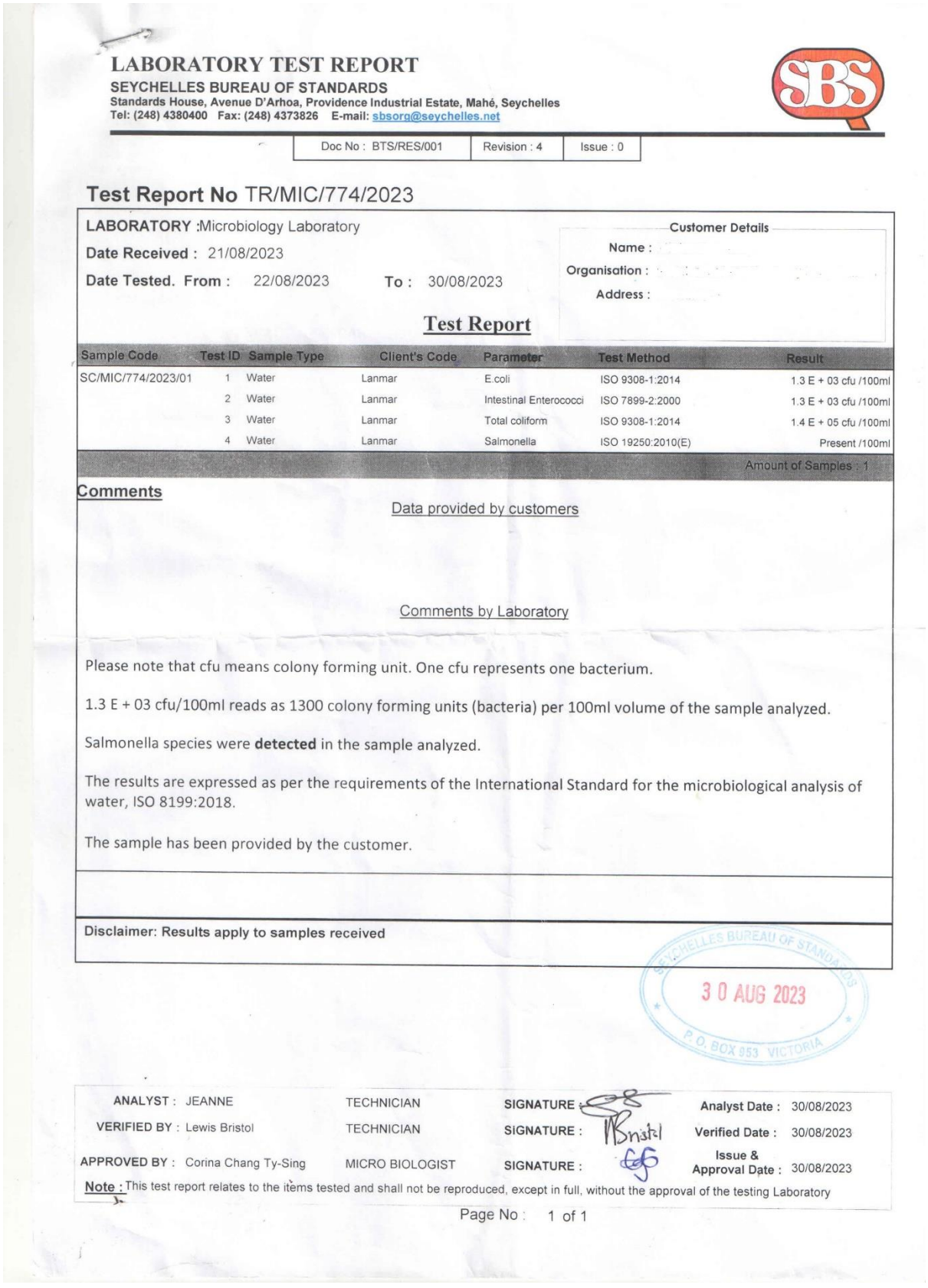
☑ Accredited analysis * Non Accredited analysis NC Non Conformance ** Customer provided data Changed Data

TMA = Total Microbial Activity / Total Viable Plate Count.
No growth = Not detected / less than the lower detection limit of the test method, for the specified sample type / volume of sample tested.
Tests marked with a tick in this report are included in the SANAS Schedule of Accreditation for this laboratory T0050.
Tests marked with a * in this report are not included in the SANAS Schedule of Accreditation for this laboratory T0050.
** Data provided by the customer.
Tests marked with a plane in this report are Subcontracted Tests and are not included in the SANAS Schedule of Accreditation for this laboratory T0050.
The test report relates only to the specific item submitted for testing. It furnishes or implies no guarantee whatsoever, in respect of a similar item that has not been tested.
The test report applies to the sample as received where the laboratory has not been responsible for the sampling stage.
Opinions and interpretations expressed in this report are not included in the SANAS Schedule of Accreditation for this laboratory T0050.

Results validated on 27/06/2023
By: Fahiema Paleker
Technical Signatory

Fahiema Paleker
Digitally Signed By: Fahiema Paleker
Reason: COA Digital Sign
Signed On: 27/06/2023 16:46:09

Figure 1: Sample 1 Lab test results of the water samples taken within the Anse Intendance wetland in June 2023



LABORATORY TEST REPORT

SEYCHELLES BUREAU OF STANDARDS
Standards House, Avenue D'Arhoa, Providence Industrial Estate, Mahé, Seychelles
Tel: (248) 4380400 Fax: (248) 4373826 E-mail: sbsorg@seychelles.net

Doc No : BTS/RES/001	Revision : 4	Issue : 0

Test Report No TR/MIC/774/2023

LABORATORY : Microbiology Laboratory
Date Received : 21/08/2023
Date Tested. From : 22/08/2023 **To :** 30/08/2023

Customer Details
Name :
Organisation :
Address :

Test Report

Sample Code	Test ID	Sample Type	Client's Code	Parameter	Test Method	Result
SC/MIC/774/2023/01	1	Water	Lanmar	E.coli	ISO 9308-1:2014	1.3 E + 03 cfu /100ml
	2	Water	Lanmar	Intestinal Enterococci	ISO 7899-2:2000	1.3 E + 03 cfu /100ml
	3	Water	Lanmar	Total coliform	ISO 9308-1:2014	1.4 E + 05 cfu /100ml
	4	Water	Lanmar	Salmonella	ISO 19250:2010(E)	Present /100ml

Amount of Samples : 1

Comments

Data provided by customers

Comments by Laboratory

Please note that cfu means colony forming unit. One cfu represents one bacterium.

1.3 E + 03 cfu/100ml reads as 1300 colony forming units (bacteria) per 100ml volume of the sample analyzed.

Salmonella species were **detected** in the sample analyzed.

The results are expressed as per the requirements of the International Standard for the microbiological analysis of water, ISO 8199:2018.

The sample has been provided by the customer.

Disclaimer: Results apply to samples received

SEYCHELLES BUREAU OF STANDARDS
30 AUG 2023
P. O. BOX 953 VICTORIA

ANALYST : JEANNE	TECHNICIAN	SIGNATURE :	Analyst Date :	30/08/2023
VERIFIED BY : Lewis Bristol	TECHNICIAN	SIGNATURE :	Verified Date :	30/08/2023
APPROVED BY : Corina Chang Ty-Sing	MICRO BIOLOGIST	SIGNATURE :	Issue & Approval Date :	30/08/2023

Note : This test report relates to the items tested and shall not be reproduced, except in full, without the approval of the testing Laboratory

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Figure 2: Sample 2 Lab test results of the water samples taken within the Anse Intendance wetland in August 2023

As can be seen, both samples contained coliforms, faecal/intestinal coliforms, and Escherichia coli (E. coli). Samples taken in August 2023 (Figure 2) also tested for salmonella. The results observed in both tests are considered abnormally high for a functional wetland habitat (Ballesteros et al. 2023; Smalling et al. 2021; Williams et al. 2016) and have shown to have detrimental effects on both humans and wildlife (Summarised in Table 2 below).

Presence of coliforms, faecal coliforms Escherichia coli (E. coli) in aquatic environments

Although wastewater naturally contains millions of bacteria per millilitre, most of them are safe (Omer 2019). The cause for concern is the existence of pathogenic bacteria, such as coliforms in wastewater. Coliform presence in aquatic environments is considered one of the most toxic forms of pollution (Havens et al. 2008), posing tremendous threat to human health (Omer 2019), and detrimental consequences for freshwater ecosystems, biodiversity, and food webs (Bhat & Qayoom 2021). Coliform bacteria are an indicator organism for microbial pollution of water and are highly resistant against inappropriate temperature and pH (Havens et al. 2008). Escherichia coli (E. coli) is the coliform that indicates faecal contamination (Takci et al. 2023). The human intestinal system carries specific populations of microorganisms, with coliform bacteria accounting for a large share of this population (Takci et al. 2008). Based on the results from the water samples within the Anse Intendance wetland, it is safe to assume that at the time of the samples taken, the wetland had faecal contamination.

Presence of salmonella in aquatic environments

Salmonella in aquatic environments is considered among the most significant human pathogens originating from faecal contamination (e.g., Cabral 2010; Cho et al. 2020). Salmonella infections alone are responsible for more than 1 million cases of human illness annually just within the United States (Scallan et al.2011; Huang et al. 2017). Salmonella also poses a serious threat to wildlife in aquatic environments (Table 2).

Table 2: Summary of effects of pathogens found within the Anse Intendance water samples, and the effects it may have on humans and wildlife.

Bacterial Agent	**Associated diseases on Humans**	**Reference(s)**	**Associated effects on resident and migrant wildlife**	**Reference**
Escherichia coli (E. coli)	Acute diarrhea, bloody diarrhea, and gastroenteritis	Ramirez-Castillo et al. 2015 Saxena et al. 2015	Sickness, Mass mortality	Elbahnasawy et al. 2021
Salmonella	Typhoid fever, paratyphoid, salmonellosis	Saxena et al. 2015	Poisoning, Mass mortality	Sadegh Ali et al. 2021
Faecal coliforms	Cholera, Gastroenteritis	Ramirez-Castillo et al. 2015 Saxena et al. 2015	Poisoning, Mass mortality	Sadegh Ali et al. 2021

4. Other possible impacts of wastewater in an aquatic environment

Eutrophication

Eutrophication refers to the abundant growth of phytoplankton, causing an imbalanced system of primary and secondary productivity within an ecosystem (Havens et al. 2008). This imbalance of productivity is caused by nutrient enrichment primarily from fertilizer runoff and/or human waste (i.e., faeces and urine) (Bhat & Qayoom, 2021; Havens et al. 2008; Khan et al. 2014). It is triggered when a water body moves toward becoming enriched in key-limiting nutrients, such as nitrates, phosphates, and initiating symptomatic changes, including the expanded production of algae (Havens et al. 2008). This overgrowth of algae has the potential to cause oxygen depletion (Bhat & Qayoom 2021) within a wetland, and as a result, potentially suffocating wildlife and altering food webs (Valiela et al. 2023). Signs of eutrophication were documented within the wetland at Anse Intendance, by the presence of excessive amounts of duckweed at the surface (Figure 3).

Figure 3: A series of photos taken between February and June 2023 depicting excessive overgrowth of duckweed within the Anse Intendance wetland

PH alteration

Physio-chemical constituents of the water column, such as pH are regarded as potentially important determinants of biotic assemblage composition in wetlands (Harison 1962; Batzer et al. 2006). Alteration of these factors through anthropogenic disturbance, such as wastewater discharge has potential to mediate ecosystem changes in these wetlands, through bottom-up effects on biota (Bird & Day 2014).

Alteration of PH in either direction (i.e., lowering or increasing) can have detrimental effects to wildlife (Williams et al. 2016). Tolerance limits of PH may vary depending on the species (Chen et al. 2008). For example, it has been shown that if certain fish are exposed to acidic waters (low pH) it will affect the number and distribution of chloride cells within their gills, which in turn leads to loss of sodium chloride, acidification of plasma, and can eventually killing the fish (Wendelaar et al. 1990). Contrastingly, when the PH is increased, it may result in the conversion of ammonium to toxic ammonia (NH3) within the wetland. Ammonia is known to cause fish deaths (Goss et al. 1992; Evans 1998; Claiborne et al. 2002). Another study by Chen at al. (2008) showed that exposure to low PH may affect the larvae of amphibians, impacting the survival of certain species.

The current PH or impacts of PH alteration on the wildlife within the Anse Intendance wetland is currently unknown.

Conclusion

The Anse Intendance beach and wetland region on Mahé, Seychelles, are considered areas of high biodiversity. Since development/ renovation of the Hotel (ex-Banyan Tree) commenced in 2020, there have been various suspected breaches of the EIA. One of main suspected breaches documented was the unauthorised discharge of wastewater into the wetland at Anse Intendance. Based on the results from the water samples within the Anse Intendance wetland, it is safe to assume that at the time of the samples taken, the wetland had faecal contamination. Furthermore, there are signs of eutrophication that were documented within the wetland at Anse Intendance. There may be other effects such as PH alteration and extensive wildlife deaths or disease, however, these cannot be confirmed without further investigation.

The current status of the wildlife within the wetland is unknown. Given that there is baseline data on certain species, such as the terrapins, and an inventory on ‘Key Biodiversity Area (KBA) species documented as part of the EIA process, it recommended that extensive investigation is undertaken to determine the possible impact on the wildlife within the Anse Intendance wetland. In addition, it is advisable that long-term ecosystem monitoring (e.g., monitoring of pollutants, water quality and biodiversity) is established to mediate future impacts.

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