Everything you need to know about Bti

2021 UPDATE

gdg Environment
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Bacillus thuringiensis israelensis (Bti) : here and abroad

Being considerably harmless and compatible with non-target species, larvicides created from the toxins of Bacillus thuringiensis var. israelensis (Bti) are globally established by WHO and governing authorities as the preferred alternative to chemical insecticides in mosquito control.

«Canada is no exception and has been a real precursor by adopting, since the early 80s, the responsible choices of equipping itself with biological control tools against insect pests (Btk) (see the Health Canada website: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/bacillus-thuringiensis-subspecies-kurstaki.html and biting insects (Bti)» (see the Health Canada website: https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/bacillus-thuringiensis-subspecies-israelensis.html .

In Europe, more than 150 million people have benefited from the treatments with Bti since the authorities abandoned chemical larvicides and switched to Bti. It should be noted that, on the European side, Bti treatments are authorized in protected areas (such as areas included in the European Natura 2000 inventory), while in most provinces, protected areas (parks, reserves) are excluded from any Bti treatments.

Biological is better: Canada occupies a very enviable position; many provinces rely exclusively on biological larvicides for the control of mosquitoes and black flies.

How is Bti used?

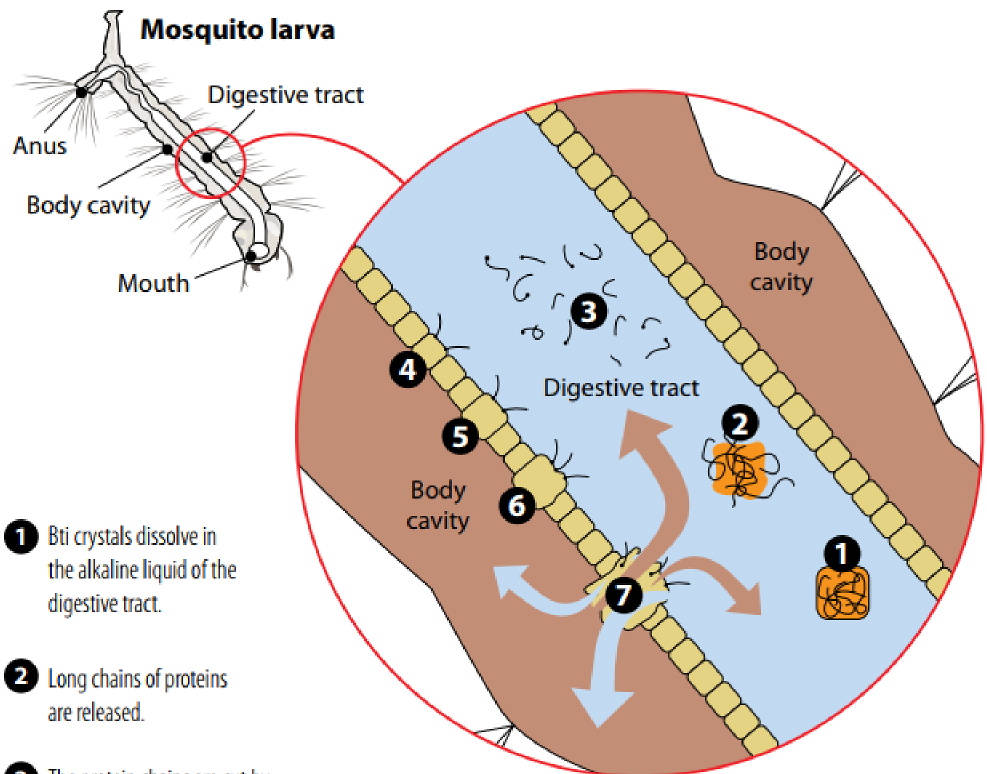
Bti is used to control mosquitoes and black flies. It is also used in the prevention of diseases transmitted by mosquitoes, such as West Nile virus, and allows a better quality of life for people affected by the nuisance caused by these insects. Bti is a non-toxic environmentally friendly solution for humans and animals and is rapidly degraded in the environment. It has no significant impact on the eating habits of other animal species. This bio-larvicide is applied to standing or running water, or where the mosquitoes and black flies lay. The fight against biting insects using biological larvicides, shows a collective sensitivity to the preservation of natural environments and can contribute to achieving a better balance between the actions of nature and those of man.

Since when do we use Bti?

Bti was first isolated from mosquito larvae in an isolated stagnant pond in the Negev Desert of Israel by Goldberg and Margalit during the summer of 1976. Their work was published in 1977 and, since 1982, Bti is used throughout the world for the biological control of mosquitoes and black flies.

HOW DOES BTI WORK?

During the spore-forming stage of its life cycle, the Bti bacterium produces a protein crystal which is toxic only to mosquito and black fly larvae. These microscopic crystals are ingested by insect larvae when they are feeding. In the alkaline environment of the susceptible insect's digestive system, the crystals are dissolved and converted into toxic protein molecules that destroy the walls of the insect's stomach.



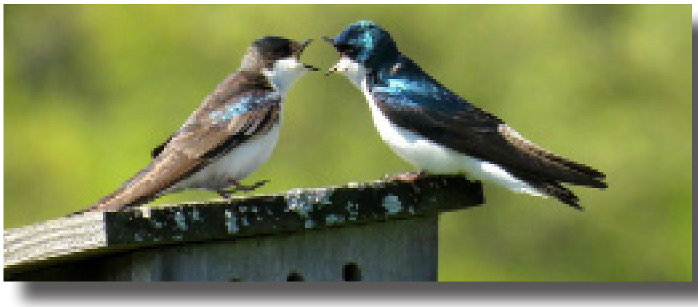
1. Bti crystals dissolve in the alkaline liquid of the digestive tract.
2. Long chains of proteins are released.
3. The protein chains are cut by the enzymes.
4. The segments, which are toxic to the cells of the digestive tract, cling to these cells.
5. Under the effect of the toxin, the cells begin to swell.
6. The cells continue to swell and weaken.
7. Eventually, the affected cells burst causing a perforation of the digestive tract which produces the movement of digestive juices to the body cavity and a reverse motion of the blood of the insect.

The bursting of the digestive tract causes the death of the insect.

SAFETY OF BTI

Authorized in Canada since 1982, Bti-based products are commonly used to control mosquito and black fly populations around the world. Larvicidal activity stems exclusively from the crystalline structure produced during the bacterium's life cycle.

To be toxic, the crystal must be ingested by the target organism, which must have a highly alkaline pH digestive tract, enzymes capable of releasing the toxic molecules and, finally, toxin-compatible cellular receptors.



The safety of Bti and the safety margins for the recommended operational doses indicate that Bti is harmless for micro and macro invertebrates, amphibians, fish, birds and mammals.

Since the first use of Bti (40 years ago), extensive research has provided a strong scientific consensus around the safety of Bti. Long-term studies in Minnesota, Sweden, France and Germany have shown no direct or indirect impact of Bti on non-target organisms.

It should also be noted that the studies, in the field or in the laboratory are carried out with the complete formulation (including additives) and that the effects are well known.

In brief:

1. The harmless nature of Bti is based on a strong global scientific consensus established for nearly 40 years.

2. Bti, as a product, is the best alternative when it comes to controlling biting insects.

3. The control has made it possible to restrict, almost to nothing, the use of pesticides and chemical insect repellents in several municipalities in Canada.

4. Efforts to clean and protect our rivers over the past few decades have allowed these sensitive aquatic insects, known to be excellent bio-indicators, to recolonize and re-establish themselves in our waterways.

NON-TARGET WILDLIFE

Effects on Amphibians

A publication released in 2015 demonstrated a possible impact, in the condition of above legal application rates, on amphibians. Since then, two other articles, published in 2018 and 2019 in Germany, have contradicted the results of this study, recording no mortality and no impact on development. In 2020, a Quebec study commissioned by the Ministère des Forêts, de la Faune et des Parcs (MFFP) came to the same conclusions, showing no significant biological effect. Previously, no direct or indirect effects of Bti on amphibians had been reported following several studies (identified in the article by Boisvert and Boisvert, 2000).

An additional laboratory and field study conducted in Minnesota on the northern leopard frog for 2 consecutive years and another study conducted in India in 2011 came to the same conclusions. Finally, a study carried out in Trois-Rivières on native frogs, had demonstrated no effect on the development of tadpoles feeding on the corpses of mosquito larvae killed by Bti.

Effects on Chironomids

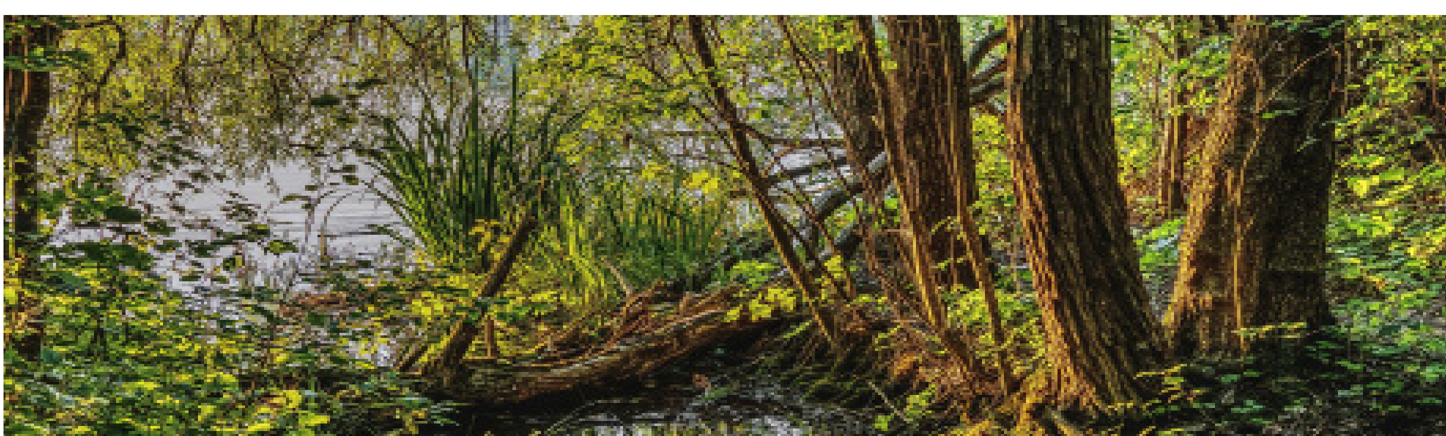
A few long-term field studies have noted a reduction in chironomid density in Bti-treated areas compared to untreated areas. However, no impact was observed in many other field or semi-field studies at similar application rates. The reason is that field studies provide a more accurate picture of the impacts of Bti treatments. Studies carried out in mesocosms and particularly in the laboratory, do not allow to replicate what happens in the field because of the extremely complex variables found in these environments. For example, a researcher determined, in the laboratory, the LC50 of heavy metals on chironomids in three different environments: only water, with sand and with mud taken from the field (Halpern et al 2002). He arrived at 3 completely different results, the larvae in the silt being up to 24 times less sensitive to toxic agents (60 times less sensitive to higher lethal concentrations!).

Recently, the University of Ottawa, sponsored by the City of Ottawa, studied the effect of Bti on chironomids in the field. The report provided to the City of Ottawa reveals that there has been no decline in chironomid population or biodiversity and that the use of Bti had no impact on trapping results.

Effects on Birds

Literature confirms that mosquitoes are not important prey for both insectivorous birds and bats. Studies on the analysis of stomach contents show that the diet of aerial predators (insectivorous birds, bats) has only 1% of mosquitoes, regardless of the high density of mosquitoes available. The energy gain is simply too small to allow predators to feed on these small insects.

In addition, a recent study conducted in Nova Scotia on three swallow species concluded that insect abundance has no effect on brood survival and nestling weight. One of the reasons given is that despite the fact that one region has fewer insects than another, the quantity is still sufficient to allow the birds to survive.



Finally, mosquitoes transmit diseases to birds, including The West Nile virus, here in Canada. Thus, populations of millions of birds have been decimated by mosquitoes in the last 20 years. Bird populations are indeed being impacted by West Nile virus, according to the American organization Center for Disease Control on its page dedicated to this subject.

Research by Poulin et al. 2010, seems to have raised uncertainties with respect to the indirect impact on non-target wildlife of Bti treatments. This study is now contested by several researchers who denounce, among other things, the initial ecological heterogeneity between the control and treated areas chosen for the study and the lack of studies on the availability of prey whose conclusion is based on a hypothesis. The latter have published a study on the impacts of routine Bti treatments on the availability of flying insects as prey for aerial predators.

FOOD WEB

In wetlands, a balanced ecosystem will include a food web, where black fly and mosquito larvae are not the only source of food for aquatic predators. The greater the food web's diversity, the less likely it is that the complete or partial elimination of a single species will have significant consequences.

In the case of biting fly control, biomass reduction is only partial and temporary since treatments are carried out only when the larvae have reached a certain stage of development, meaning they remain available to predators for a good period of time. In addition, during treatment, larvae are always available in the environment for some time for plecoptera, other aquatic insects and fish. Finally, the interval between treatments also gives the biting insects time to recolonize the environment and become available again a few days after treatment. Biological control of biting insects has a low impact on the food web as it affects a highly diversified biocenosis with a high biomass (Figure 1).

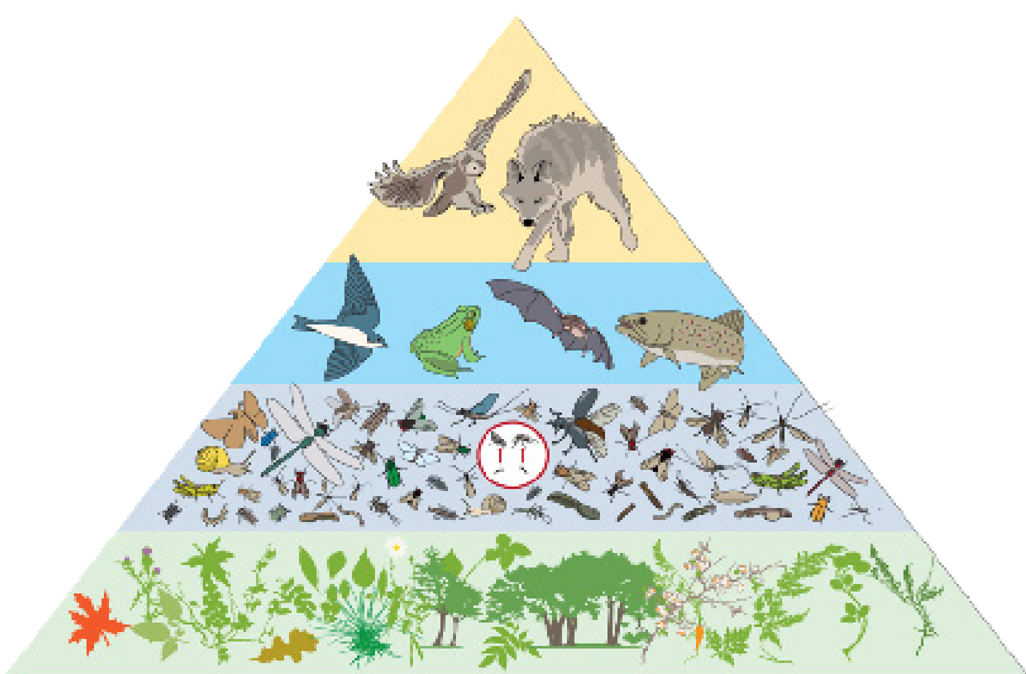


Figure 1: Example of a food web with mosquitoes and black flies (highlighted in the red circle)

Despite the decline of several groups of terrestrial insects, aquatic insects have increased by 38% over the past 30 years, according to a meta-analysis of 166 long-term studies. These data are reliable and very recent since the results were published in the journal Science on April 24, 2020.

These data are not a surprise at GDG since the findings in the field abound in the same direction. In this regard, entomological samplings conducted for more than 30 years in Quebec testify to this increase in mosquito and black fly populations.

Thus, the efforts to clean and protect our rivers over the past few decades have allowed these sensitive aquatic insects, known to be excellent bio-indicators, to recolonize and re-establish themselves in our waterways.

RESISTANCE

There is no resistance to Bti detected in nature. The complexity of the mode of action between the pathogen and the target insect means that the possibility of an insect developing resistance is low. Indeed, this complexity results from the combined and synergistic action of the four proteins associated with the toxic process of the crystals. Although it is theoretically possible to develop resistance to Bti crystals in the field, the probability of such an event occurring is very low.

In addition, in Québec, only a few Bti treatments are carried out during the summer and individuals from untreated areas mix with exposed populations, hindering the development of resistance.

In Germany, a mosquito control program using Bti has been in place since 1981. Over the years, it is estimated that 189 generations of Aedes vexans have been subject to selection pressure due to Bti. A recent study showed that no resistance has developed at treated sites for 36 years. These results are in agreement with those of da Silva Carvalho et al., 2018, which showed no resistance to Bti following exposure of 30 generations of Aedes aegypti.

It has been observed that there may be resistance to individual toxins in a population of a species in the laboratory, but there is no resistance that has been observed on wild mosquito populations after decades of treatment with Bti bioinsecticide.

PUBLIC HEALTH

Effect of Bti on Humans

Mammals do not have an apparatus that can activate the toxin contained in Bti and therefore it is safe for humans. In its 2006 re-evaluation of the registration of Bacillus thuringiensis, the Pest Management Regulatory Agency (PMRA) states that:

"Consumption of treated products cannot be expected to pose a risk to the public, children and infants. The risk of exposure through drinking water is negligible. The low toxicity of Bacillus thuringiensis and the demonstration of its safety suggest that human exposure through drinking water does not pose a significant risk."[1]

1 https://www.inspq.qc.ca/es/node/1127

In addition, no harmful toxic effects, infectivity or pathogenicity by the oral, inhalation, intraperitoneal or dermal routes were observed. It appears that no known toxin or metabolite of B. thuringiensis is an endocrine disruptor or has a toxic effect on the immune system. It is important to note here that the PMRA has access to the complete list of ingredients (even those kept confidential) for each of the registered formulations.

Human health and ecotoxicity studies are conducted on formulations and therefore include the effects of additives or adjuvants in their results. The U.S. Environmental Protection Agency (EPA) also concluded that it was reasonable to believe that dietary exposure to residues of B. thuringiensis would be safe for infants and children. The World Health Organization Pesticide Evaluation Scheme (WHOPES) published a report in 2009 authorizing direct application in drinking water to control certain mosquitoes in countries with diseases such as malaria or yellow fever. This clearly shows that the product is completely safe for humans.

Mosquito-Borne Diseases

In addition to being harmless to humans, Bti reduces the risk of the spread of certain diseases by eliminating their vectors. Indeed, the mosquito is the deadliest animal in the world because of the diseases it can transmit following its bite. A book that was recently published states that «some extrapolated statistics indicate that nearly half of all human beings who have lived to date, or about 108 billion people, have died from mosquito-borne diseases».

Canada's climate, with its cold winters, helps to regulate mosquito populations and prevents some particularly dangerous species from establishing themselves here. However, climate change is currently expanding mosquito territory.

Researchers have found Aedes albopictus, nicknamed the tiger mosquito, in southern Ontario. This mosquito is known to transmit diseases such as the Zika virus, Chikungunya and Dengue fever.

In addition, West Nile virus is endemic in Canada and the number of cases of this reportable disease varies according to weather conditions, mainly as a result of heat episodes that are becoming more frequent in our latitudes.

In 2016, leading world organizations such as the World Health Organization (WHO) recommended a return to larvicide application for healthy vector control. According to WHO, the resurgence of Dengue fever and the spread of emerging diseases such as Zika and Chikungunya are due to reduced funding and vector control efforts. With climate change and global warming in particular, the mosquitoes that carry these diseases are in southern-Ontario and at the gates of Québec... and are gradually moving northward.

LEGAL FRAMEWORK

The registration of biopesticides composed of Bacillus thuringiensis israelensis is managed at the federal level by Health Canada's Pest Management Regulatory Agency (PMRA). The risk assessment is based on scientific data on both the active ingredient and the finished product. For example, the risks on non-target insects are evaluated in relation to Bti, but also in relation to all the by-products that are in the formulations.

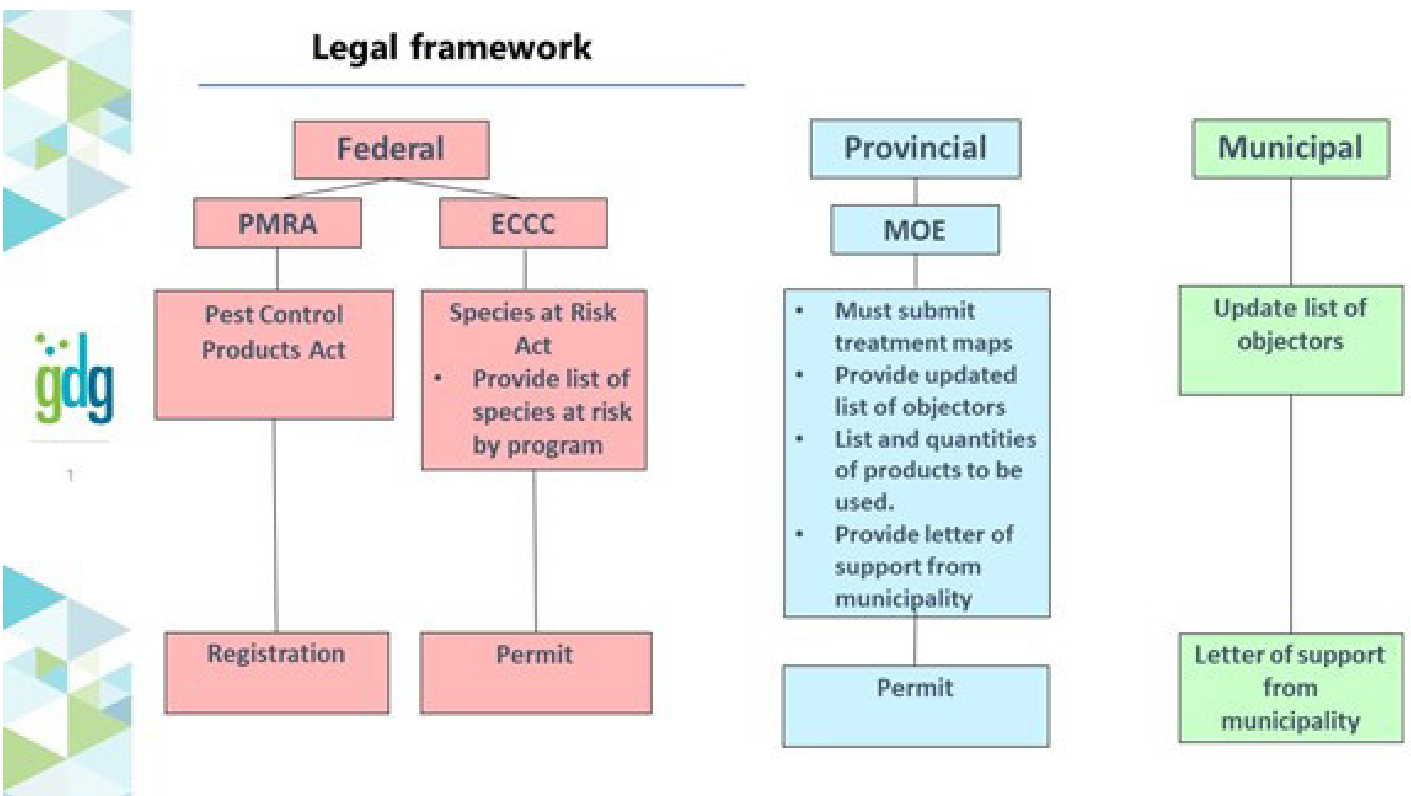
Although Bti is a biopesticide and its safety has been demonstrated for many years, biting insect control programs are nevertheless governed by the Environment Quality Act (EQA) and its regulations. In Canada, a company seeking to treat with Bti must first obtain a permit from the provincial ministry of Environment. In addition, company employees carrying out treatments must obtain a certificate for users of pesticides, specific to operations involving the control of biting insects.

Each biting fly control program must go through the process of applying for environmental permits with the provincial Ministry of the Environment. During the process of permit application, a wildlife notice is requested from the provincial ministry and restriction zones may be applied depending on the species present on the territory. Finally, when the treatments are located in provincially significant wetlands, an authorization from the province must also be requested.

On federal lands, Bti users must also verify for the presence of species at risk and apply for a permit under the Species at Risk Act (SARA) from Environment and Climate Change Canada (ECCC).

Where aerial spraying is required, in addition to complying with the EQA, operators must comply with Transport Canada requirements. All aircraft are certified by Transport Canada for this specific type of application. All pilots are also certified to provincial and Canadian standards. Flight operation policies and procedures are written in accordance with the standards governing the use of aircraft for aerial work, in accordance with the Canadian Aviation Regulations (CARs). Pilots avoid flying over inhabited and sensitive areas and comply with Transport Canada directives (altitude, wind speed, manoeuvring, visual flight rules, etc.).

Regulatory Phases



METHODS USED

The control of biting insects with Bti is already an innovative practice since it uses a biopesticide. Companies and/or organizations follow an integrated pest management plan as part of their control program. To better understand the context in which operations take place, the following is a summary of the methods most commonly used.

First, there are two types of control programs depending on the nuisance observed in the municipality: the treatment of mosquito populations and the treatment of black fly populations. Mosquito larvae develop in standing water while black fly larvae develop in water that flows. It is very rare that aerial applications are carried out to control black flies.

Mosquito Treatment Sequence

For mosquito populations, the ideal time of treatment, taking into account efficacy and label recommendations, is when the majority of mosquito larvae have reached development stages 3 and 4, just before pupation. The first treatment of mosquitoes in the spring is predictable and synchronized with snowmelt and spring flooding.

Subsequent treatments are carried out depending on when the larvae hatch. The outbreak of summer biting species is highly dependent on rainfall. As early as mid-May, heavy rainfall can allow so-called summer species to hatch. Aedes vexans is the most abundant species. Certain habitats can be treated several times. Field teams are trained in mosquito species recognition and are supported by entomologists.

The main species targeted by control programs are those of the Aedes-Ochlerotatus group, which includes the majority of biting species. The following chart shows the evolution of spring and summer mosquito populations, without treatment (Figure 2), and with Bti treatment (Figure 3).

It should be noted that mosquito populations are never exterminated entirely and there is always a residual nuisance. The purpose of biological control of biting insects is to reduce mosquito populations to a level that is acceptable to surrounding populations. Sometimes, the residual nuisance can even be quite significant.

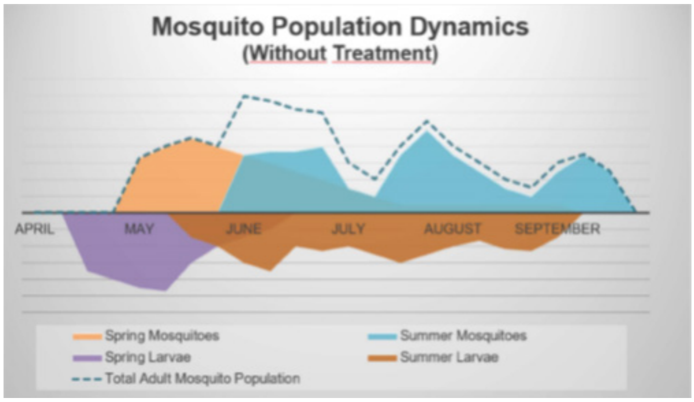


Figure 2: General cycle of larval and adult mosquito populations in Québec without any treatment.

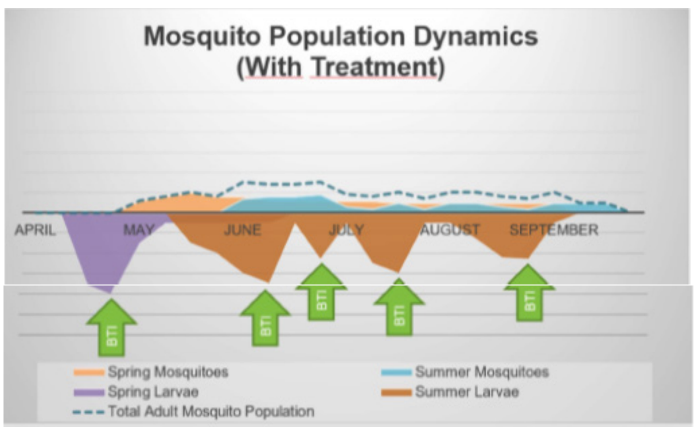


Figure 3. General cycle of larval and adult mosquito populations in Québec with Bti treatment.

Black Fly Treatment Sequence

For black fly populations, the position and number of treatment points may change depending on the location of the larvae. The effective range of the product varies greatly depending on the hydrology and physico-chemical conditions of the watercourse. The flow of small rivers is highly variable throughout the season (snowmelt, rainfall or drought, beaver dams) and this modifies the number and distribution of treatment points. Some warmer watercourses may be treated up to ten times during the season.

Before and After Treatment

Regardless of the type of treatment considered, a sampling of the habitats always precedes spraying operations. Treatments are only carried out if there are larvae of species that bite humans. Prospecting of various habitats allows controls to be carried out at the appropriate time. There is no blanket treatment carried out as a preventive measure. Quality control of treatments is ensured in several ways. The effectiveness of applications is assessed by larval mortality 24 to 48 hours after larvicide applications. Then, the resulting nuisance is assessed using standard entomological net testing and Centre for Disease Control (CDC) light traps.

Aerial Application

Products used for the treatment of mosquito and black fly larvae are all biological products and available in liquid form (VectoBac 1200L) or in granular form (VectoBac 200G). Granules mixed with crushed corn are used in aerial applications. This granular formulation does not contain any residues that could drift or solvents that could evaporate into the atmosphere.

A wind of below 10 knots has virtually no impact on the granular formulation, which falls to the ground and penetrates vegetation to reach aquatic environments. The risk of drift is therefore practically nonexistent.

Aerial applications (by plane or helicopter) are highly accurate due to the use of a GPS guidance system. Using a granular formulation prevents drift and evaporation. In addition, this work is supervised by Transport Canada as mentioned in the section Legal Framework.

Treatment Area

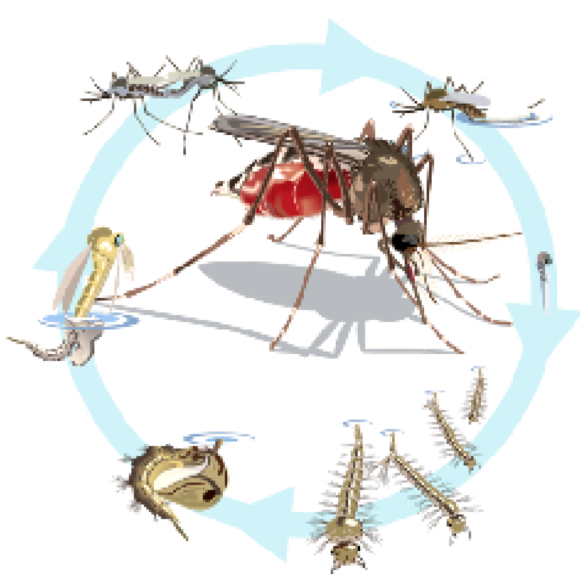
On the maps provided with environmental permit applications, the treatment area indicated corresponds to the potential treatment area. It should be noted that the entire area is never treated, but only the habitats where water is found (following snowmelt or rainfall), and in which larvae of human biting insects are found. Since it is impossible to predict flooded areas, treatment maps cover a larger area than what is actually treated. Often, the first treatment, which follows snowmelt, will cover a larger area than the second, whose area could be reduced by half. Requesting permission to treat a larger area allows for the unexpected occurrence of seasonal weather conditions.

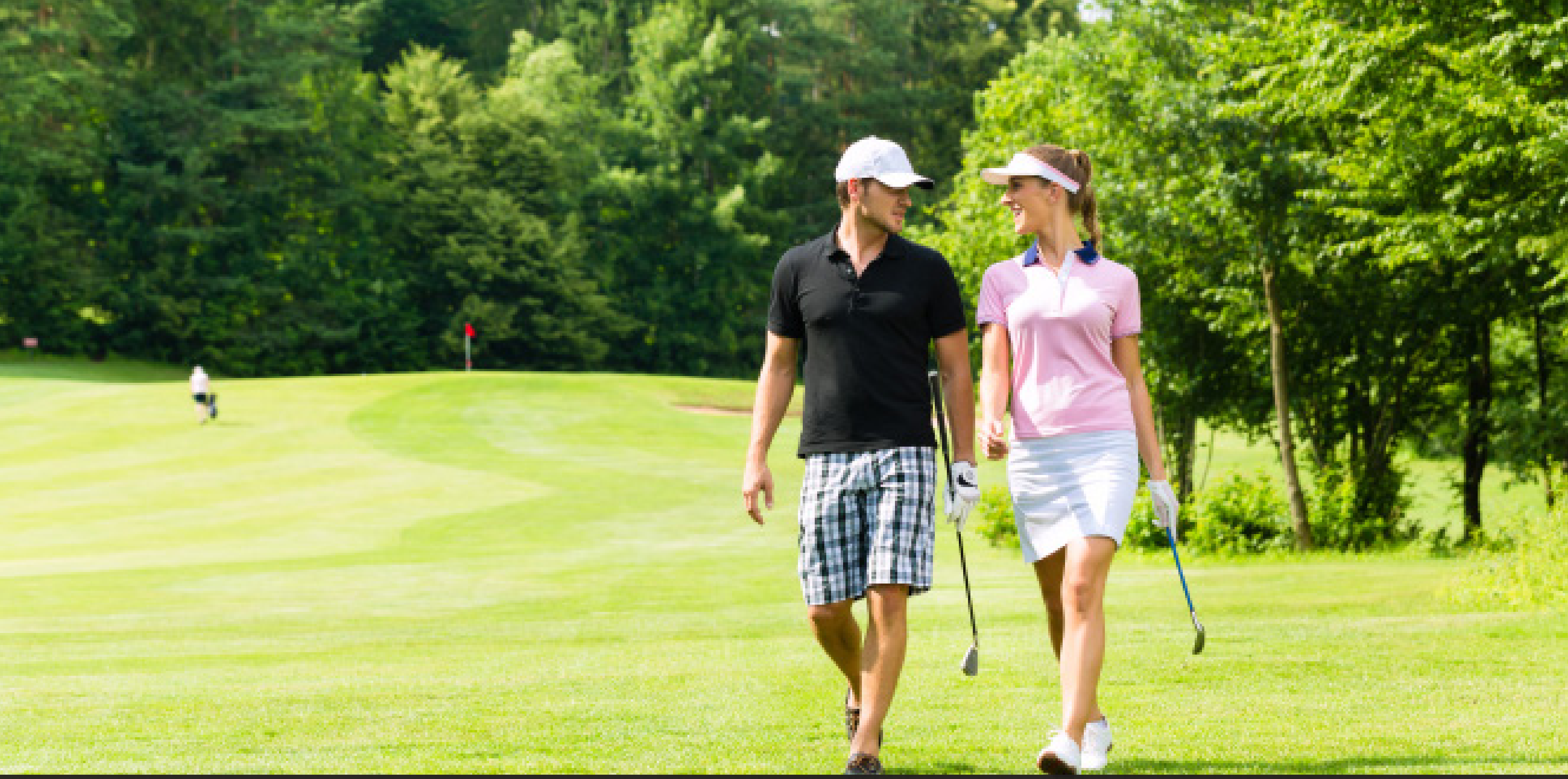
In addition, it is surprising to see the total treatment area required to protect an entire municipality. The intervention areas represent a very small fraction (under 1%) of the total territory. To explain how the surface area for treatments is determined, it is good to have a clear understanding of the biology of biting insects. Females of most mosquito and black fly species require a blood meal in order for their eggs to develop. To find this blood meal, they can travel varying distances depending on the species, the environment in which they are located, the presence of migration corridors, the weather, etc.

According to scientific literature, mosquitoes can easily fly up to several kilometres from their emergence site, but 2 km is the average for several species. Black flies have an even greater range of action, the average being between 4 and 6 km. Determining the limits for intervention is a complex process and unique for each project. For mosquitoes, an intervention limit of 2 km around the target area is usually sufficient to maintain a decrease of at least 80% of the nuisance. There are also migration corridors that favour the movement of biting insects, such as lakes enclosed between two mountain ranges or hydroelectric power lines. These corridors lead to a reinvasion that leads to new spawnings in treated water bodies and streams, from which mosquitoes and black flies will emerge again if they are not treated regularly throughout the summer.

Bti is applied directly to wetlands and streams where it selectively attacks mosquito and black fly larvae. This method considerably reduces the impact on the territory, since the larvae are concentrated in specific areas. The control of adult biting insect populations would require action throughout the territory.

Mosquito and Black Fly life cycle





SOCIAL ACCEPTABILITY

All municipal biting insect control programs are carried out at the request of the residents of a municipality with a nuisance problem. Biological control programs for biting insects are implemented at the request of groups of citizens and are subject to several public consultations.

Projects can develop over many years, and go through several stages, before being implemented. Here is an example of the consultation process for implementing the programs:

1. **Public presentations**

2. **Municipal surveys**

3. **Public tender process**

4. **Adoption of the project**

5. **Display on each citizen's tax bill**

6. **Sample press release**

7. **Implementation of a communication plan, including a mosquito info-line and clients requests system**

The public nature of municipal control programs (using biological larvicides (Bti)) requires several stages of consultation, clear communication of all aspects of the program and adoption by a majority of stakeholders. Municipal environmental committees also have competent and involved local resources that reflect social acceptability.

The control of biting insects does not increase pressure on wetlands. On the contrary, biological control allows for better cohabitation and increases the civic acceptability of wetlands in urban and peri-urban areas, thereby protecting sensitive areas. The loss of such habitats is one of the causes of the decline of insectivorous birds and aquatic biodiversity.

It should be noted that biting insect control programs using Bti actually ensure control in a more environmentally friendly way for citizens and the environment. Indeed, some of the population, without this alternative, would turn to other solutions such as individual chemical pesticides (coil, spray can, fumigation, etc.) or non-selective traps.

In addition, the justification for the biting insect control program is included in the application process for a ministerial authorization for the use of pesticides (Regulation 63/09) and is therefore included in the environmental authorization application.

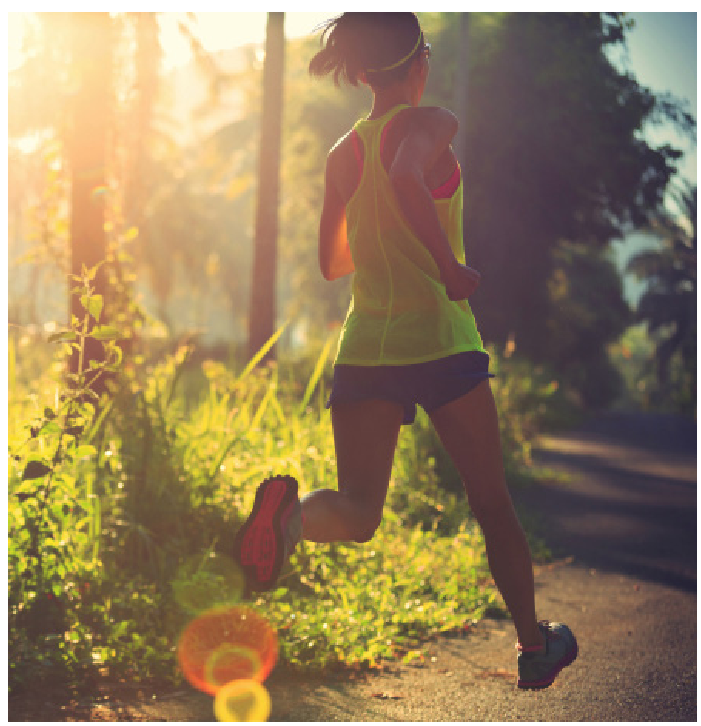
The regulatory framework of the various government bodies, including the Environmental Protection Act and the Pesticides Act, is an implementation of the precautionary principle. All the guidelines put in place reduce the risks to an almost zero level and make it possible to establish that we are in the absence of any significant damage to the environments. Since the primary objectives remain the protection of habitats and the maintenance of biodiversity, it would be desirable for biological solutions to be advocated and also applied to other sectors of activity.

According to the very definition of the precautionary principle, stated in Principle 15 of the Rio Declaration, 1992: «Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation", control of biting insects poses no serious or irreversible risk.

Benefits related to the control of biting insects

Biting insects prevent many citizens from enjoying the outdoors. In some cases, they can be responsible for allergic reactions or transmissions of much more serious diseases (arboviruses).

Controlling the larval populations of mosquitoes and black flies in aquatic environments is the most environmentally friendly and effective way to reduce the nuisance caused by these insects by intervening at the very source of the problem. Biting fly control programs using biological larvicides fit perfectly into a family policy that focuses on the quality of life and outdoor activities. It is a sound management of resources and contributes to the protection of the wetlands of the territory by allowing to live nearby without suffering the discomforts. It is a great development tool for about sixty Canadian cities and a very good argument to attract new families in the affected areas. This responsible control also makes it possible to retain visitors and attract tourists (campgrounds and others) thus maximizing the economic benefits of recreational tourism activities. It also showcases and maximizes the full potential of investments in municipal recreational infrastructure.



In addition, this is possible within the limits of everyone's current budget since they no longer have to buy sprays, insecticides, lemongrass or mosquito net shelters that do not have the desired effect.

1. Increased family activities, full accessibility to summer activities
2. Increase in recreational tourism activities
3. Increase in market values of properties
4. Better use of municipal recreational infrastructures
5. Taking advantage of the richness of the environment and natural environments
6. Significantly improved quality of life of citizens and visitors
7. Hiring and local economic activities
8. Reduced risk of disease transmission by vector species
9. Decrease in allergic reactions and stress caused by severe nuisance
10. Reduction of sedentary lifestyles and social compartmentalization

Controlling the larval populations of mosquitoes and black flies in aquatic environments is the most environmentally friendly and effective way to reduce the nuisance caused by these insects by addressing the root cause of the problem.

The costs associated with implementing a control program are comparable to, and often even lower than, the current expenditures of each individual on the purchase of repellent products.

ALTERNATIVES

The market offers more and more alternative methods to control mosquitoes. It is, however, necessary to analyze the alternatives available to the population.

Non-invasive methods include biological control using predators (e.g. bats, birds, fish), the use of plant extracts, entomopathogenic fungi, male mosquitoes (irradiated, genetically modified or carrying bacteria), amino acids and the use of baited traps. Most of these alternatives are either still in the research stage, ineffective, unavailable, or unregistered in Canada.

Among the alternatives currently available in Canada, it is possible to install nest boxes for insectivorous birds or bats, but these, contrary to the myths propagated, feed on very few mosquitoes and no effectiveness has been demonstrated. The use of large-scale aquatic predators is not realistic given the diversity of breeding environments, but their use in artificial ponds can be effective (e.g. the introduction of fish into water gardens).

Several models of mosquito traps are also available. These light traps are often equipped with a small fan to create a vacuum and sometimes use baits to lure the biting insects (carbon dioxide, lactic acid, octenol or other lures). It should be noted that mosquito traps have a very limited radius of attraction and that the tests reveal that in the presence of humans, the mosquito will choose the real meal rather than the trap. At the municipal level, the number of traps needed to protect citizens and allow them to enjoy outdoor activities would be far too great. Acquisition and operation costs would be in the order of 50 to 100 times higher than larval control. In addition, these traps capture many other insects, more than 40% of chironomids, moths, etc. which are a component of the diet of some predators. Conversely, programs using Bti are selective to biting insects. It should also be noted that no traps target populations of small black flies that are easily controllable in programs using Bti.

Mosquito control based exclusively on a trapping method does not produce interesting results. **Traps can, however, be used in addition to other methods, such as a biolarvicide control program.** For example, at the boundaries of treatment areas, traps arranged in a tight line can have a barrier effect and restrict the horizontal migration of mosquitoes.

It should also be noted that, in the absence of control, several undesirable methods may be used by citizens. Indeed, it is observed that some exterminators offer a chemical treatment against mosquitoes. These treatments are to be avoided since they unfortunately affect beneficial insects with certain consequences.

Wetland drainage, sometimes used to limit the proliferation of mosquitoes, has disastrous and permanent consequences for our environment.

When the different methods of controlling biting insect populations are exposed in a decision matrix, it becomes quite obvious that the use of Bti is the best approach to controlling biting insects (Table 1).

Table 1. Decision matrix with the different methods of control of biting insects

	No activity	Chemical product	Drainage	Predators	Trap	Personal Protection	Bti
Efficacy		+++	+		+	+	+++
Impact on environment		− − −	− −	+	−	−	−
Impact on health	−	−			+	+	+
Total	-1	-1	0	1	1	1	3

Further Information

www.gdg.ca/en

https://www.ontario.ca/page/permit-applicant-guide-municipalities-and-health-units

https://www.publichealthontario.ca/en/diseases-and-conditions/infectious-diseases/vector-borne-zoonotic-diseases/west-nile-virus

https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/bacillus-thuringiensis-subspecies-israelensis.html

WHO ARE WE?

The mission of GDG Environment is to improve the quality of life of citizens and ensure public health protection through ecological solutions. Since 1984, the company has been involved in the control of biting insects (mosquitoes and black flies) using biological larvicides. The company offers its services to over 50 municipalities throughout Ontario, New-Brunswick, Newfoundland-Labrador and Québec. Throughout Eastern Canada, our organization conducts operations to control biting insects (mosquitoes and black flies) in order to reduce the nuisance caused by these species. GDG Environment also carries out actions targeted to the species: vector control to prevent the spread of mosquito-borne diseases, such as West Nile virus.

Our team consists of professionals from the fields of biology, environment, forestry and entomology.

In addition, sustainable development is at the heart of GDG Environment's concerns. The team registered for and obtained Level 2 certification from RECYC-QUÉBEC and was also awarded a sustainable development certification from the City of Trois-Rivières.

GDG's head office is located in Trois-Rivières. GDG Environment, through its subsidiary GDG Canada, has permanent offices in Ottawa.

FREQUENTLY ASKED QUESTIONS

Does Bti affect bees?

Many studies were conducted on the effect of Bacillus thuringiensis israelensis (Bti) on honey bees. No harmful effects were observed on bee colonies following the treatment of Bti on plants that bees harvest from. Bti is non-toxic for bees and does not affect their behaviour and activities.

Does reducing the quantity of mosquitoes, by treating with Bti, affect the survival of bats?

In general, bats are opportunistic feeders that feed on what is available at any given moment. In the case of a massive emergence of mosquitoes, bats will momentarily feed on this resource. However, mosquitoes are not the only source of food available to bats. It would require between 604 and 659 mosquitoes per day to attenuate the hunger of a bat, whereas it only requires 164 to 179 moths per day. Feeding on mosquitoes represents a greater effort, which is not advantageous for the animal. Also, mosquitoes are very small prey, and some larger bats have difficulty detecting their presence by echolocation.

Does reducing the quantity of mosquitoes, by treating with Bti, affect the survival of insectivorous birds such as swallows?

Mosquitoes are not an important source of nutrition for insectivorous birds. In fact, mosquitoes were not found in great numbers in the stomachs of birds in several studies. For example, even if many small preys are available for food, insectivorous birds prefer to prey on larger more nutritious insects to feed their chicks. There is also a study that demonstrates that the long-term use of Bti in the coastal wetlands of the French Atlantic has no influence on the diet of birds, since the quantity of invertebrates that birds feed on is maintained even within treated zones. This study, conducted in France, represents the largest long-term investigation for studying impacts of Bti on non-target organisms. Another study concludes that Bti has no indirect risk for birds that feed on chironomids, a closely related insect to mosquitoes.

Does Bti affect chironomid populations?

Several studies demonstrate an effect of Bti on chironomid populations. However, these studies were either conducted in a laboratory, or in the context of overdosing. At the prescribed application rate stated on the pesticide label and in the field, Bti has no effect on chironomid populations. As well, in a Swedish study, scientists showed that there was no significant effect of Bti on the abundance and diversity of chironomids.

Does Bti directly or indirectly affect amphibian populations?

The world health organisation has analysed several studies conducted in laboratory and in the field concerning the possible impact of Bti on frogs, newts, salamanders and on toads and no direct effect was observed. A study conducted in Quebec, in laboratory, determined that there is no significant biological impact. Even if Bti treatments reduce mosquito populations in the environment, several studies show that mosquitoes are not an important resource for amphibians. Amphibians are opportunistic predators, meaning they feed on a wide variety of prey.

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